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Technical Report No. 25

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BIBLIOGRAPHY
ELECTROMAGNETIC PHENOMENA
WITH SPECIAL REFERENCE TO ELF (1-3000 cps).

by

L. BROCK-NANNESTAD

OCTOBER 1964

VIALE SAN BARTOLOMEO, 92
LA SPEZIA, ITALY

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TECHNICAL REPORT NO. 25

NORTH ATLANTIC TREATY ORGANIZATION
SACLANT ASW RESEARCH CENTRE
Viale San Bartolomeo 92
La Spezia, Italy.

Bibliography

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APPROVED FOR DISTRIBUTION


HENRIK NØDTVEDT
Director

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P R E F A C E

The present bibliography on electromagnetic phenomena in the ELF-range and related fields is a new edition of the one published in September 1962. Before the previous bibliography was published, no known compilation of papers in this important field of research had appeared since 1953. This fact was rather surprising when seen in the light of the great efforts in this field during the IGY and other international and national investigations. The previous bibliography soon became very popular and the stock has been depleted for a long time. The present one has been prepared with the purpose to fill this obvious need and to bring the previous one up to date.

Although the bibliography emphasised ELF, it was necessary to cover the frequency regions below and above this range. The research during the recent years has shown a strong interdependence between the phenomena measured in a frequency range of 7 decades below 30 kc. The coverage of the ranges outside the ELF has been extended somewhat, and quite a number of papers published in the period 1952-1962 have been added. Thus, the new edition gives a more complete picture of the state of the art than the previous one. This policy also reflects some of the suggestions made by several readers of the previous edition. The drawing on page iii shows clearly the overlapping between ranges of interest and the more or less arbitrarily defined frequency ranges. It also indicates the confusion in the names and abbreviations used for the phenomena under investigation. This confusion can make the proper grouping of papers rather difficult. In many cases a paper falls within the frame of several groups and, in which case, a cross reference is made. Generally a given paper is, however, placed in that group which corresponds to the main objective of the paper. The groups have been selected relative to subjects and not to frequency range. In the author index at the end of the bibliography reference is made to parts and pages.

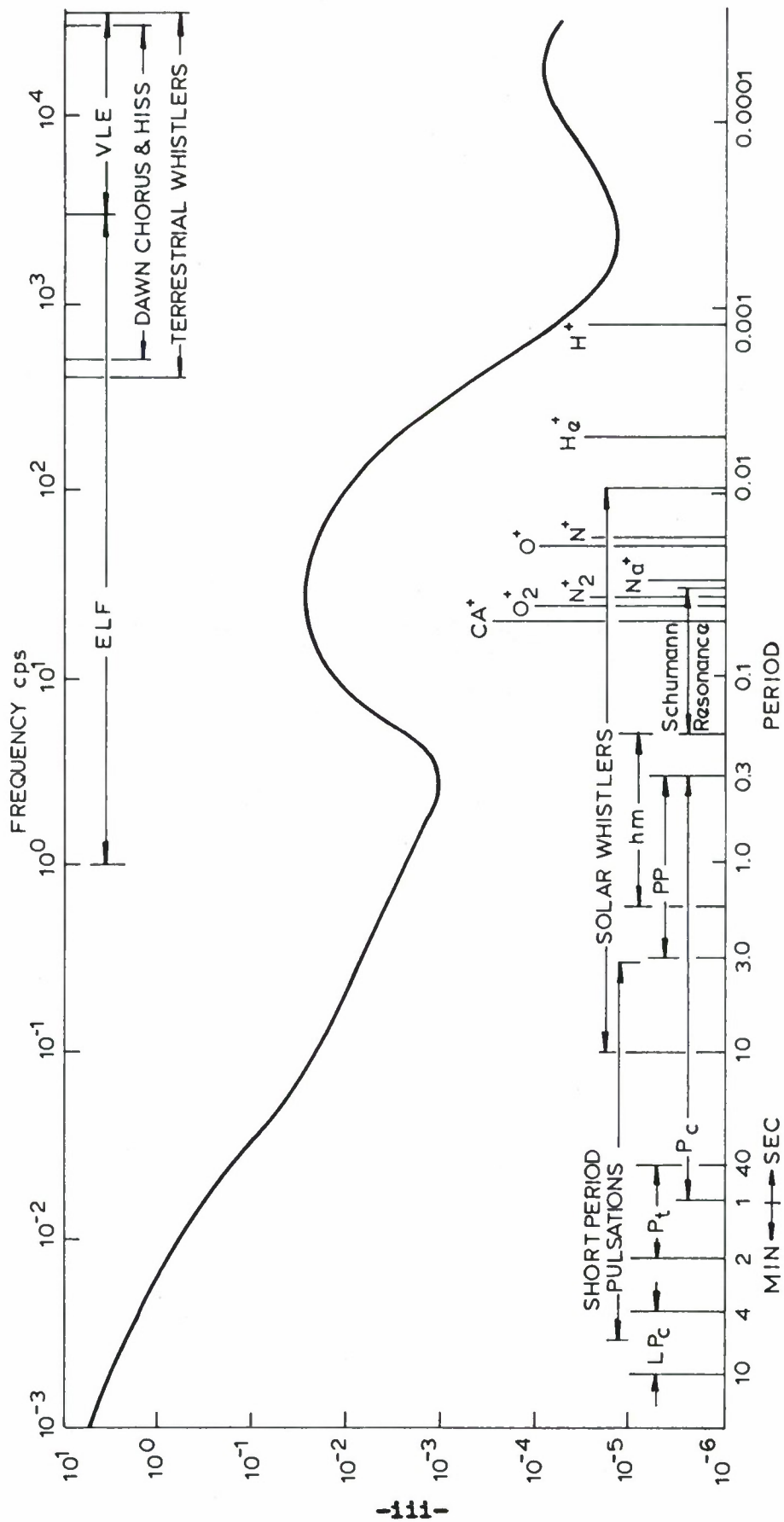
The bibliography covers unclassified literature and is based on information available from the abstract literature, the former U.S. Armed Services Technical Information Agency (ASTIA) indexes and bibliographies, company reports, references in published papers, etc. Physics and Electrical Engineering Abstract numbers and ASTIA numbers (AD) are given where they are known. Abbreviations of the journals are as shown in the January 1962 issue of the Electrical Engineering Abstracts with a few minor exceptions.

Whenever available, abstracts are given. This increases the volume of the bibliography considerably; however, it greatly increases its value. As a space saving measure some of the abstracts have been shortened - also in those cases where they are taken directly from the abstract literature.

The author wishes to express his acknowledgment of the great help he has received from Mr. John Graham, Head, Technical Information Office, and from Miss Valerie Termini, Secretary, Electromagnetic Research Group, in preparing this bibliography.

LA SPEZIA, October 1964.

L. Brock-Nannestad



PART I

PART I

PROPAGATION OF EM WAVES, SURFACE WAVES, IONOSPHERE

SUR LA PROPAGATION DES ONDES ELECTROMAGNETIQUES DANS LES MILIEUX STRATIFIES

Ann. Phys. (France), July-August 1948.
F. Abelès

No abstract

ELECTROMAGNETIC ENERGY TRANSMISSION AND RADIATION

1960, \$14.50, text. ed. \$12.00, Wiley.
R.B. Adler, L.J. Chu, R.M. Fano.

NAVIGATION RECEIVERS FOR USE IN RADUX VLF-LF NAVIGATION SYSTEM

AD 51 325; 21st July 1953, Hastings Instrument Co., Hampton, Va.,
Quarterly interim development rept. March-June 1953, 10 p., illus.
P.W. Albro.

No abstract

FREQUENCY VARIATIONS IN NEW ZEALAND OF 16 KC/S TRANSMISSION FROM GBR RUGBY
Nature, Vol. 177, No. 4500, Pgs. 178-179, 28th January 1956.
A.H. Allan, D.D. Crombie, W.A. Penton.

The recording of frequency variations in the GBR signals as received in New Zealand has been started. Diurnal variations are shown and are less than those recorded on WWVH.

LONG-PATH VLF-FREQUENCY VARIATIONS ASSOCIATED WITH THE SOLAR FLARE OF 23RD FEBRUARY 1956

Phys. Abstr. 304/1960; J. atmos. terrest. Phys. (GB), V. 10, No. 2, Pgs 110-113, 1957.
A.H. Allan, D.D. Crombie, W.A. Penton

The frequency and phase variations of GBR on 16 kc as received in New Zealand during the solar flare of 23rd February 1956 are described and compared with the effects during a normal flare. The difference is attributed to the cosmic-ray increase accompanying the 23 February flare.

SUDDEN CHANGES IN AMPLITUDE AND PHASE OF 16 KC/S VERY LOW FREQUENCY RECEIVED IN NEW ZEALAND

EE Abstr. 2649/1964. Nature (GB), Vol. 199, 582-3, 10th August 1963.
A.H. Allan

A short note confirming results previously reported (Abstr. 7715 of 1963) on anomalous reception of GBR signals on 31st May and 25th June 1962. Although the disturbance was noted on 16 kc/s it was not observed on 18 kc/s thus making a general ionospheric disturbance unlikely. Evidence shows that the transmitted signal was normal.

LIGHTNING AND THE PROPAGATION OF AUDIO FREQUENCY ELECTROMAGNETIC WAVES

Phys. Abstr. 2451/1957; Uspekhi fiz. Nauk (USSR), V. 60, No. 3, pgs 369-89, 1956.

Ya L. Al'pert

The difficulties are first discussed of treating theoretically the problems which arise with the 300-30,000 cps propagated in a spherical waveguide, one wall of which is the ionosphere of not-too-well-known properties and the other is the "perfectly" reflecting ground. Lightning sets up em waves of low frequency in a burst of atmospherics. Results obtained in determination of the shape, and the harmonic analysis, of atmospherics are discussed, also variation of the velocity of propagation of such waves with wave-length.

COMPUTATION OF THE FIELD OF LF AND VLF RADIO WAVES OVER THE EARTH'S SURFACE UNDER NATURAL CONDITIONS

Radiotekh. Elektron (USSR), Vol. 1, No. 3, Pgs 281-292 (March 1956).

In Russian. For translation, order from LC or SLA, mi \$2.40, 60-14028. See Tech. Translations, Office of Tech. Services, Washington, D.C.

Ya L. Al'pert.

Results are presented of theoretical calculations of the propagation over the earth's surface, of electromagnetic waves in the 500-30,000-cycle range with allowance for the stratiform inhomogeneity, of the ionosphere and for the dependence of ionospheric conductivity on frequency. The pole equation is solved for the selected model of the ionosphere, and thus the wave numbers of the discrete spectrum of waves forming the field at the point of observation are calculated. Analysis of the "interference co-efficient" has shown that the phase and amplitude of the field vary in a complicated irregular fashion in relation to distribution and frequency. Graphs were constructed for the relationship between field intensity and frequency for various distances in the 500- to 10,000- km range. Field intensity measurements known from the literature and also results from other experiments are compared with the theoretical computations. A good agreement is found, even to a number of details.

VELOCITY OF PROPAGATION OF ELECTROMAGNETIC WAVES AT AUDIO FREQUENCIES

Zhurn, Eksper, Teoret, Fiz. (USSR), Vol. 33, Pgs 1305-1307 (November 1957).

Translation in Soviet Physics JETP, Vol. 6, Pgs 1004-1006 (1958).

Ya L. Al'pert, S.V. Borodina

This note describes an investigation covering the frequency range 1-30 kc based on waveform analysis of thunderstorm discharges at distances of 800-3,100 km. Experimental and theoretical values deviate significantly below 3 kc, at which frequencies the model of the ionosphere used in the calculations may be inappropriate.

THE VELOCITY OF PROPAGATION OF AUDIO-FREQUENCY ELECTROMAGNETIC WAVES.
EE. Abstr. 3132/1960; Radiotekhnika i Elektronika (USSR), V. 4, No.2,
pgs 195-201, February 1959.
Ya L. Al'pert, S.V. Borodina

The results of a determination of the phase velocity of propagation of e.m. waves in the 10-20 ko range are given. A method of harmonic analysis of atmospherics and their phase characteristics was used. Comparison of the results of theoretical calculations with experiment, taking into account the non-homogeneity of the ionosphere and the dependence of its conductivity on frequency, show good agreement. With decrease in frequency the phase velocity becomes larger than the velocity of e.m. waves in free space. The results enable the effective conductivity of the lower ionosphere to be determined. (English summary PB 141106T-13, obtainable from Office of Technical Services, U.S. Dept. of Commerce, Washington, D.C., U.S.A.)

SYNTHESIS OF ATMOSPHERIC FORMS AND THE EFFECTIVE PARAMETERS OF THE LOWER IONOSPHERE AT LOW FREQUENCIES

Radiotekh. Elektron, Vol. 4, No.2, Pgs 202-211 (February 1959).
In Russian. Translation in Radio Engineering & Electronics, Vol.4, No.2,
pgs 65-77 (1959).
Ya. L. Al'pert, D.S. Fligel

The results of theoretical calculations of the form $E(t,r)$ of atmospherics and their comparison with signals received at distances of $r \sim 500-3,000$ km from the source are briefly described. Theoretically values of an effective conductivity previously obtained using an ionospheric model in the form of transition layers, characterized by the relationship of electron density N to the number of collisions ν dependent on height X , were used. The close resemblance of temporal variation of theoretically synthesized signals $E(t,r)$ to the observed ones is noted.

CHAPTER ON LONG WAVES FROM BOOK "IONOSPHERIC PROPAGATION OF RADIO WAVES"
Nat. Bur. Stand. (USA), translation T5-60, August 5, 1961.
Ya L. Al'pert

No abstract

WAVE PROPAGATION IN STRATIFIED MEDIA FOR NORMAL INCIDENCE, AND ITS APPLICATION TO CIRCUIT THEORY, ELECTROMAGNETIC WAVES, OPTICS, ACOUSTICS, WAVE MECHANICS, AND TO MECHANICAL AND ELECTRICAL QUADRIPOLE NETWORKS.
EE Abstr. 1754/1954; Ann. Phys. (E. Germany), V.13, No. 1-5, pgs 1-43, 1953.
K. Altenburg, S. Kästner

The above phenomena in the one-dimensional case have the same two simultaneous first-order linear partial differential equations (or simultaneous difference equation) with constant coefficients, for which the general periodic solutions containing 3 complex constants, are obtained for a homogenous (or discrete) medium. The transparency, reflection (and normal modes) for a set of finite layers (or discrete

elements) are treated by a matrix method. Applications include anti-reflection films, transmission lines, concentric Lecher lines, tunnel effect, vibrations of infinite chain of coupled mass points, etc. Analogue computers for one type of system are discussed in terms of a system more amenable to experimentation. 67 References.

ABSORPTION OF AUDIO-FREQUENCY ELECTROMAGNETIC WAVES TRAVERSING THE IONOSPHERE IN THE MAGNETO-IONIC MODE

Phys. Abstr. 17972/1962. Bull. Res. Coun. Israel, Vol. 11C, No. 1, Pgs 1-18, April 1962.
C. Altman, H. Cory.

Typical absorption curves for magneto-ionic propagation were calculated for various geomagnetic latitudes and various values of solar zenith angle. The feasibility of communication with satellites beyond the direct line of sight is evaluated, and the connection with "whistler" and vlf noise radiations is shown.

COMMENTS ON "PENETRATION OF THE IONOSPHERE BY VERY-LOW-FREQUENCY RADIO SIGNALS - INTERIM RESULTS OF THE LOFTY I EXPERIMENT"

EE Abstr. 13944/1963. Proc. Inst. Elect. Engrs. (USA), Vol. 51, No. 1, 250, January 1963.
C. Altman, H. Cory, J.P. Leiphart.

It is pointed out that the condition $\theta = 0$, where θ is the inclination of the wave normal to the geomagnetic field, taken by Leiphart et al. in the paper quoted in the title (Abstr. 10101 of 1962) is justifiable only for regions of field-aligned ionization, which are not typical for the D layer. It is further shown that vlf radio waves will propagate with least absorption when θ has a variety of values, depending on latitude, height, etc. but always $\theta > 0$. In reply, Leiphart confirms that the assumption $\theta = 0$ provides only a rough approximation.

GEOLOGICAL AND GEOPHYSICAL CONSIDERATIONS IN RADIO PROPAGATION THROUGH THE EARTH'S CRUST

EE Abstr. 1230/1964. IEEE Trans Antennas and Propagation (USA), Vol. AP-11, No. 3, 369-71, May 1963.
L.A. Ames, J.W. Frazier, A.S. Orange.

Geological and geophysical considerations applicable to radio propagation through the rock strata of the basement complex are presented. Information on electrical characteristics of rocks based on laboratory measurements on samples is shown to be misleading because in situ conditions are very difficult to analyse and reproduce. The complexity of the basement geology adds to the difficulty of predicting in situ rock characteristics pertinent to radio propagation. Folding and fracturing of the strata, variegated rock types and the anisotropy of rock resistivity cause the actual propagation path loss to be vastly different than that predicted on the basis of a simple geological model. This conclusion is supported by the available experimental data. Deep resistivity measurements made from the surface indicate that basement strata will have resistivities of the order of 10^3 - 10^4 ohm-meters over most of the United States.

RECEPTION OF SKYWAVE SIGNALS NEAR A COASTLINE

EE Abstr. 11306/1963. J. Res. Nat. Bur. Stand. (USA), Vol.67D, No.3,
325-30 (May-June 1963)
J.B. Andersen

An experimental investigation was made on the influence of ground inhomogeneties on the reception of skywave signals, especially the influence of the conductivity contrast near a coastline. This gives rise to a rapid decrease in field strength near the coastline, as is well known from groundwave mixed path theory. Comparison with theory is given. Influence of diffuse reflection from the ionosphere is also considered.

THE FIELDS OF ELECTRIC DIPOLES IN SEA WATER. THE EARTH-AIR IONOSPHERE PROBLEM

AD 253 130; University of New Mexico, Albuquerque, New Mexico,
Technical rept. EE-44, February 1961.
W.L. Anderson

The theory of extremely low frequency radio propagation from vertical and horizontal electric dipoles in a half space, separated by an infinite slab from another half space, is discussed and application is made to the specific case of the sea water-atmosphere-ionosphere problem, with dipoles located in the sea water. Each of the media is assumed homogeneous and isotropic. When attention is restricted to the frequency range 1 to 1,000 cps, integration in the complex plane leads to consideration of the pole corresponding to the TEM mode of transmission and two branch cut integrals. One of these, (that giving rise to propagation of energy along and in the ionosphere) is found to be important in the case of the horizontal dipole.

RADIO AND THE IONOSPHERE

Phys. Abstr. 24030/1962. Nature (GB), Vol. 195, 225-6 (21 July 1962)
E. Appleton

A general account is given of the history of our knowledge of the ionosphere, of the methods of studying the ionosphere using radio-frequency signals, and of our present state of knowledge of the various ionospheric layers.

PHASE-MEASURING EQUIPMENT FOR VLF PROPAGATION INVESTIGATIONS

EE Abstr. 5498/1960; Electronic Technol. (GB), V. 37, No.7, Pgs 252-5,
July 1960
G.E. Ashwell, C.S. Fowler

The equipment described was developed to investigate the phase difference between the signals from a single very low frequency (vlf) transmitter received at two sites simultaneously. A reference frequency at each site was derived from the pulse recurrence frequency of the transmissions from stations of the Gee navigational system and, by using it to change the frequency of the received vlf signal, an audio-frequency signal was obtained which had the phase characteristics

of the vlf signal. The a.f. signal from one station was passed over a telephone line to the other station where the phase difference was measured between it and the local a.f. produced in an identical manner. The long-term accuracy of measurement was $\pm 2^\circ$ of phase in the frequency range 15-20 ko and the short-term accuracy, for periods up to 30 minutes, was better than $\pm 1^\circ$ of phase. One station was designed to be mobile and satisfactory operation of the system was obtained with receiver separations up to 400km.

THE IONOSPHERIC PROPAGATION OF RADIO WAVES OF FREQUENCY 16 KC/S OVER DISTANCES OF ABOUT 540 KM.

Proc. IEE (London), Vol. 99, Part 4, No. 3, Pgs 250-9 (July 1952).
W.C. Bain, R.N. Bracewell, T.W. Straker, C.H. Westcott

The paper describes an investigation of the ionospheric propagation of waves of frequency 16 ko/s over a distance of 535 km. It represents an extension of other investigations in which the propagation over distances of 90 and 200 km was studied.

OBSERVATIONS ON THE PROPAGATION OF VERY LONG RADIO WAVES REFLECTED OBLIQUELY FROM THE IONOSPHERE DURING A SOLAR FLARE

Phys. Abstr. 11616/1954; J. atmos. terrest. Phys. (GB), V.3, Pgs 141-52, April 1954.
W.C. Bain

A discussion is given of the general appearance of anomalies in the field of GBR (16 kc) during solar flares, when observations are made at distances from the transmitter of 400-500 km. It is shown that the main effect is due to a sky wave reflected once from the ionosphere varying in phase but not in amplitude. An explanation of the size of anomaly found at these distances is given in terms of two layers below the E layer of the ionosphere. The layer which is usually the lower of the two is that normally responsible for oblique incidence propagation, and the other is that which is affected by the solar radiation during a flare. The timing of the oblique incidence anomaly is also discussed. A value of 70km for the apparent reflection height of the layer responsible for the reflection of 16 ko radiowaves at oblique incidence is obtained with the aid of the field strength changes noted during these anomalies.

THE POLARIZATION OF VERY LONG RADIO WAVES REFLECTED FROM THE IONOSPHERE AT OBLIQUE INCIDENCE

Proc. IEE (London), Vol. 103, Part C, Pgs 447-448 (September 1956)
W.C. Bain, C.B.I. Glass

A study of some additional evidence has been made to determine the polarization of radio waves reflected from the ionosphere at 16 ko/s over a transmission path 540 km long. The ratio between the amplitudes of the vertical and horizontal electric fields is found to be appreciably greater than unity, the mean value of the determinations made here being 5.

OBSERVATIONS OF EARTH-IONOSPHERE CAVITY RESONANCES
Nature, Vol. 188, Pgs. 638-641 (19th November 1960)
M. Balsler, C.A. Wagner

Careful observations of extremely low frequency atmospheric radio noise (5-35 c/s) made on 27th - 28th June 1960, at Lincoln Laboratory, have revealed a power spectrum with a maximum at 7.8 c/s and several successive smaller maxima at higher frequencies. This is in keeping with the theory of resonant modes for the concentric spherical cavity bounded by the earth and the lower region of the ionosphere. Moreover, the application of the theory to the derivation of the fundamental frequency from the higher modes yields values greater than 7.8 c/s, in agreement with the higher Q (and hence smaller downward shift of the resonant frequency) appropriate to the higher modes.

VLF REFLECTION FROM THE IONOSPHERE IN THE PRESENCE OF A TRANSVERSE MAGNETIC FIELD

Phys. Abstr. 15164/1960; J. atmos. terrest. Phys. (GB), V.16, No. 1-2, Pgs 37-45, October 1959.
N.F. Barber, D.D. Crombie.

The reflection coefficient is found for waves that are incident on a sharply bounded ionosphere and have their electric vector in the plane of incidence. The earth's magnetic field is assumed to be horizontal and perpendicular to the direction of propagation. Hence the analysis is appropriate for propagation round the magnetic equator. It is found that the reflection coefficient for waves incident from the west is numerically greater than that for waves incident from the east, when the angle of incidence is large.

SURFACE WAVES

EE Abstr. 2691/1953; Instn. Elect. Engrs (GB), Paper No. 1482, 13 p., 1953.
H.M. Barlow, A.L. Cullen

The paper is an attempt to present, in the simplest possible terms, a unified picture of the theory of various forms of surface wave and a clear physical interpretation of their behaviour. The Zenneck wave, the radial cylindrical surface and the Sommerfeld-Goubau or axial surface wave are each discussed and shown to represent basically one and the same phenomenon. The link with the Brewster angle, for which a wave incident on a surface suffers no reflection, is clearly established. The transition from a TAM-wave supported by a parallel-strip transmission line, with metal plates close together, to two Zenneck waves independently supported by the plates, when these are separated by a very large distance, is demonstrated. The effect of bends in the supporting surface is considered, and methods of reducing radiation are explained. Finally, the principles governing the launching of surface waves are surveyed with particular reference to the Brewster-angle approach.

SURFACE WAVES: A PROPOSED DEFINITION

EE Abstr. 4139/1960; Proc. Instn. Elect. Engrs (GB), V. 107B, No.240,
May 1960
H.E.M. Barlow

Defines a surface wave as one that propagates along an interface between two different media without radiation, such radiation being construed to mean energy converted from the surface-wave field to some other form.

NOTE ON "THE EXCITATION OF ELECTROMAGNETIC SURFACE WAVES ON A CURVED SURFACE"

EE Abstr. 627/1961; Inst. Radio Engrs (USA), Trans., V. AP-8, No. 4,
p. 449, July 1960.
H.M. Barlow

No abstract

VELOCITY OF A PLANE ELECTROMAGNETIC WAVE IN A LOSSY MEDIUM

EE Abstr. 1838/1963
Proc. Instn. Elect. Engrs (GB), Vol. 109B, No. 46, p. 335, July 1962.
H.E.M. Barlow

Wave propagation in a lossy medium introduces an ambiguity into the definition of group and energy velocities $\frac{\partial \omega}{\partial \beta}$. For the lossless plane wave this gives both the phase and energy propagation velocities $\frac{\omega}{\beta}$. With the introduction of loss, the energy and phase velocities are equal, but the signal-velocity differs from them.

BOOK REVIEW: "RADIO SURFACE WAVES" by H.M. BARLOW & J. BROWN

Proc. IRE 50, 2150, October 1962.
Reviewed by J.R. Wait

No abstract

THE WAVEGUIDE MODE THEORY OF RADIO WAVE PROPAGATION WHEN THE IONOSPHERE IS NOT SHARPLY BOUNDED

EE Abstr. 8284/1960; phil. Mag. (GB), (Eighth Ser.), Vo. 4, Pgs 1068-81,
September 1959
D.W. Barron

The propagation of radiowaves to great distances can be treated by considering the space between the earth and the ionosphere as a waveguide and discussing the properties of the various waveguide modes. Previous authors have generally assumed that the upper boundary of the waveguide is a sharply bounded homogeneous ionosphere. A method of calculating the mode characteristics for any horizontally stratified ionosphere in which the electron density and collision frequency vary with height in some arbitrary prescribed manner is described. The theory

is given in full for a flat, perfectly conducting earth with no magnetic field, and its extension is outlined in an appendix. Results of some calculations carried out on EDSAC 2 are given. The effect on the waveguide modes of changing from a sharp to a gradual boundary on an otherwise homogeneous ionosphere is investigated by considering a variation of electron density (N) with height (z) according to the law

$$N = N_0 (1 + \tanh \beta (z-h))$$

using a range of values of β , and mode characteristics are also calculated for an ionosphere in which the electron density increases exponentially with increasing height. The effect on the waveguide modes of changes in the parameters of the exponential model, and the difference between the modes for vertical and horizontal polarization are described.

LIMITING CONDITIONS FOR THE ELECTROMAGNETIC FIELD ON THE SURFACE WITH AN ARBITRARY VALUE OF DIELECTRIC CONSTANT.

EE Abstr. 4774/1961; Radiotekhnika i Elektronika (USSR), V.5, No.3, Pgs 389-92, March 1960
F.G. Bass

A mathematical theory of the subject is given which as far as possible is in general terms. It is shown that approximate limiting conditions applied in existing theories of e.m. wave propagation can be derived from more general ones.

STUDY OF THE PROPAGATION OF ELECTROMAGNETIC WAVES THROUGH LITHOLOGIC FORMATIONS

AD 33 576; Final Progress Report - January 20, 1951, December 31, 1953.
C.A. Bays and Associates, Inc., Urbana, Illinois.

This is a report of a study of electromagnetic propagation through, along and over stratified rocks and other earth materials. Electromagnetic fields, excited by standard broadcast stations, were examined by means of continuously recorded intensity traverses which indicated definite correlation between field intensity and the lithologic nature of the configuration of underlying earth and rock materials. The orientation of these electromagnetic fields exhibited local variations that were correlative with geologic features at depths as great as 600 feet. In these studies, topography, soil types, and depth to indurated rock had little or no influence on electromagnetic fields. Lateral electromagnetic propagation 300 feet below the earth's surface was accomplished by transmitting a signal 2,200 feet between drill-holes. Attenuation was great and the received signal was weak. An analysis involving the theoretical aspects of electromagnetic propagation through earth materials is presented. Several wave types that might exist in and over such materials are considered and the results of this study are presented in graphical form. A rather extensive annotated bibliography of material relevant to this study was compiled and is included in this report.

PROPAGATION OF PLANE ELECTROMAGNETIC WAVES PAST A SHORELINE

EE Abstr. 3018/1953; New York University (Washington Sq. Coll.) Math. Res. Group, Res. Rep. No. EM-46, 64 pp., July 1952.
J. Bazer, S.N. Karp.

The problem of propagation of electromagnetic waves over a land sea surface is treated. In particular the field is considered which arises from the diffraction of a plane wave (or ground wave) whose direction of propagation is normal and whose magnetic vector is parallel to the shore-line of a land-sea surface. The sea is treated as a perfect conductor, and at the air-land interface the customary impedance boundary condition is imposed. Mathematically, the problem of determining these fields involves the solution of a two-part boundary value problem for the time-reduced wave equation. Exact integral representations of this solution are obtained by means of techniques allied with those of Wiener and Hopf. Far field approximations are found in both the illuminated and shadow regions. Conditions are given which ensure the uniqueness of the field. In addition, some comments are made regarding the possibility of coastal refraction in our formulation.

PROPAGATION OF PLANE ELECTROMAGNETIC WAVES PAST A SHORELINE

Phys. Abstr. 16067/1962. J. Res. Nat. Bur. Stand (USA), Vol. 66D, No. 3, Pgs 319-34, May-June 1962
J. Bazer, S.N. Karp

The problems of the diffraction of homogeneous plane waves and ground waves by a linear shoreline in a planar land - sea surface are discussed. The direction of propagation of these incident waves is assumed perpendicular, and that of their magnetic vectors parallel, to the shoreline. At the air-land interface, the customary impedance boundary condition is imposed while the sea is treated as a perfect conductor; atmospheric and ionospheric effects are ignored. Exact integral representations of the solutions are presented. In the case of homogeneous plane-wave excitation originating over the sea, the integral representations are employed to obtain expressions for the geometrical optics field and for the far-field form of the remaining scattered field, transition regions included. The possibility of coastal refraction is discussed.

SOME UNUSUAL RADIO OBSERVATIONS MADE ON 23RD FEBRUARY, 1956

Phys. Abstr. 949/1957; J. Atmos. Terrest. Phys., V.8, No. 4-5, Pgs. 281-6, May 1956.
J.S. Belrose, M.H. Devenport, K. Weekes

All records of sky-wave signals showed clearly the effects of the solar disturbances at 0345 U.T. On 70-300 kc, a very strong absorption was noted which decreased after 0420. On 16kc, a decrease of reflection-height of between 7 and 8 km occurred, with little change of amplitude. Conditions remained abnormal throughout daylight hours, but recovered during the ensuing night.

PROPAGATION OF VERY-LOW FREQUENCIES IN THE EARTH IONOSPHERE SYSTEM
Phys. Abstr. 7766/1962; Ann. Geophys. (France), Vo. 17, No. 4,
Pgs 370-3, 1961.
R. Benoit, A. Hourl

The spectrum of electromagnetic energy emitted by distant spherics was measured between 11 and 8000 ops using their statistical characteristics. The spectrum can be interpreted by considering the couple earth-ionosphere as a resonant cavity for ultra-low frequencies, and as a wave guide for frequencies around a few kilo-cycles.

SOME REMARKS ON THE WATSON TRANSFORMATION AND MODE THEORY
Radio Sci. Journal of Research NBS/USNC-URSI, Vol. 68D, No. 1,
January 1964, Pgs 59-66
Leslie A. Berry

The Watson transformation, which is the basis of VLF mode theory, is reviewed. It is shown that the disappearance of the line integral ("continuous spectrum") depends only on the properties of the earth (for a homogeneous ionosphere). Thus, the integral is interpreted just as in the classical groundwave case, i.e. it represents the waves which have re-entered the air after travelling through the earth.

The limitations of the second-order Debye approximations have been discussed vaguely before. Actual calculation in specific cases shows that the attenuation rate of the first mode is in error by 60% ko/s, 25% at 10 ko/s, and 15% at 8 kc/s when the Debye approximations are used for all wave functions.

It is not possible to deduce effective parameters for the homogeneous ionosphere from consideration of the attenuation rate alone. It is suggested that simultaneous consideration of attenuation rate and phase velocity will remove ambiguity and an example calculation is given for 10.2 ko/s. The resulting model ionosphere is at a height of 65 km with $(\omega_r) \sim 1.2 (10^5)$.

EFFECTS OF THE IONOSPHERE ON VLF NAVIGATIONAL AIDS
J. Res. Nat. Bur. Stand (USA), V. 65D, No. 6, November-December 1961.
W.T. Blackband

Long range navigational aids could be devised using VLF transmissions. The propagation of such waves is controlled by the lowest level of the ionosphere. The small changes in phase velocity which accompany the diurnal ionospheric changes have been studied using ground monitor stations. Preliminary measurements made in an aircraft show internal consistency in fixing of about 1 nautical mile at ranges of 5,000 to 6,000 miles.

POSSIBLE PROPAGATION OF VERY-LOW-FREQUENCY SIGNALS BETWEEN RUGBY
AND ROME THROUGH THE IONOSPHERE

Phys. Abstr. 17968/1962; Nature (GB), Vol. 193, Pgs. 863-4,
3rd March, 1962.

W.T. Blackband

Most measurements of the diurnal phase change of 16 kc/s signals from Rugby received at Rome show effects which fit the generally accepted waveguide mode or geometrical optics theories of propagators of v.l.f. waves between the earth and the lower boundary of the ionosphere. On some occasions (e.g. mid-November 1960), the diurnal variations were 4 or 5 times greater than normal and the plot of phase against time is of the same form as that for meteor burst rate observed on the Janet system. It is suggested that at these times propagation follows a path which penetrates to an appreciable extent into the lower layers of the ionosphere.

ON THE RECEPTION OF ELECTROMAGNETIC WAVES

Phys. Abstr. 16545/1961; Proc. Roy. Soc. (GB), V. A261, Pgs 1-9,
11th April 1961.

H. Bondi

The energy that can be obtained from an electromagnetic wave by a localized receiver is considered for the non-harmonic case. If the currents in the receiver are chosen so as to maximize the amount of energy obtained, with conditions implying that the receiver is quiescent outside a finite interval of reception, then there exists a well-defined maximum. For a limited interval of transmission, this maximum depends closely on the length of the interval of reception. If the restriction on the receiving current is relaxed, then there exist circumstances in which the wave theory considerations must be supplemented by allowing for induction effects.

REVIEW OF THE PRESENT STATE OF RESEARCH OF THE PROPAGATION OF VLF
ELECTROMAGNETIC WAVES.

Radiofizika (USSR), Vol. III, No. 1, Pgs 5-32, 1960. Translation,
News of Higher Education Institution, Ministry of Higher Education,
USSR, Radio Physics Series, Vol. III, No., Pgs 1-80, Office of
Technical Services, U.S. Dept. Of Commerce, Washington D.C., 14th
February 1961. OTS 61-21270. \$5.00.
S.V. Boredina, Yu K. Kalinin, etc.

The present status of the research on the propagation of long and very long electromagnetic waves is discussed. In the first part are considered theoretical problems and results are given of the calculations on the propagation of electromagnetic waves with allowance for inhomogeneities in the ionosphere, and for the finite conductivity and sphericity of the earth. The second part details the fundamental results of both direct and indirect experimental researches, carried out over a wide range of frequencies (approx. from 10 cycles to 50 kc.). These results make it possible to judge the distinguishing features of wave propagation in this range and their practical utilization.

At frequencies upward of 3, kc, good agreement is observed between the experimental data and the theoretical calculations. A need is noted of the development of a general theory of propagation of super-long waves with allowance for the effective sphericity and the finite conductivity of the earth, particularly for frequencies lower than 3 kc.

There is a bibliography of 109 items.

ON THE PROBLEM OF THE PLANE OF PROPAGATION OF THE HORIZONTAL ELECTRIC DIPOLE

EE Abstr. 5592/1957; J. Phys. Radium (France), V.18, No. 7, Pgs 453-4, July 1957.
G. Boudouris. D. Ilias.

A method, other than the classical one making use of the Hertz vector, is given for a more rapid solution of the propagation problem concerning the field radiated from a horizontal electric dipole over a flat earth. By means of this method, the problem is reduced to the previous cases which are supposed as known, of the vertical electric dipole and the horizontal elementary loop.

THE WAVEFORM OF ATMOSPHERICS AND THE PROPAGATION OF VLF RADIO WAVES
P.W.A. Bowe

See Part V, page 350.

IONOSPHERIC IRREGULARITIES CAUSING RANDOM FADING OF VERY LOW FREQUENCIES

J. Atmos. Terrest. Phys., Vol. 11, No. 2, Pgs 90-101, 1957. Similar material appeared in Prepublication Papers, NBS-IRE PGAP Symposium on the Propagation of V.L.F. Radio Waves, Boulder, Colorado, 23-25 January 1957, Vol. III, Paper 28
S.A. Bowhill

The process by which random irregularities in the ionosphere cause random fading in a reflected radio wave at the ground may be divided into two parts; the scattering process within the layer which builds up an inhomogeneous field in free space immediately beneath it, and the diffraction process by which this field propagates to the earth's surface, possibly changing in form as it travels.

The extent of this change is evaluated by finding the correlation coefficients for three pairs of quantities measured experimentally at 75 and 150 kc/s frequency. These are:

- (a) the signal amplitude at two horizontally separated receivers;
- (b) the amplitudes of the first and second reflections;
- (c) the amplitude and phase of the first reflection.

The diffractive changes are found to be considerable, but the wave emerging from the layer is probably modulated in phase rather than amplitude.

A study of the variation of fading speed at 75 ko/s with height of reflection appears to confirm existing ideas concerning the presence of small-scale irregularities above a critical height in the lower E-region.

STATISTICS OF A RADIO WAVE DIFFRACTED BY A RANDOM IONOSPHERE
EE Abstr. 3482/1961; J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 3,
Pgs. 275-92, May-June 1961.
S.A. Bowhill.

For some purposes, particularly in connection with the study of the random structure of the lower ionosphere, using very low frequencies, it is necessary to find the detailed statistical properties of a random signal diffracting in free space. Mathematical tools for evaluating these parameters have been developed, and are applied in this paper. Allowance is made for the effect of sphericity of the wave incident on the ionosphere, and anisotropy of the irregular variations of signal is permitted. The case of oblique incidence of a wave on the ionosphere is also considered.

AN EXPLANATION OF RADIO PROPAGATION AT 16 KC IN TERMS OF TWO LAYERS BELOW E LAYER
Phys. Abstr. 11593/1954; J. atmos. terrest. Phys. (GB), V. 2, No. 4,
Pgs. 216-25, 1952
R.N. Bracewell, W.C. Bain.

An ionospheric model consisting of two ionized layers below the normal E layer is postulated in an attempt to account for observed features of the propagation of 16 ko radiowaves over distances of 90 and 535 km. These observations suggest the existence of more than one ionized layer below the E layer. The lower of the two postulated layers reflects very long waves over 535 km range, but over 90 km this layer is penetrated and the waves are reflected from the upper layer. The field produced by a transmitter at distances up to about 300 km is composed of the ground wave plus waves reflected one and more times from the upper layer. At 535 km, waves from both layers contribute to the total field, especially the wave reflected once from the lower layer and waves reflected more than once from the upper layer. New experimental data for 535 km are interpreted in terms of this model.

THEORY OF FORMATION OF AN IONOSPHERIC LAYER BELOW E LAYER BASED
ON ECLIPSE AND SOLAR FLARE EFFECTS AT 16KC

Phys. Abstr. 11594/1954; J. atmos. terrest. Phys., V.2, No. 4,
Pgs. 226-35, 1952

R.N. Bracewell

The height of reflection of 16 ko waves from the ionosphere at steep incidence was carefully observed during the partial solar eclipse of 28th April, 1949, and a symmetrical anomaly was found. This observation, and the observed effects of solar flares, are shown to be incompatible with the theory that reflection takes place from the bottom of a Chapman layer. An alternative mechanism is proposed whose essential feature is the removal of the restriction in the Chapman theory that the electron density should be negligible compared with the density of ionizable particles. The resulting theory is worked out. In the extreme case of virtual exhaustion of the supply of ionizable particles in the top of the ionized layer, an increase in the incident ionizing radiation simply lowers the lower boundary of the layer. The consequences of this sort of behaviour are in agreement with observation as regard (i) the eclipse effect, (ii) the effect of solar flares and (iii) the diurnal variation of height.

THE IONOSPHERIC PROPAGATION OF RADIO WAVES OF FREQUENCY 30-65 KC
OVER SHORT DISTANCES

EE Abstr. 347/1954; Instn. Elect. Engrs. Monogr., No. 84, 9 pp.,
15 December 1953

R.N. Braoewell, J. Harwood, T.W. Straker

The paper describes experiments carried out at Cambridge on waves of frequency 30-65 kc reflected from the ionosphere at steep incidence. The phases and amplitudes of two linearly polarized components of the downcoming wave were measured with reference to the ground wave. The results for frequencies of 30, 43, and 65 kc are considered in turn, and compared with the results for 16 kc. The main conclusions were as follows: (a) The day-to-day variations of the downcoming wave were greater at the higher frequencies. (b) The change of height of reflection in passing from day to night was about the same for all the frequencies. (c) In summer, the amplitudes by day and night were very different, except at 16kc. (d) The polarization at all the frequencies was approximately circular, left-handed and constant. The height of reflection of waves of frequency 30ko was determined by using the frequency-change method of Appleton and Barnett.

A SURVEY OF SOME PROMISING METHODS FOR THE STUDY OF RAY PROPAGATION
IN A GENERAL MEDIUM.

Abstract in Symposium on Whistler Propagation,
Programme of Joint URSI-IRE Meeting, Washington DC.
4th - 7th May, 1959, P. 28.
J.J. Brandstatter

This paper will attempt to give a survey of some promising methods for the study of the propagation of rays in non-homogeneous anisotropic media. Based on an extension of Hamilton's principle, the ray path equations are deduced together with certain properties of the associated wave normals and surfaces. The latter provides an aid in the study of refraction and reflection, particularly in the ionospheric case. It is shown that by the extension of Hamilton's principle stated above, the concepts of dispersion and group velocity appear quite naturally. For the study of dispersion, a perturbation method developed by the author is presented. Finally, it is indicated how a field theory, that is, a diffraction theory, may be constructed. Some of the proceeding has already been applied to the study of whistler path phenomena and further applications are already in progress.

THE THEORY OF PROPAGATION OF RAYS IN AN INHOMOGENEOUS AND ANISOTROPIC
MEDIUM

Final Letter Rept., Pt. I, Contract AF 18(603)-126, SRI Project 2241,
Stanford Research Inst., Menlo Park, California, December 1959.
AFCRC-TN-60-138. AD-233 108.
J.J. Brandstatter

This is the first of two reports covering the work done on the theory and application of ray tracing techniques to whistler propagation in the outer ionospheres. (Part II is Computation of Whistler Ray Paths by I. Yabroff.)

The theory of the propagation of rays in non-homogeneous media has received considerable attention in recent years. The developments in ray theory for anisotropic media have not paralleled those for the isotropic case. The best formulation of a compact theory for the study of ray propagation in non-homogeneous anisotropic media was given in a paper by J. Haselgrove in 1955. The origin of the formulation and method of approach has its roots in Hamilton's classical work in optics and mechanics. However, Haselgrove's paper was so concise that it prompted many questions on the derivations and their validity. Consequently, we, in an attempt to understand and apply the results of this work, were led to develop the background theory and final equations, starting from first principles.

PROPAGATION OF (ACOUSTIC) WAVES IN A NON-UNIFORM WAVEGUIDE

Akust. Zh. (USSR) V.6, No. 3, Pgs 284-91, 1960. Soviet Physics-Acoustics V.6, No. 3, January-March 1961, Pgs 335-9.
L.M. Brekhovskikh, V.A. Eliseevnin

A waveguide is considered whose properties vary along the propagation path. For a special case, the problem of propagation is solved both exactly and using the ray approximation. The present theory can be used in the analysis of long-distance propagation of acoustic and electromagnetic waves in natural waveguides. Possible generalizations of the results are indicated.

THE EXTENSION OF SOMMERFELD'S FORMULA FOR THE PROPAGATION OF RADIO WAVES OVER A FLAT EARTH, TO DIFFERENT CONDUCTIVITIES OF THE SOIL.

EE Abstr. 409/1955; Physios (Netherlands), V. 20, Pgs 441-60, August 1954.
H. Bremmer

The influence of non-homogeneous soil conditions on the propagation of radio waves over a flat earth can be investigated with the aid of an integral equation based on Green's theorem. This equation applies to all types of distributions (also continuous) of the conductivity and of the permittivity of the earth; it is essentially identical with the integral equation considered by Hufford for the propagation over irregular terrain. The special solution for two adjacent regions of homogeneous electrical constants can be treated numerically with the aid of two different expansions for the field near the separating boundary and for the field far beyond this boundary; the rigorous solution of the integral equation proves to be identical with the corresponding expression derived in a very different way by Clemmow. The solution for three adjacent homogeneous regions can be obtained by solving the integral equation by a similar method.

APPLICATIONS OF OPERATIONAL CALCULUS TO GROUND-WAVE PROPAGATION, PARTICULARLY FOR LONG WAVES

Inst. Radio Engrs (USA) Trans., V. AP-6, P. 267, 1958.
H. Bremmer

No abstract

APPLICATIONS OF OPERATIONAL CALCULUS TO GROUND-WAVE PROPAGATION,
PARTICULARLY FOR LONG WAVES

Trans. IRE, PGAP-6, No. 3, Pgs 267-72, July 1958.

H. Bremmer

All results of the approximate diffraction theory dealing with the propagation of radio waves around a smooth spherical earth (surrounded by a homogeneous atmosphere) can be derived from a one-dimensional integral equation originally discussed by Hufferd.

This equation can be solved in terms of operational calculus which leads, first of all, to the well-known residue series. In this treatment the Sommerfeld theory for a flat earth appears at once as a limiting case; moreover, analytic expressions for correction terms accounting for the finite value of the earth's radius are easily determined. Finally, the equation in question can also be used for the extension to inhomogeneous soil conditions, without neglecting the earth's curvature.

THE SURFACE-WAVE CONCEPT IN CONNECTION WITH PROPAGATION TRAJECTORIES
ASSOCIATED WITH THE SOMMERFELD PROBLEM

Inst. Radio Engrs (USA), Trans., V. AP-7, Pgs 175-82, 1959.

H. Bremmer.

Both the continuous-wave solution and the pulse solution of the Sommerfeld problem can be represented as multiple integrals which describe cooperating contributions propagated along continuous sets of trajectories. The latter consist of a number of rectilinear sections that connect the transmitter and the receiver. The propagation velocity along each section is in accordance with the corresponding medium. The velocity along section lying in the earth's surface is that of the well-known surface wave. Transient phenomena at the receiver start after the arrival of a main pulse along the trajectory connecting the transmitter and the receiver in accordance with ordinary geometric optics, ignoring surface-wave effects. Pulses along trajectories containing a surface-wave section may arrive earlier; however, their joint contribution then cancel each other until the arrival of the main pulse.

MODE EXPANSION IN THE LOW-FREQUENCY RANGE FOR PROPAGATION THROUGH A
CURVED STRATIFIED ATMOSPHERE

J. Research NBS, Vol. 63D, No. 1, Pgs. 75-85, July-August 1959.

H. Bremmer

This expansion is particularly useful when considering ionospheric propagation at low frequencies. The complex problem dealing with two media, viz. a homogeneous earth and a surrounding stratified atmosphere, leads to intractable expressions. However, as the influence of the earth may be accounted for by an approximate boundary condition at the earth's surface, the problem is then reduced to that of the outer medium only. The coefficients of the mode expansion for this simplified problem will be derived

taking into account the earth's curvature; however, the latter proves to be negligible under very general conditions. The expansion to be derived is wanted in particular when studying the influence of a gradual transition in the electron density with height at the lower edge of the ionosphere.

THE PROPAGATION OVER AN INHOMOGENEOUS EARTH CONSIDERED AS A TWO-DIMENSIONAL SCATTERING PROBLEM

Reprinted from "Electromagnetic Wave Propagation" published by Academy Press, 1960.

H. Bremmer

This article deals with a two-dimensional integral equation for the distribution of field-strength across a flat inhomogeneous earth. The equation is based on an approximative boundary condition, which accounts for the local distribution of the electrical constants. An infinite series representing the solution is interpreted in terms of scattering effects. The result applying to a special situation (two homogeneous regions separated by a straight boundary) is compared with that derived from the conventional one-dimensional equation which constitutes a saddle point approximation of the above two-dimensional equation.

PRELIMINARY STUDY OF PROPAGATION CHARACTERISTICS OF LOW-FREQUENCY COMMUNICATION

Mathematical Note 181, Mathematical Services Unit, Boeing Scientific Research Laboratories, Seattle, Wash. 6th October 1957.

R.L. Brook, R.C. McCarty

This mathematical note constitutes a final report made in connection with a study to determine the feasibility of a reliable long-distance communication system operating at the very low frequencies (VLF) or low frequencies (LF). This preliminary study was formally undertaken in late January 1957. The phase of the study reported here pertains principally to the effects of atmospheric noise and regular and anomalous propagation characteristics of the medium at these frequencies as they are related to the feasibility of a highly reliable long-distance communication system. The material presented here is to be considered as supplementary to that given in Math. Note No. 166, Memorandum 2-7716-75, and BAC Documents D2-1466 and D2-2302.

THE EFFECT OF SUNRISE ON THE REFLECTION HEIGHT OF LOW FREQUENCY WAVES

Can. J. Phys., 32, Pgs 90-8, January 1954.
S.B. Brown, W. Petrie.

It has been found that when radio waves of frequency 16 kc and somewhat higher are transmitted over distances of 540 km, the phase and amplitude of the received signal change suddenly about 1 hour before ground sunrise at the mid-point of the transmission path. This effect results from a lowering of the night-time reflection height 95km to the day-time value of 70 km. By considering the geometry of the situation, it is apparent that the process of photo-ionization of atmospheric molecules cannot produce the observed effect since the relevant wavelengths are absorbed before reaching the 95 km height. On the other hand, electrons may be removed from negative oxygen ions by visible and near infra-red radiation which does reach the 95 km level prior to sunrise. The problem is then to determine the intensities of the relevant wavelengths at the 95 km level, and to compute the rate at which electrons are released from negative ions. It is shown that the pre-sunrise effect at 95km is readily explained as a negative ion phenomenon, and the rate of fall of reflection height is discussed.

THE PROPAGATION OF A RADIO-ATMOSPHERIC

Phil. Mag., V. 42, Pgs 1-19, January 1951.
K.G. Budden

The author shows that if one surface of the wave guide is an imperfect conductor, then all the modes including the zero-order mode, are heavily attenuated below a certain critical frequency. There are two modes where amplitudes are much greater than those of all other modes, and these both give an oscillatory response to a lightning flash at a great distance.

THE PROPAGATION OF VERY LOW FREQUENCY RADIO WAVES TO GREAT DISTANCES

Phys. Abstr. 7804/1953; Phil. Mag., 44, Pgs 504-13, May 1953.
K.G. Budden.

In discussing the propagation of v.l.f. radio waves to great distances, it is convenient to treat the space between the earth and the ionosphere as a waveguide. This treatment is applied to some experimental measurements made on signals of frequency 16 kc, over distances of 340-3640 km from the sender. It is shown that the measurements can be explained in terms of the four least attenuated waveguide modes. If the earth's magnetic field is neglected, and the ionosphere is assumed to be sharply bounded homogeneous, ionized medium, then it is shown that the height of the boundary is 69.1 ± 0.5 km.

A RECIPROCITY THEOREM ON THE PROPAGATION OF RADIO WAVES VIA THE IONOSPHERE

Proc. Cambridge Phil. Soc., Vol. 50, Part 4, Pgs 604-613,
October 1954.
K.G. Budden

The reciprocity theorem for electrical systems that include a radiation link was believed to be true only when the media within the system have dielectric constants that are symmetric tensors. This condition is not fulfilled by the ionosphere, so that the reciprocity theorem is not generally applicable when the radiation link includes one or more reflections from the ionosphere. It is here proved that when the ionosphere is horizontally stratified, and when the path from transmitter to receiver is in the magnetic meridian (north-south and south-north transmission), the reciprocity theorem applies (a) when the transmitting and receiving aerials both radiate or receive waves whose electric vector is in the plane of incidence, and (b) when both aerials radiate or receive waves whose electric vector is horizontal. Further, (c) if the electric vector radiated or received is horizontal for one aerial and in the plane of incidence for the other, then there is reciprocity in signal amplitudes, but the phase changes for transmission in the two directions differ by 180° . These results are valid for any law of variation of electron density and collision frequency with height. They are based on a "full-wave" theory, and therefore apply to all frequencies. They are unaffected if the path includes multiple reflections and if allowance is made for the curvature of the earth.

THE "WAVEGUIDE MODE" THEORY OF THE PROPAGATION OF VERY-LOW FREQUENCY RADIO WAVES

Phys. Abstr. 8033/1957; Proc. Inst. Radio Engrs., V.45, No. 6,
Pgs 772-4, June 1957.
K.G. Budden

Relates to the theory in which the propagation of v.l.f. radio waves is treated by regarding the space between the earth and the ionosphere as a waveguide. Its purpose is to answer some criticisms of earlier papers by Budden (Abstr. 7804/1953). The earth is assumed to be a perfectly conducting plane, and the ionosphere is assumed to be a homogeneous medium with a sharp boundary. In general, there is no unique way of assigning numbers to the waveguide modes. The numbers are usually assigned by continuity with the case where the ionosphere is a perfect conductor, but this method fails for some values of the height and the conductivity. If the product of the height and the conductivity is less than a certain critical value, the attenuation for the zero order mode has a maximum at some frequency, and thereafter decreases as the frequency increases, as was found by Budden. If the critical value is exceeded, the attenuation for the zero order mode increases indefinitely with increasing frequency, as was found by Wait, and Liebermann.

THE INFLUENCE OF THE EARTH'S MAGNETIC FIELD ON RADIO PROPAGATION BY
WAVE-GUIDE MODES

Phys. Abstr. 7756/1962; Proc. Roy. Soc. A (GB), V. 265, No. 1323,
Pgs 538-53, 1962.

K.G. Budden

A general theory of radio propagation by wave-guide modes is given, which simultaneously makes allowance for the gradualness of the lowest part of the ionosphere, the earth's curvature and the earth's magnetic field. The method involves solving differential equations satisfied by the matrix admittance or matrix reflection coefficient variables. The mode condition, excitation factor, and polarization of the waves in a mode are derived by evaluating the residues of a series of poles of a contour integral. The earth's curvature is allowed for by the method of the "modified refractive index", thus avoiding the use of cumbersome spherical wave functions. This also permits the replacement of a point source by a line source with consequent further simplification of the mathematics. Formulae are given which have been used for computations described elsewhere.

SOME EXPERIMENTAL RESULTS CONCERNING NON-RECIPROCAL EAST-WEST VLF WAVE
PROPAGATION

Radio Science Journal of Research NBS/USNC-URSI, Vol. 68D, No. 1,
January 1964, Pgs 17-18

B. Burgess

Experimental data collected in recent years by Crombie (1958), and Reder et. al. (1962) and theoretical work on VLF propagation by Wait (1960) have given strong evidence to the fact that VLF propagation is non-reciprocal in the east-west and west-east directions. Experimental data relating to this topic are at present sparse. This paper presents some experimental results obtained during the past two years which will substantiate the existing evidence as to this non-reciprocal propagation.

PROPAGATION OF VLF WAVES UNDER DISTURBED CONDITIONS

Radio Science Journ. of Research NBS/USNC-URSI, Vol. 68D, No. 1,
January 1964, Pgs. 115-6.

B. Burgess

The very stable phase properties of VLF wave propagation over great distances are being currently considered or utilized for worldwide frequency comparisons, time synchronization, and long-range radio navigational aids. All these uses rely on very stable properties of VLF propagation, and hence a knowledge of disturbed propagation conditions, their cause, and understanding is of practical importance.

PROPAGATION OF VLF WAVES OVER DISTANCES BETWEEN 1000 AND 3000 KM
Radio Science, Journal of Research NBS/USNC-URSI, Vol. 68D, No. 1,
January 1964. Pgs 15-16.
B. Burgess

The study of the propagation of very-low-frequency radio waves over distances lying between 1000 and 3000 km will provide valuable information regarding the propagation characteristics of such waves and the physical properties of the reflecting walls of the earth-ionosphere waveguide.

This paper will deal mainly with the diurnal phase variations of VLF signals received over these distances.

EXTREMELY LOW-FREQUENCY RADIO PROPAGATION IN AN INHOMOGENEOUS IONOSPHERE

EE Abstr. 2666/1964. Nature (GB), Vol. 199, 581-2, 10th August 1963
R. Burman, R.N. Gould.

Exact solutions of the wave equation in the zero-order mode for waves propagating in the earth-ionosphere waveguide are determined for a linear refractive index profile. The results indicate that the attenuation of e.l.f. waves may increase as frequency decreases at the lower frequencies - a result in agreement with some experimental measurements.

ON THE PROPAGATION OF VERTICALLY POLARIZED ELECTROMAGNETIC WAVES IN A HORIZONTALLY STRATIFIED MEDIUM

Phys. Abstr. 3142/1964. J. Atmos. Terrest. Phys. (GB), Vol. 25, 543-5, September 1963.
R. Burman, R.N. Gould

It is pointed out that the differential equation describing wave propagation in a stratified medium is solvable for linear exponential and hyperbolic refractive index profiles for vertically polarized waves. Solutions are given for these three cases. Earth curvature may be allowed for by the usual methods. Further tabulation of the Whittaker functions may be necessary in order to apply the derived solutions. The results have significance in the theory of elf and vlf propagation.

RADIO COMMUNICATION WITHIN THE EARTH'S CRUST

EE Abstr. 1172/1964. IEEE Trans Antennas and Propagation (USA),
Vol. AP-11, No. 3, 311-17, May 1963.
C.R. Burrows

Discusses four methods of electrical communication within the earth's crust. Mode I may be described as similar to propagation over the ground, except that the rock dielectric substitutes for air as the propagation medium and the under surface of the overburden takes the place of the earth's surface. Mode II results when the Q of the propagating medium is small so that the aerials must be modified, which also results in a modification of the propagation formulae. Two other modes are considered for conditions where the depth to the good dielectric basement rock is prohibitive. Mode III is indicated when the overburden is a highly conducting layer. It makes use of "d.c. signalling" with vertical aerials extending below the surface layer. Mode IV is indicated when the overburden is so thin that it does not provide an effective conducting plane. It makes use of "d.c. signalling" with the aerials consisting of a pair of vertical conductors insulated from the thin layer of higher conductivity, but making contact with the medium of intermediate conductivity, hence, generating a horizontally polarized wave. Distances and information rates are given for these modes under various propagation conditions.

OBSERVATIONS ON PHASE STABILITY OF SIGNALS FROM NBA (18 KC/S) PANAMA AS RECEIVED IN NEW ZEALAND

EE Abstr. 1739/1964. Proc. Instn. Elect. Engrs (GB), Vol. 110, No. 11,
Pgs 1928-32, November 1963.
G.J. Burt

An analysis of observations made over a period of a year shows that the phase changes of the signals from NBA as received in Lower Hutt, New Zealand, have a diurnal pattern but with considerable day-to-day and seasonal variations. It is concluded that, as recorded at present, the signal is not sufficiently stable to be used as a reference for standard frequency measurements. A suggestion is made for improving the reception of the signals for frequency-comparison purposes.

RADIO WAVES IN ROCK NEAR OVERBURDEN-ROCK INTERFACE

EE Abstr. 1229/1964. IEEE Trans Antennas and Propagation (USA),
Vol. AP.11, No. 3, Pgs 336-8, May 1963.
J. Carolan, Jr., J.T. de Bettencourt.

An account is given of a theoretical investigation of radio wave propagation in a rock medium situated below a highly conducting plane boundary overburden, due to a vertically polarized electric dipole source immersed in the rock near the boundary. Excluded from this discussion are propagation modes in the rock guided between plane boundaries on top and bottom. Just as with dipoles in air above a plane ground, the rock wave can be considered as the result of a "direct wave", a wave "reflected" from the overburden and an "interface

surface wave". Rock with complex phase constant K_2 replaces air with real phase constant β_0 . Of interest is the variation with depth below the boundary of the fields in the rock, analogous to "height gain" for fields in air. Of importance is the effect of the relative refractive index of overburden-to-rock. A sample calculation is given for a one-mile path assuming typical electrical constants for the rock and overburden media. At the v.l.f. of interest, loss tangents in the media are large. These results may assist in determining whether or not a received signal is due predominantly to a rock propagated wave or to a possible "up-over-and-down" mode.

VLF PROPAGATION MEASUREMENTS FOR THE RADUX-OMEGA NAVIGATION SYSTEM
EE Abstr. 4905/1959; Proc. Inst. Radio Engrs. V. 47, No. 5(I),
Pgs 829-39, May 1959.
C.J. Casselman, D.P. Heritage, M.L. Tibbals.

Describes special v.l.f. propagation measurements in connection with a feasibility study of a long range navigation system. Round-trip single-frequency measurement of phase stability was made between Hawaii and San Diego on frequencies from 10.2 kc to 18.2 kc in 1 kc increments. During 15th to 23rd January 1958, the standard deviation of phase stability on 12.2 kc was 4 μ sec daytime and 5 μ sec nighttime. One-way two-frequency transmissions were monitored in San Diego and Washington, D.C., to determine the phase stability of a 1 kc difference frequency for pairs of frequencies from 10.2 kc to 18.2 kc. Data analysed at time of submission of this paper (10.2 - 16.2 kc) indicate limitations of the two-frequency system for lane identification (resolution of cyclic ambiguities corresponding to one period of the carrier frequency). The techniques used to instrument these tests are considered somewhat unique. Data reported herein are general and applicable to any propagation study. The data being collected are leading to a better understanding of the mechanism of v.l.f. propagation.

ON THE ROLE OF THE PROCESS OF REFLECTION IN RADIO WAVE PROPAGATION
Phys. Abstr. 16041/1962. J. Res. Nat. Bur. Stand (USA), Vol. 66D,
No. 3, 273-84, May-June 1962.
F. du Castel, P. Misme, A. Spizzichino, J. Voge.

Nature offers numerous examples of irregular stratification of the medium for the propagation of radio waves. A study of the process of reflection in such a medium distinguishes between specular reflection and diffuse reflection. The phenomenon of trans-horizon tropospheric propagation offers an example of the application of such a process, necessary for the interpretation of experimental results. Other examples are those of ionospheric propagation (sporadic-E layer) and propagation over an irregular ground surface (phenomenon of albedo).

PROPAGATION OF AUDIO FREQUENCY RADIO WAVES

Nature, V. 177, Pgs. 930-3, May 1956.

F.W. Chapman, R.C. Macario.

No abstract

VLF PHASE PERTURBATION ASSOCIATED WITH METEOR SHOWER IONIZATION

J. Geophys. Research 66, 379-383, February 1961.

C.J. Chilton.

No abstract

THE AFTERNOON HUMP IN THE DIURNAL VARIATION OF ATMOSPHERICS ACTIVITY ON 27 KC/S

Phys. Abstr. 2209/1964. Indian J. Pure Appl. Phys. Vol. 1, No. 7, Pgs 256-9, July 1963.

M.W. Chiplonkar, R.N. Karekar

The phenomena of "afternoon hump" and "sunset dip" observed in the diurnal variation of atmospheric activity on 27 kc/s, are discussed with reference to the data obtained at Poona during 1958-59. Two basic variations are considered: (a) the diurnal variation of winter months and (b) the afternoon hump of summer months. Any type of observed diurnal variation can be explained by them either individually or by their superposition. The processes by which these basic variations may be produced are also discussed. It is concluded that though the diurnal and seasonal variations of thunderstorm activity and their geographical distribution play an important part in the production of the afternoon hump, the late occurrence of sunset rise in winter and presence of sunset dip in summer suggests that the role of the ionosphere is of no less importance.

RADIO PROPAGATION OVER A FLAT EARTH ACROSS A BOUNDARY SEPARATING TWO DIFFERENT MEDIA

Phys. Abstr. 4934/1953; Phil. Trans. A, V. 246, No. 905, Pgs 1-55, 1953.
P.C. Clemmow.

A theoretical investigation of the phenomena arising when vertically polarized radio waves are propagated across a boundary between two homogeneous sections of the earth's surface which have different complex permittivities. The problem is treated in a two-dimensional form, but the results, when suitably interpreted, are valid for a dipole source. In the first part one section of the earth is taken to have infinite conductivity and is represented by an infinitely thin, perfectly conducting half-plane lying in the surface of an otherwise homogeneous earth. In the second part the restriction that one of the earth media should be perfectly conducting is waived. A condition, usually met in practice, is assumed, namely, that the modulus of the complex permittivity of each section of the earth is large. Approximate boundary conditions are then likely to be valid, and their introduction makes possible an analytical treatment on the same lines as before.

RELATIONS BETWEEN THE CHARACTER OF ATMOSPHERICS AND THEIR PLACE OF ORIGIN

EE Abstr. 5214/1957; Proc. Instn. Radio Engrs., V. 45, No. 6, Pgs 804-6, June 1957.
J. Chapman, E.T. Pierce

It is shown that atmospheric originating from geographical localities are systematically different in character, even when the distances of propagation are the same and there is no reason to anticipate appreciable dissimilarities in the ionospheres along the respective propagation paths. Detailed and precise information is given of how these "geographical" effects may be traced by recording and classifying types of waveforms. It is also shown that the effects are apparent for observations of atmospheric at fixed frequencies between 0.65 and 27 kc. No attempt is made to assign a reason for the geographical phenomena, but the most promising approach would seem to be by considering differences in the conductivity of the earth's surface, and in particular, those between land and sea.

PHASE VARIATIONS OF 16 KC TRANSMISSIONS FROM RUGBY AS RECEIVED IN NEW ZEALAND

EE Abstr. 3251/1958; Proc. Instn. Elect. Engrs, Paper 2562R, publ. May 1958, V. 105B, Pgs 301-4.
D.D. Crombie, A. H. Allan, M. Newman

The results of approximately one year's measurement of the diurnal phase variation, in New Zealand, of the highly stable 16 kc transmission from GBR are given and discussed. If it can be considered that the signal is received by the short great-circle path, the observed phase variations appear to be in accordance with propagation via the TM_{01} -mode which exists between parallel, plane metallic sheets.

DIFFERENCES BETWEEN THE EAST-WEST AND WEST-EAST PROPAGATION OF VLF SIGNALS OVER LONG DISTANCES

J. Atmos. Terrest. Phys. Vol. 12, Nos. 2/3, Pgs 110-117, 1958.
D.D. Crombie

An early suggestion by Round, Eckersley, Tremellen, and Lunnon, that VLF signals received from the west are less attenuated than those from the east is investigated. The original evidence, together with further experimental data, gives strong support to the hypothesis. The outline of a possible explanation of the effect is given.

ON THE MODE THEORY OF VERY-LOW FREQUENCY PROPAGATION IN THE PRESENCE OF A TRANSVERSE MAGNETIC FIELD

EE Abstr. 6953/1960; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 3, Pgs 265-7, May-June 1960.
D.D. Crombie.

The effect of a purely transverse horizontal magnetic field on the propagation of very-low frequency (v.l.f.) waves is considered. It is shown that the magnetic field introduces non-reciprocity, and that for the propagation along the magnetic equator, the rate of attenuation is less for west-to-east propagation than for east-to-west propagation.

REFLECTION FROM A SHARPLY BOUNDED IONOSPHERE FOR VLF PROPAGATION PERPENDICULAR TO THE MAGNETIC MERIDIAN

Phys. Abstr. 5484/1962; J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 5, Pgs. 455-63, September-October 1961.
D.D. Crombie

There is experimental evidence that signals propagating from west-to-east suffer less attenuation than from east-to-west. Earlier work treating the case of non-reciprocal propagation along the magnetic equator is extended in latitude. The non-reciprocity shown by $\parallel R \parallel$ for highly oblique propagation along the magnetic equator persists when the reflection point moves towards a magnetic pole, but at the pole itself $\parallel R \parallel$ is reciprocal. To a first approximation $\perp R \perp$ is reciprocal at all magnetic latitudes. The conversion coefficient $\parallel R \perp$, $\perp R \parallel$, are greater for east-to-west propagation than for propagating in the opposite direction, except at a magnetic pole where they are equal.

NON-RECIPROCALITY OF PROPAGATION OF VLF WAVES ALONG THE MAGNETIC EQUATOR

EE Abstr. 9181/1963. Proc. Inst. Elect. Electronics Eng (USA), Vol. 51, No. 4, Pgs. 617-8, April 1963.
D.D. Crombie

An explanation for the non-reciprocity of vlf propagation along the magnetic equator has been given by Barber and Crombie (Abstr. 15164A of 1960; J. Atmos. Terrest. Phys. Vol. 16, Nos. 1-2, Pgs 37-45 (October 1959)). They implied that the reason for the reduced reflection for waves incident from the east was due to increased dissipation of wave energy in the ionosphere. In this note Crombie states that this is no longer believed to be true, that the absorption coefficient in the ionosphere is independent of the direction of incidence, and that the non-reciprocal reflection is balanced by a non-reciprocal transmission coefficient at the ionospheric boundary.

PERIODIC FADING OF VLF SIGNALS RECEIVED OVER LONG PATHS DURING
SUNRISE AND SUNSET

Radio Science Journal of Research NBS/USNC-URSI, Vol. 68D,
No. 1, January 1964. Pgs. 27-34.
D.D. Crombie

Data on the periodic changes in amplitude and phase of VLF signals received over long VLF paths is examined. It is concluded that the variations are due to multimode propagation in the night-time portion of the path.

INFLUENCE OF THE TOTAL ECLIPSE OF THE SUN ON 15TH FEBRUARY 1961
ON THE TRAVEL TIME OF VERY LONG WAVES

Phys. Abstr. 16588/1961; CR Acad. Sci. (France), V. 252, No. 16,
Pgs 2387-9, 17th April 1961.
B. Decaux, A. Gabry, J. Lachâtre, J. Lucas.

The phase and amplitude of the signals from two standard low-frequency broadcast stations, and atmospherics at 27ko, were observed. Effects during the eclipse are described and it is shown that the eclipse produces night-time propagation conditions.

RAPID CHANGES WITH SEASON IN THE DIURNAL VARIATIONS OF THE TIME OF
TRAVEL OF VLF WAVES PASSING WITHIN THE ARCTIC CIRCLE

C.R. Acad. Sci. (France), Vol. 257, No. 3, Pgs 722-4, 17th July 1963.
In French.
B. Decaux, A. Francès, A Gabry.

The changes can be explained by considering the changing pattern of solar illumination of the path.

SOME PARTICULAR OBSERVATIONS ON DIURNAL PHASE VARIATIONS OF VLF
TRANSMISSIONS RECEIVED IN PARIS

Radio Science Journ. of Research NBS/USNC-URSI, Vol. 68D, No. 1,
January, 1964. Pgs 21-25.
B. Decaux, A. Gabry

Observations made in Paris, France, of the phase of various frequency stabilized VLF transmitters are reported. Descriptions are given of the seasonal dependence of the diurnal phase shift on an arctic path, effects following solar flares, effects of two solar eclipses, and observation following the high-altitude nuclear explosion of 9th July, 1962.

THE MAGNETIC FLASH OF THE NUCLEAR TEST OF 13TH FEBRUARY 1960
AT REGGANE
CR Acad. Soi. (France), V. 250, No. 14, Pgs 2536-7, April 1960.
J. Delloue

An electromagnetic signal originating from the nuclear explosion was recorded at a distance of 2500 km and the field strength shown to be 0.1 V/m.

ELECTROMAGNETIC WAVE PROPAGATION: Proceedings of a conference sponsored by the postal and telecommunication group of the Brussels Universal Exhibition, 1960.
\$22.00 Academic Press.
M. Desirant, J.L. Michiels, eds.

EFFECTS IN VLF MODE TRANSMISSION DUE TO THE EARTH'S MAGNETIC FIELD
Document DI-82-0055, Boeing Scientific Research Laboratories, Seattle, Washington, June 1960. AD-245 794. For ref. at ASTIA Headquarters only. ASTIA does not furnish copies. Copies may be obtained from the author.
D.R. Dobrott.

The effect of the earth's magnetic field is analyzed for the propagation of VLF electromagnetic waves about the earth. These waves are considered to be propagating by modes in a parallel plate waveguide. The lower boundary of the guide is considered to be a perfect conductor, while the upper boundary is assumed to be a sharply defined, semi-infinite, homogeneous plasma with a constant magnetic field applied. A relative dielectric tensor is derived and its components plotted. Several types of sources are discussed. Admittance relations are derived for the upper boundary of the guide by considering the waves to be of grazing incidence. It is found that in the case of TM waves propagating across the earth's magnetic field these admittance parameters depend upon the direction of propagation. This phenomenon is known as the East-West effect. The admittances for this particular case are plotted versus frequency for various heights. Expressions for the eigenvalues and the eigenfunctions are found as functions of the admittance. By employing the Green's function, the amplitudes of the various modes due to their sources are evaluated. A numerical example of field strength versus distance is calculated illustrating the East-West effect of VLF transmission. All solutions are included in the appendix.

ON COASTLINE EFFECTS IN VLF MODE TRANSMISSION

Report DI-82-0066, Boeing Scientific Research Laboratories, Seattle, Washington, August 1960. AD-244-242. For ref. at ASTIA HQ only. Because this report cannot be satisfactorily reproduced, ASTIA does not furnish copies.

D.R. Dobrott

The effect of a coastline on VLF transmission is analyzed. Three boundaries - the land, the sea, and the ionosphere - are taken into account. A vertically polarized source is introduced, and the Green's function for this source is found by the "Wiener-Hopf" technique. In the process of applying this technique, use is made of the Fourier integral and contour integration. A numerical example is calculated for the far-field approximation, where only one propagating mode is present. The so-called "recovery effect", a sharp increase in field strength past the shoreline, due to changes in conductivities at the coastline is observed.

EAST-WEST EFFECT ON VLF MODE TRANSMISSION ACROSS THE EARTH'S MAGNETIC FIELD

EE Abstr. 2025/1961; J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 1, Pgs 47-52, January-February 1961.

D. Dobrott, A. Ishimaru.

The effect of a constant transverse magnetic field is analysed for the propagation of v.l.f. electromagnetic waves about the earth. These waves are considered to be propagating by modes in a parallel-plate waveguide. The lower boundary of the guide is considered to be a perfect conductor, while the upper boundary is assumed to be sharply defined, semi-infinite, homogeneous plasma with a constant magnetic field applied. The source of these waves is an infinite number of short, horizontal, cophased dipoles, uniformly spaced parallel to the constant magnetic field vector. Admittance relations are derived for the upper boundary of the guide by considering the waves to be of grazing incidence. Expressions for eigenvalues and the eigenfunctions are found as functions of the admittance. By employing a two-dimensional Green's function, the amplitude of the various modes due to the dipole source are evaluated. It is noted that the propagation constants differ depending on the direction of propagation, thus offering an explanation of the east-west effect of v.l.f. transmission. A numerical example is calculated and field strength versus distance values are found to correspond to some experimental results.

PULSE SKY WAVE PHENOMENA OBSERVED AT 100 KC

Prepublication Papers NBS-IRE PGAP. Symposium on Propagation of VLF Waves, Boulder, Colorado, 23rd-25th January 1957, Vol. III, Paper 44, Similar material was presented at IRE-URSI Symposium, Washington DC, 23rd-26th April 1958.

R.H. Doherty

Sky wave measurements made at 100 kc indicate that signals exist for beyond the geometrical optical limit for these signals. Data observed tend to support a theory that these waves are propagated partly as ground waves. The stability observed for these long range sky waves suggests that they may be utilized for relatively accurate navigational fixes.

The various phenomena observed on higher-order multiple hops (3rd through 7th) are also discussed.

THE MAGNETIC FIELD AT THE SURFACE OF A STRATIFIED FLAT CONDUCTOR IN THE FIELD OF PLANE WAVES WITH APPLICATION TO GEOPHYSICS

Phys. Abstr. 4243/1963. Canad. J. Phys., Vol. 40, No. 11, Pgs 1583-92, November 1962.

H.W. Dosso

The problem of plane electromagnetic waves incident on a stratified flat conductor is considered. Expressions for the amplitude and phase of the components of the resultant magnetic field at the surface of the conductor are obtained and evaluated for a wide range of frequencies, conductivities, surface layer depths, and angles of incidence. The frequencies $f = 10^{-3}$ to 10^3 cycles/sec and the conductivities $\sigma = 10^{-11}$ to 10^{-16} e.m.u. considered are of interest in studying geomagnetic variations.

AIR-TO-UNDERSEA, COMMUNICATION-ELECTROMAGNETIC FIELDS IN THE TWO MEDIA, CAUSED BY VERTICAL AND HORIZONTAL ELECTRIC DIPOLES IN AIR.

University of New Mexico, Albuquerque, New Mexico, Technical Report EE-61, September 1961, P.59.

S.H. Durrani

A brief description of the salient features of electromagnetic waves in a conducting medium is followed by a discussion of the practical ranges of various parameters involved in the problem of air-to-undersea communication at frequencies of 10 and 10^3 cps. Using the integrals given by Sommerfeld, expressions are developed for components of the $\vec{\pi}$ vectors in both air and sea, in terms of certain auxiliary integrals and their functions evaluated at specific points. Asymptotic series expansions for these integrals, which may be differentiated or integrated term-wise to get the necessary functions, are derived by extending the work of Banos and Wesley. Values of the $\vec{\pi}$ vector and electromagnetic field components are obtained for the so-called "quasi-near-range" - when r , the horizontal distance between the point of observation and the source, is less than a wavelength in air (of the order of miles) but more than a wavelength in sea (of order of feet) - with the restriction that the source height or depth of the point of observation are both smaller than r . It is found that the strongest E field in the

sea is the horizontal component of the field produced by a vertical dipole in air. Combining this with the known results for E fields in air produced by submerged dipoles, it is concluded that from considerations of field strength alone, the best inter-communication scheme has a vertical dipole in air with a horizontal dipole in the sea. Some comments on reciprocity and a discussion of the practical communication-ranges are included.

AIR-TO-UNDERSEA COMMUNICATION WITH ELECTRIC DIPOLES

AD 265 476; University of New Mexico, Albuquerque, New Mexico, 1961, P. 18, illus. IRE Trans. Antennas and Propagation (USA), Vol. AP-10, Pgs. 524-8, September 1962. E.E. Abstr. 1007/1963.
S.H. Durrani

The ranges of various parameters involved in air-to-undersea communication at 10 to 10 to the 5th power ops are briefly discussed. Sommerfeld's integrals for the pi components in the two media are presented and are solved for the quasi-near range, subject to certain mild restrictions. This is accomplished by defining two auxiliary integrals, asymptotic series expansions for which are made available by extending the work of Banos and Wesley. The solution for pi leads to the derivation of electromagnetic field components. It is found that, from field strength considerations alone, the best inter-communication scheme consists of a vertical electrical dipole in air with a horizontal electric dipole in the sea. Simple calculations for estimating the satisfactory communication range are included.

INFLUENCE OF POLAR CAP ABSORPTION EVENTS ON VLF PROPAGATION

Ark. Geophys. (Sweden), V. 3, Paper 21, Pgs 481-8, 1961.
A. Egeland, B. Hultqvist, J. Ortner.

"Polar cap absorption" symposium paper. Between September 1958 and September 1960 eleven periods of absence of the sunrise and sunset minima of the 16 kc signal strength from Rugby were noted at Kiruna in northernmost Sweden. Ten of these instances coincided with the ten polar absorption periods recorded during that time, and even the eleventh case of anomalous v.l.f. propagation may have been associated with similar phenomena. The propagation effect was observed well before the start of the geomagnetic storm and there was close correlation between the intensity and duration of the v.l.f. propagation effects and the corresponding parameters of the polar cap absorption. The conclusion is that polar cap absorption and the anomalous v.l.f. propagation are caused by the same agent, high-energy protons originating from the solar flare. The corollary is that protons arrive even below the geomagnetic latitude of 60 degrees - usually the approximate lower limit of the absorption effect - even prior to the onset of the geomagnetic storm.

VERY LOW FREQUENCY RADIO WAVE PROPAGATION OVER A LONG HIGH-LATITUDE PATH

Ark. Geofys. (Sweden), V. 3, Paper 22, Pgs 539-56, 1961.
A. Egeland.

This report deals with ionospheric propagation of radio waves at 16 kc between Rugby, England, and Kiruna, Sweden, a distance of about 2100km. The results of the investigations on VLF are summarized under the headings of field strength and its twenty-four hourly day-to-day, and seasonal variations as well as the effects of ionospheric, magnetic and solar disturbances. The principal findings are as follows:

- (1) The received signal almost invariably shows a marked minimum around the time of sunrise and sunset.
- (2) The signal strength is greatest during the daylight hours of summer. In winter, especially during the night, the field intensity is lower and more variable.
- (3) No "black-out" periods were noted during the whole observation period, although a large number of major ionospheric disturbances occurred.
- (4) Propagation conditions undergo a rather abrupt seasonal change in March and April, and another, more gradual but opposite change in the autumn.
- (5) Between September 1958 and September 1960 there were eleven periods during which the signal strength of VLF transmissions from Rugby showed little or no diurnal variation. The average duration of these eleven periods was three days. The explanation advanced is that polar cap absorption and the anomalous VLF propagation originates from the same layer which is produced by high energy protons stemming from the solar flare.
- (6) No effect on VLF propagation of solar activity or ionospheric disturbances (SID and SEA) was observed.
- (7) It was not possible to demonstrate a close correlation between the occurrence of abnormal VLF PROPAGATION AND MAGNETIC STORMS NOT ASSOCIATED WITH PCA, although there is some indication that major magnetic disturbances affect the propagation of VLF waves.

THE INFLUENCE OF SOLAR DISTURBANCES ON VERY LOW FREQUENCY RADIO WAVE PROPAGATION OVER A LONG HIGH-LATITUDE PATH

Scientific Report 2; Contract AF 61(052)-418, Kiruna Geophysical Observatory, Sweden, 15th April 1961, AFCRL-724. Ad-263 899.
A. Egeland, B. Hultqvist, J. Ortner

This analysis deals with the effects of solar and terrestrial disturbances on the propagation conditions on 16 kc radio waves between Rugby, England, (latitude 52.2N) and Kiruna, Sweden (latitude 67.8N) a distance of about 2100km. The most reliable method of long distance radio communication in polar regions during all types of polar black-outs, is to use very low and low frequency radio waves (VLF & LF). The VLF and LF propagation conditions are even better than normal during the existence of absorbing periods, when radio communications over almost the whole frequency range used for long distance communication are interrupted. The VLF propagation may under certain conditions be a much more sensitive indicator of protons causing polar cap absorption PCA than are riometers. Sudden ionospheric disturbances do not influence the signal strength of 16 kc radio waves on the high latitude path. No direct correlation between sunspot numbers and the yearly average VLF field strength was observed. It was not possible to demonstrate a close correlation between augmentation or diminution of 16 kc signal strength and magnetic storms not associated with PCA.

THE INFLUENCE OF SOLAR DISTURBANCES ON VERY LOW FREQUENCY RADIO WAVE
PROPAGATION OVER A LONG HIGH-LATITUDE PATH

Report, Contract AF 61(052)-418, Kiruna Geophysical Observatory,
Royal Swedish Academy of Science, Kiruna C, Sweden (1960).

A. Egeland, B. Hultqvist, J. Ortner.

This paper deals with the effects of solar and terrestrial disturbances on the propagation conditions on 16 ko/s radio waves between Rugby, England, (lat. 52.2°N) and Kiruna, Sweden, (lat. 67.8°N) a distance of about 2,100 kilometres.

The principal findings of the investigation are as follows:

- (1) Between September 1958 and March 1961 there were fourteen periods during which the signal strength of VLF radio waves showed little or no diurnal variation. The interpretation given is that polar cap absorption and anomalous VLF propagation are caused by the same ionized layer, which is produced by high energy protons stemming from solar flare. Although the heavily absorbing PCA layers interrupt radio communication over almost the whole frequency range used for long distance communication, it has been found that the VLF propagation conditions for the fourteen PCA periods studied were, on the average, better than ordinary conditions. The average duration of the periods of anomalous VLF propagation was three days.
- (2) SIDs do not influence the signal strength of 16 ko/s radio waves on the high latitude path studied.
- (3) No direct correlation between sunspot numbers and the yearly average VLF field strength has been found.
- (4) It has not been possible to demonstrate a close correlation between the occurrence of abnormal VLF propagation and magnetic storms not associated with PCA, although there is some indication that major magnetic disturbances may affect the propagation of VLF waves.
- (5) No "black-out" periods were noted during the whole observation period, although a large number of major ionospheric disturbances occurred.
- (6) An auroral D-layer may influence the propagation conditions for VLF radio waves considerably, but no close connection between f_oE , $h'E$, f_oF2 and $h'F2$ and 16 ko/s signal strength has been found to exist.

THE INFLUENCE OF POLAR BLACKOUTS ON VLF CIRCUITS

Interim Report T-197, in connection with Modification 1 to Contract N62558-2025(X), Task B, and Contract N62558-2380(X), Task B, Norwegian Defence Research Establishment, Kjeller-Lillestrøm, Norway.
(March 1960)

K.W. Eriksen, B. Landmark.

The purpose of this report is to present some preliminary results from a study of the behaviour of long distance VLF circuits during polar radio blackout conditions, as compared with quiet conditions. There are at least two major types of polar radio blackouts. The most common type is closely related to magnetic disturbances, and occurs most often near the zones of maximum auroral activity. The preliminary results of our study indicate that these disturbances have no great effect on the VLF circuits. The other type of polar blackouts occurs after strong solar flares. This type is not closely related to magnetic activity, and occurs over most of the polar cap simultaneously. During this type of event a significant reduction of the strength of the VLF signals has been observed.

PROPAGATION OF PLANE ELECTROMAGNETIC WAVES OVER REAL EARTH IN THE PRESENCE OF HORIZONTAL REFLECTING LINES

EE Abstr. 6403/1963. Radiotekhnika (USSR), Vol.18, No. 2, 15-26 (February 1963). In Russian.

Yu. A. Erukhimovich.

The investigation deals with the practical problem of reflection effects due to overhead telegraph and power wiring. Formulae are derived for the field vectors of the plane wave front falling onto a conductive infinite horizontal line parallel to the earth surface and for the resulting changes in amplitude, phase and angle of turn of the summated wave (interference field created by the original and the reflected wave). The analysis makes use of Sommerfeld's normal attenuation function and leads to equations containing Macdonald's functions of zero order, illustrated by curves. A large number of graphs are reproduced, plotting various characteristic functions versus distance and angles in linear and polar reference systems. Some special cases of practical importance are considered in more detail, and means are indicated for the estimation of deleterious effects of overhead wiring on aerial installations below.

A DETAILED INVESTIGATION OF THE ABSORPTION BY WATER OF ELECTROMAGNETIC RADIATION

Hudson Labs., Dobbs Ferry, New York, Tech. Rept. No. 73, August 15th, 1957. B.P. Fabricand

The various mechanisms for the absorption and scattering of electromagnetic radiation in sea water has been examined with the idea of evaluating the possibilities of windows anywhere in the spectrum. It is concluded that the chances of finding a window are negligible except of course for the one in the visible region which however is rather cloudy.

PROPAGATION OF RADIO WAVES ALONG AN ACTUAL SURFACE
AD 38 630; Izv. Akad. Nauk SSSR., 1944, an English translation.
E.L. Feinberg.

No abstract

75 KC PULSED NORMAL INCIDENCE IONOSPHERIC SOUNDING
Submitted to: J. Res. Nat. Bur. Stand. (USA), Section D, Radio
Propagation.
A.J. Ferraro & Others

No abstract

AN EXTENSION TO VLF REFLECTION COEFFICIENTS
Phys. Abstr. 11802/1962. J. Geophys. Res. (USA), Vol. 67, No. 2,
898-901 (February 1962).
E.C. Field, P. Tamarkin, E.M. Fairbrother

The derivation of v.l.f. ionospheric reflection coefficients made by Field and Tamarkin (Abstr. 19045 of 1961) for the case of propagation perpendicular to the magnetic meridian has been extended to the case of propagation in arbitrary directions. Some sample numerical results are also given for all four reflection coefficients for propagation in the magnetic meridian.

VLF IONOSPHERIC REFLECTION COEFFICIENTS--DERIVATION FROM IMPEDANCE CONCEPTS AND VALUES FOR SOME MODEL IONOSPHERES
Phys. Abstr. 19045/1961; J. geophys. Res. (USA), V.66, No. 9, Pgs 2737-50, 19th September 1960
E.C. Field, P. Tamarkin

A convenient general method is presented for computing the reflected wave excited by an arbitrarily polarized, plane VLF e.m. wave incident at an arbitrary direction upon a sharply bounded, absorptive ionosphere in the geomagnetic field. The relative simplicity of the method results from the use of impedance concepts coupled with Booker's (1938) treatment of the propagation vector. Expressions for reflection coefficients are given that are exact (for the model assumed) in the case of propagation perpendicular to magnetic meridians and indicate clearly lack of east-west and west-east reciprocity. The results of calculations for eight model ionosphere are given in the form of graphs of reflection coefficient amplitude and phase versus angle of incidence for both east-west and west-east propagation at 16 kc. The model ionospheres are characterized by values of electron density and collision frequency. A brief survey is made of the relation between the computations and some experimental results.

THE FIELD OF A PLANE WAVE NEAR THE SURFACE OF A CONDUCTING BODY
AD 117 276(f); 1945, 29 p., an English translation.
V.A. Fook

Approximate formulas are derived for the field induced by an incident plane wave on and near the surface of a convex body of finite conductivity. The results obtained previously are generalized by (1) finding the field distribution on the surface of the body as well as in its neighbourhood; and (2) considering the body a good conductor only in the sense that the Leontovich conditions for the tangential field components are valid on its surface. The solution is obtained directly for the general case of an arbitrary surface by the method of parabolic equation proposed by Leontovich and developed for the case of a point or on a spherical surface.

HYDROMAGNETIC WAVES IN THE IONOSPHERE

J. Geophys. Research, Vol. 65, No. 11, Pgs. 3593-3600, November 1960.

W.E. Francis, R. Karplus.

A numerical integration of the hydromagnetic wave equations in the ionosphere has been carried out. Tables and graphs are given for the relations between the field amplitudes above and below the ionosphere, and for the power dissipated as a function of altitude. The case of a vertically incident plane monochromatic wave near 45° geomagnetic latitude is treated. The results are used to confirm earlier estimates of ionospheric heating by hydromagnetic waves and to estimate the transit time of extremely low-frequency signals.

MODES IN THE IONOSPHERE

Boeing Airplane Company Document DI-82-0002, Boeing Scientific Research Laboratories, Seattle, Washington (29 June 1959).
AD-257 247. ASTIA does not furnish copies. Copies may be obtained from the author.

B. Friedman.

In BAC Document D2-2302, Low Frequency Propagation, it was shown that the attenuation of very low frequency waves propagated for large distances around the earth depended on the modes of a certain "leaky wave guide" which was used as a model for the ionosphere. In this report, the modes of this model are studied more thoroughly and certain confusions that have arisen in other work are clarified.

LOW FREQUENCY PROPAGATION IN THE IONOSPHERE

Boeing Airplane Company Document DI-82-0003, Boeing Scientific Research Laboratories, Seattle, Washington, 29th June 1959. AD-257 248. ASTIA does not furnish copies. Copies may be obtained from the author.

B. Friedman

The work of Budden has shown that, for ionospheric propagation of radio waves with frequencies below 100 kc, the effect of the earth's magnetic field can be neglected. Using this fact, Budden, Al'pert and Wait have studied the extremely long-range propagation of low-frequency radio waves and have shown that the long-range propagation can be explained in terms of the modes that are produced when a radio wave travels between the earth and the ionosphere.

In this paper, we shall consider a simpler model of the ionosphere than has been used previously and we shall discuss the modes that exist in this model and how they affect long-range propagation.

LOW FREQUENCY PROPAGATION IN THE IONOSPHERE

Electromagnetic Wave Propagation, edited by M. Désirant and J.L. Michiels, Pgs. 261-70 (Academic Press, London, 1960).

B. Friedman.

The propagation of low frequency radio waves between a conducting earth and a constant impedance layer is studied. For a highly conducting ionosphere, the attenuation is a minimum at a frequency of $260 H^{-1}$ kc where H is the height of the atmosphere in kilometres.

PROPAGATION OF RADIO-FREQUENCY ELECTROMAGNETIC FIELDS IN GEOLOGICAL CONDUCTORS

Phys. Abstr. 9944/1963. J. Res. Nat. Bur. Stand (USA), Vol. 67D, No.2, Pgs. 161-78, March-April 1963.

V. Fritsch

Propagation in conducting spaces was theoretically investigated. The knowledge gained cannot always be applied directly to propagation in the upper strata of the earth. The reason for this is that these strata consist of geological conductors which are arranged in a complicated way. Specified values of conductivity and dielectric constant can be given for geological conductors, and applied to subsequent calculations. But most theoretical investigations apply either to homogeneous spaces or to spaces having an electrically simple structure, and the electrical structure of the spaces occupied by geological conductors is almost always very complicated. If this fact is not taken into account sufficiently agreement can never be obtained between experimental results and theoretical calculations.

ON COMMUNICATION IN THE SEA BY VLF ELECTROMAGNETIC WAVES

J. Radio Research Labs (Japan), Vol. 5, Pgs 19-33, January 1958.
Similar material appeared in Quarterly Review of Radio Research Labs.
(vernacular edition), Vol. 4, No. 14, January 1958.
K. Furutsu

As a method of communication in the case where either or both of transmitting and receiving points are in the sea, the use of electromagnetic waves on very low frequencies is here investigated and the propagation modes, the radiation apparatus and the diagrams of field strength on several frequencies are prepared for practical use.

For the radiation apparatus in the sea, a magnetic bar antenna is found to be most favourable. Hence, for the case where the bar antenna is used as a transmitting or receiving antenna in the sea, the numerical values of the input impedance and induced electric voltage are also displayed in figures in a wide range of parameters.

ON THE THEORY OF RADIO WAVE PROPAGATION OVER INHOMOGENEOUS EARTH

J. Research (D. Radio Propagation) Nat. Bur. Standards 67D, Pgs 39-62,
January-February 1963
K. Furutsu

ATTENUATION IN THE ARCTIC OCEAN: SP LINE ITEM

SP Line Item 16405, USL Report 521, US Navy Underwater Sound Lab.,
Fort Trumbull, New London, Connecticut, 20th July, 1961. AD-264 382.
M.K. Gagnon.

Values of VLF field strength in the Arctic Ocean obtained experimentally with an AN/URM-6B receiver and a loop antenna are compared with values computed from temperature and salinity data. The comparison indicates that temperature and salinity data provide sufficient information for the calculation of conductivity in sea water and therefore for the calculation of the attenuation of radio waves in sea water. The experimental data indicate no attenuation of the radio wave in passing through the ice cover.

TERRESTRIAL EXTREMELY LOW FREQUENCY NOISE SPECTRUM IN THE PRESENCE OF EXPONENTIAL IONOSPHERIC CONDUCTIVITY PROFILES

Phys. Abstr. 13027/1962. J. Geophys. Res.(USA), V.66, No.9, Sept.1961
J. Galejs

Calculations by Raemer of the terrestrial ELF noise spectrum which are based on a sharply bounded homogeneous ionosphere of frequency-dependent height and conductivity are extended to a non-homogeneous ionosphere of exponential conductivity profile. The exponential ionosphere model provides slightly lower resonant frequencies and less damping of the resonant peaks than the sharply bounded ionosphere. The exponential model improves the agreement with noise spectrum measurements by Balser and Wagner.

ELF WAVES IN THE PRESENCE OF EXPONENTIAL IONOSPHERIC CONDUCTIVITY PROFILES

Trans. IRE, PGAP-9, No. 6, Pgs 554-562, November 1961.
J. Galejs

Based on the theory of Nicolet and Aikin, the profile of ionospheric conductivity exhibits a nearly exponential variation with latitude through the D-layer and the lower edge of the E-layer. Propagation of ELF waves below this exponential layer is considered after calculating the surface impedance Z_s at an altitude h where the local refractive index does not necessarily satisfy $|n| \gg 1$. The propagation constant is determined by an iteration process. This model of an isotropic nonhomogeneous ionosphere is a closer approximation of the propagation geometry than are earlier models, where Z_s was defined at h where $|n| \gg 1$. The present model accounts simultaneously for ELF attenuation rates as measured by Jean, and earth-ionosphere cavity resonances as observed by Balser and Wagner.

ELF WAVES IN THE PRESENCE OF EXPONENTIAL IONOSPHERIC CONDUCTIVITY PROFILES

EE Abstr. 7253/1962

IRE Trans. Antennas and Propagation, Vol. AP-9, No. 6, Pgs 554-62, November 1961.

J. Galejs

On the assumption that the profile of ionospheric conductivity exhibits a nearly exponential variation with altitude through the D layer and lower edge of the E layer, propagation of e.l.f. waves below this exponential layer is considered, after calculating the surface impedance at an altitude where the local refractive index is not necessarily much greater than unity. The propagation constant is determined. The model accounts for measured e.l.f. attenuation rates and earth-ionosphere cavity resonances.

TERRESTRIAL EXTREMELY LOW-FREQUENCY PROPAGATION IN THE PRESENCE OF AN ISOTROPIC IONOSPHERE WITH AN EXPONENTIAL CONDUCTIVITY-HEIGHT PROFILE

Phys. Abstr. 16260/1963. Ionosphere Conference, London 1962 (see Abstract 11422 of 1963), Pgs. 467-71.

J. Galejs

The exponential ionosphere model of Galejs (IRE Trans. Antennas and Propagation, Vol. AP-9, No. 6, Pgs 554-6 (November 1961) and Abstract 13027 of 1962) is re-examined in view of recent night-time ionosphere measurements by Bowhill. The calculated day and night-time attenuation rates are in reasonable agreement with measurements by Jean et al. (J. Res. Nat. Bur. Stand (USA), Vol. 65D, No. 5, Pgs. 475-9 (September-October 1961)) and Chapman and Macario (Abstr. 6037 of 1956) respectively. The earth-to-ionosphere cavity resonance frequencies are computed using the average of day and night-time data and differ by less than $\frac{1}{2}$ c/s from the resonance frequencies measured by Balser and Wagner (Abstr. 2567 of 1961). The calculated Q-factors of the cavity are approximately

4.5 in the frequency range between 10 and 30 c/s. The computed terrestrial e.l.f. noise spectrum approximates to the measurements of the initial three spectral peaks, but it exhibits a more rapid decay at higher frequencies than does the measured spectrum. The waveform that results after passing the calculated noise spectrum through a bandpass filter exhibits an average frequency consistent with measurements of König (Z. angew. Phys. Vol. 11, No. 7, Pgs 264-74, July 1959).

A FURTHER NOTE ON TERRESTRIAL EXTREMELY LOW-FREQUENCY PROPAGATION IN THE PRESENCE OF AN ISOTROPIC IONOSPHERE WITH AN EXPONENTIAL CONDUCTIVITY HEIGHT PROFILE

EE Abstr. 1046/1963. J. Geophys. Res. (USA), Vol. 67, No. 7, (1961), Pgs 2715-28, July 1962).

J. Galejs

The mode theory of e.l.f. waves was extended by the author to isotropic ionosphere models of an exponential conductivity-height profile, where the refractive index may be near unit at the lower boundary of the ionosphere. Recent experimental data of Bowhill (1961) on the lower night-time ionosphere differ significantly from earlier estimates. The exponential ionosphere model is re-examined in view of these data. The calculated daytime attenuation rates were shown to agree with measurements of Jean, Murphy, Wait and Wasmundt (1961). The calculated night time attenuation rates are slightly higher than those measured by Chapman and Macario (1956). The earth-to-ionosphere cavity resonance frequencies are computed using the average of day and night ionosphere parameters. They differ by less than $\frac{1}{2}$ c/s from the resonance frequencies measured by Balser and Wagner (1960). The calculated Q factors of the cavity are approximately 4.5 in the frequency range between 10 and 30 c/s. The computed terrestrial e.l.f. noise spectrum exhibits a more rapid decay at higher frequencies than the measured spectrum. The waveform that results after passing the calculated noise spectrum through a bandpass filter exhibits an average frequency consistent with measurements of König (1958).

ELF AND VLF WAVES BELOW AN INHOMOGENOUS ANISOTROPIC IONOSPHERE

Appl. Research Lab., Sylvania Electronic Systems, Radio Science, NBS, Vol. 68D, June 1964, Research Report, No. 350 R.

J. Galejs.

The differential equations developed by Galejs and Row in the analysis of ELF wave propagation for frequencies between 60 to 3000 cps are modified to permit computations below the frequency of ion gyro-frequency. Near 8 cps West-East propagation exhibits a minimum attenuation of 0.022 db/1000 km, while the East-West direction has a local maximum of 0.165 db/1000 km. The calculations in the frequency range between 20 and 3000 cps are made with neglected ion effects, and the propagation is characterized by a monotonic decrease of phase velocity down to the lowest frequency.

PROPAGATION OF ELF WAVES BELOW AN INHOMOGENEOUS ANISOTROPIC IONOSPHERE
IEEE Transactions on Antennas and Propagation, January 1964.
J. Galejs, R.V. Row

The ionospheric anisotropy is considered with horizontal magnetic field either for transverse (east-west or west-east) or for longitudinal (south-north) propagation

The west-east direction of propagation exhibits a lower attenuation constant than the east-west direction for $f < 1000$ cps. This is contrary to the expectations based on a model of a homogeneous anisotropic ionosphere.

Over most of the frequency range the attenuation figures for south-north propagation are intermediate between the corresponding figures for west-east and east-west propagation.

PROPAGATION OF ELF WAVES BELOW AN INHOMOGENEOUS ANISOTROPIC IONOSPHERE
Radio Sci. Journ. of Research NBS/USNC URSI, Vol. 68D, No. 1, January 1964, Pgs. 103-4.
J. Galejs, R.V. Row

In the ELF range, the homogeneous, isotropic model ionosphere is not successful in explaining observed signal characteristics. This has prompted the introduction of gradually tapered ionosphere models by Wait (1960a, b, 1962) and Galejs (1961a, b, 1962), which still have not considered the effects of ion motion and the earth's magnetic field.

The purpose of this paper is primarily to estimate the probable effects on ELF propagation caused by the earth's magnetic field in combination with electron and ion densities which vary gradually with height. To this end, normal quiet day and night models of the lower ionosphere are selected.

ORIGIN OF "VERY-LOW-FREQUENCY EMISSIONS"
Phys. Abstr. 13974/1959; J. Res. Nat. Bur. Stand. (USA), V.63D,
No. 1, Pgs 21-7, July-August 1959.
R.M. Gallet, R.A. Helliwell.

Selective travelling-wave amplification in the outer ionosphere is postulated to explain very-low-frequency emissions, a class of very low-frequency (1 to 30 kc) natural noise. By analogy with the mechanism of travelling wave tubes, low-level ambient noise in the outer ionosphere is amplified in streams of incoming ionized solar particles at frequencies for which the stream and wave velocities are equal. Required velocities are in the range of 0.01 to 0.1 c (where c is the velocity of light). Streams with densities of the order of 1 electron/cm³ would provide sufficient energy. Phenomena which can be explained qualitatively by the theory are the hiss, quasi-constant tones, dawn chorus and related transients, and very long trains of whistler echoes. A

quantitative example shows how the theory can reproduce the general form of certain characteristics discrete spectra "hooks" of emissions, and how this leads to definite values of particle velocity and a law for the distribution of electron density in the outer ionosphere.

PROPAGATION AND PRODUCTION OF ELECTROMAGNETIC WAVES IN A PLASMA
Nuovo Cimento, Supplemento 13, Pgs. 234-256, July-September 1959.
R. Gallet.

LONG-DELAY IONOSPHERIC ECHOES AT 150 KC.
Phys. Abstr. 4234/1953; Letter in Nature (GB), 171, Pgs. 444-5,
March 7, 1953.
J.J. Gibbons, R.L. Schrag, A.H. Waynick.

Simultaneous recordings of the unsplit ordinary and extraordinary components far from the critical frequency have been made using a circularly polarized receiving aerial system at Pennsylvania. Extraordinary mode echoes have been received at night in November 1952 from a height of 900-950 km. Of the possible interpretations it is considered very likely that these echoes correspond to the "fourth reflection condition" indicated theoretically for the extraordinary component at a height of 940 km for this frequency in an assumed model.

EXTENSION OF FEINBERG'S THEORY TO THE CASE OF ELECTROMAGNETIC WAVE PROPAGATION OVER AN INHOMOGENEOUS SPHERICAL EARTH AND THE APPLICATION OF AN APPROXIMATE METHOD OF CALCULATION BASED ON EQUIVALENT SECONDARY SOURCES

EE abstr. 7769/1962. Prace Inst. Laczności (Poland), Vol. 5, No.2-3, (11-12), 73-111 (1958). In Polish.
Z. Godzinski

Theoretical analysis of radio wave propagation over an inhomogeneous spherical earth is given. The earth is assumed to have a large complex permittivity and to be made up of homogeneous strips. The analysis leads to an extension of known results concerning radio wave propagation over an inhomogeneous flat earth. In the light of the results obtained, an appraisal of various existing theories and methods of field-strength calculation is carried out. It is shown that the well-known Millington's method is a very good approximation in most practical applications, but for some extreme cases, a more exact formula is derived.

SURFACE IMPEDANCE CONCEPT IN THE THEORY OF RADIOWAVE PROPAGATION
EE Abstr. 588/1963. Prace Inst. Laczności (Poland), Vol. 6, No.2 (15), 3-58 (1959). In Polish.
Z. Godzinski

Integral equations are derived for the electromagnetic fields of the electric or magnetic dipoles placed over an inhomogeneous and irregular surface of the earth. Approximate boundary conditions are introduced in terms of the surface impedance; their application to the solution of the integral equations is explained. The electromagnetic field inside the earth

is approximated by a plane inhomogeneous wave. A more general analysis is made by considering the earth as consisting of horizontal and of slanting layers. In the case of horizontal layers, electric effective coefficients can be introduced; these determine the wave propagation and the shape of the polarization ellipse. In the case of oblique layers the relations become more complex and the formulae for the horizontally-homogeneous earth are no longer valid. The shape of the polarization ellipse provides a very sensitive method for detecting the inhomogeneity of the ground. Other forms of approximate boundary conditions, in terms of the surface impedance, were derived and discussed, viz., for the vector of the electric field strength, for the Hertzian vector and for the Hertz scalar function. Various practical applications are discussed. 69 references.

THE SURFACE IMPEDANCE CONCEPT AND THE STRUCTURE OF RADIO WAVES OVER REAL EARTH

EE Abstr. 2684/1961; Proc. Instn. Elec. Engrs. Monogr. (GB), 434E, V. 108 C, Pgs 362-73, September 1961.
Z. Godzinski.

Discusses the concept of surface impedance as applied to the theory of radio-wave propagation over a real, i.e. inhomogeneous and irregular, earth; some of the conclusions may also be of value in the theory of waveguides, cavity resonators and certain types of aerial. The advantages and limitations of the surface impedance concept are shown in connection with a very general integral equation for the field strength. The approximations and physical phenomena underlying the surface-impedance concept are first discussed in the simplest case of a homogeneous and flat earth. The analysis is then extended to a horizontally stratified earth; it is then possible to characterize the earth by certain effective parameters depending on frequency and the geometric structure of the soil. The same is also true in the cases of a spherical or not too excessively irregular earth. The discussion is then generalized to the case of an arbitrarily inhomogeneous earth. The height/gain function and the shape of the ellipse of polarization are discussed. Approximate boundary conditions for the Hertzian vector and Hertzian scalar function are related to the concept of surface impedance. Practical conclusions are drawn with regard to the existence and measurement of the effective earth constants and to some aspects of geological prospecting by radio methods.

SOME ASPECTS OF THE ELECTRIC PROPERTIES OF THE UPPER ATMOSPHERE
J. Astronaut. Sci., Vol. 4, Nos. 1-2, Pgs. 63-8, 1958.
P.A. Goldberg

Evaluations are presented of electrical properties of the D-region of the ionosphere for altitudes of 150,000 to 300,000 feet. Certain unique regimes of electrical behaviour of this portion of the ionosphere are pointed out. Covered are altitude profiles of the a.c. electrical conductivity, dielectric constant, index of refraction, vertical attenuation factor and penetration depth, and long oblique path radio signal attenuation for frequencies from d.c. to 100 megacycles. Applications to spacecraft environment problems are treated.

COSMIC-RAY-INDUCED ATMOSPHERIC REFRACTIVITY AT EXTRA LOW FREQUENCIES
Paper presented at 42nd Annual Meeting of the Am. Geophys. Union,
Washington D.C., 18th-21st April 1961.
P.A. Goldberg.

The effect of electrons produced by cosmic-ray ionization of the refractive index of the atmosphere is treated for the 40- to 90-km altitude range for frequencies of 1 to 10,000 ops. Allowance is made for extremes in value of electron density due to effects of minimum and maximum night-time electron detachment conditions. Over this frequency range the refractive index undergoes transitions to large values at altitudes which increase with excitation frequency. Transition altitudes are 43 km for 10 ops, 55 km for 100 ops, and 68 km for 1000 ops for maximum night-time conditions.

EXPERIMENTS IN VERY-LOW-FREQUENCY RADIO PROPAGATION
Thesis, Tech. Report 5, Contract AF 18(600)-1552, California Institute of Technology, Pasadena, California; 26th June 1959. AD-217-030.
R.M. Golden

In an effort to extend experimentally determined data on the characteristics of very-low-frequency radio waves, a VLF transmitting station (8.4 kc) was established at Shaver Lake, California. This station permitted controlled experiments in long distance propagation, ionospheric vertical sounding measurements, and attempts at the generation of round-trip gyroelectric echoes. The long distance measurements indicated that at VLF, the ground or surface wave radiated by the antenna can be detected at great distances. The ionospheric vertical incidence measurements showed rapid fading of the received signal around local sunrise and sunset. Propagation in the presence of the ionosphere is considered in the theoretical form of propagation in a homogeneous gyroelectric medium. An examination of the natural phenomena of whistlers is presented in order to determine the feasibility of generating gyroelectric echoes. Reflection and transmission coefficients are presented for vertical incidence in order to ascertain the order of magnitude of such an echo.

MAGNETO-IONIC DUCT PROPAGATION TIME (WHISTLER MODE) VERSUS
GEOMAGNETIC LATITUDE AT 4 KC

Phys. Abstr. 22349/1962; Proc. Inst. Radio Engrs (USA), Vol. 50,
No. 8, 1852 (August 1962).

C.V. Greenman

The path length of a whistler mode signal from origin to conjugate point increases with geomagnetic latitude. However, because the group velocity varies with height, the time of propagation need not increase steadily with latitude. It is shown that for one model of the ionosphere the calculated time delay curve for a 4 kc/s signal has a subsidiary maximum at a latitude of 20° and a minimum at 35° .

GROUND SYSTEM STUDIES OF HIGH POWER VLF ANTENNAS

U.S. Navy Electronics Lab. San Diego, California, Rept. No. 822,
December 1957.

W.E. Gustafson, A.N. Smith, T.E. Devaney.

No abstract.

THE DESCRIPTION OF A RANDOM PROPAGATION CIRCUIT THROUGH THE
COHERENCE BETWEEN ADJACENT FREQUENCIES

Symposium on Electromagnetic Theory and Antennas, Copenhagen,
23rd-30th June, 1962.

T. Hagfors.

No abstract

AN EXPERIMENTAL STUDY OF THE PHASE STABILITY OF VLF SIGNALS

Radio Science Journ. of Research NBS/USNC-URSI, Vol. 68D, No. 1,
January 1964, Pgs. 19-20.

D.E. Hampton.

A large amount of experimental evidence is now available on both the field strength and phase of VLF waves which have travelled over a wide variety of paths. Since the phase of the signal is the characteristic which can be exploited most for practical application, particularly navigation systems this paper is primarily concerned with the diurnal variation of phase.

FIELD INTENSITY MEASUREMENTS AT 10.2 KC/S OVER RECIPROCAL PATHS

Radio Science Journ. of Research NBS/USNC-URSI, Vol. 68D, No. 1,
January 1964, Pgs. 11-14.

J.C. Hanselman, C.J. Casselman, M.L. Tibbals, J.E. Bickel

Experimental data at 10.2 kc/s are presented which demonstrate non-reciprocity in attenuation rates for propagation in the east-west directions and that reciprocity exists in the north-south direction along a magnetic meridian. The experimental evidence, recorded for propagation paths of 3,820, 7,830 and 8,450 kms, compares well with theoretical attenuation rates at 10 kc/s given by J.R. Wait and K. Spies.

A SYSTEM OF SHORT-RANGE COMMUNICATION BY PASSING AUDIO-FREQUENCY
ELECTRIC CURRENTS THROUGH WATER

PB 153954. Photoduplication Service, Library of Congress, Washington,
D.C., microfilm, \$5.70.

H. Hardy

No abstract.

RANDOM FLUCTUATION IN VERY-LOW-FREQUENCY SIGNALS REFLECTED OBLIQUELY
FROM THE IONOSPHERE

EE Abstr. 7044/1961; J. atmos. terrest. Phys. (GB), V.20, No. 2-3,
Pgs 155-66, March 1961.

J.K. Hargreaves

Describes the analysis of observations made on the amplitude fluctuations of very low frequency signals received from transmitters at Varberg, Sweden, and Annapolis, U.S.A. The observations were made at numerous receiving points simultaneously at ranges between 800 and 6000 km from the transmitters. The fluctuations in amplitude were of the order of 0.15 of the mean amplitude at 1000 km range and of the order of 1.02 at 6000 km range. From the calculated correlation between observations at two separated locations the size and movements of the ionospheric irregularities causing the fluctuations were deduced. The correlation patterns were between 50 and 120 km wide and the fading times of the order of 20 mins. The fluctuations were due mainly to changes in their structure rather than to drifts. The measured changes in the phase difference between the signals received at two separated points have been compared with those deduced from the amplitude measurements and good agreement was obtained. The nature of the changes in the ionosphere which give rise to the fluctuations were studied with the aid of data obtained from phase and amplitude measurements at short distances from the 16 ko transmitter at Rugby. It is found that the ionosphere modulates the phase rather than the amplitude of the wave and that a model of the ionosphere in which the reflection coefficient is constant and the height fluctuates is in conformity with the observed fluctuations at the ground.

THE PROPAGATION OF VERY-LOW-FREQUENCY RADIO WAVES OVER DISTANCES UP
TO 2000 KM.

Phys. Abstr. 16070/1962; J. atmos. terrest. Phys. (GB), Vol. 24,
Pgs 435-50, June 1962.

J.K. Hargreaves, R. Roberts

The amplitude of very-low-frequency radio waves was observed at distances up to 2000 km from the transmitter with the main emphasis on the diurnal variations at ranges of 1000 km. An interpretation is attempted of these observations, and also of earlier short-range work, in terms of a model of the ionosphere which assumes a sharp lower boundary. It is found that this model cannot explain the details of the observations and there is evidence for the more complex structure already suggested by other workers. This involves ionization at lower levels throughout the summer day and also a transitory layer at sunrise in all seasons.

RADIO WAVE PROPAGATION THROUGH THE EARTH'S ROCK STRATA - A NEW
MEDIUM OF COMMUNICATION

Inst. Radio Engrs., Globecom Conv. Rec., Pgs 31-4, 1961.
G.J. Harmon

No abstract.

THE ROLE OF THE REQUIREMENT OF OUTGOING RADIATION FOR A COMPLEX
WAVE NUMBER AND ITS SIGNIFICANCE FOR THE SURFACE WAVE PROBLEM

Z. Naturforsch., 7a, Pgs 501-5, August 1952.

Phys. Abstr. 979/1953

A. Haug

It is shown that Sommerfeld's requirement of the absence of converging radiation ensures the uniqueness of the solution of the wave equation $\Delta u + k^2 u = 0$ in a uniform medium also for complex k . This can be extended to 2 semi-infinite regions and it follows that Sommerfeld's surface wave is not inconsistent with the above requirement.

PROPAGATION OF ELECTROMAGNETIC WAVES IN EARTH

Geophysics (USA), V. 14, Pgs 162-71, April 1949.

O.C. Haycock, E.C. Madsen, S.R. Hirst.

No abstract.

REFLECTION OF VERTICALLY-INCIDENT LONG RADIO WAVES FROM THE IONOSPHERE
WHEN THE EARTH'S MAGNETIC FIELD IS OBLIQUE

Proc. Roy. Soc. (London), Vol. 231A, No. 1186, Pgs. 414-35,
6th September 1955.

J. Heading

Approximate equations are developed for the reflection of plane electromagnetic waves from a horizontally stratified anisotropic ionosphere, when the earth's magnetic field is in an arbitrary direction. Two distinct regions of height arise in the theory, each governed by its respective equations of propagation. For the special case of vertical incidence in an oblique magnetic field when the distribution of electron density is exponential, the equations for the lower region are solved analytically in terms of hyper-geometric functions. The equations for the upper region are solved in terms of generalized hypergeometric functions under more general conditions, namely for oblique propagation when the plane of incidence coincides with the magnetic meridian. Explicit expressions in terms of Γ functions of complex arguments are obtained for the reflection and conversion coefficients of the upper region. The theory is illustrated numerically by a typical model.

THE EPHI SYSTEM FOR VLF DIRECTION FINDING

J. Research NBS, Vol. 65C, No. 1, Pgs 43-49, January-February 1961
G. Hefley, R.F. Linfield, T.L. Davis.

A new system of VLF direction finding has been developed and tested by the National Bureau of Standards, Boulder, Colorado. The system has been named "Ephi" ($E - \phi$) because the bearing of the transient signal is determined from the relative phase (ϕ) of the vertical electrical field (E) received at spaced antennas. The advantage of this scheme compared to conventional crossed-loop techniques is that it minimizes sitting and polarization errors. A minimum of three antennas must be used to resolve directional ambiguity, and the preferred antenna location is at the vertices of an equilateral triangle with baselines equal to $1/3$ to $1/10$ wavelength (at 10 kc). Appropriate phase detectors, delay lines and coincidence circuits are used to obtain a directional code in preset sectors. Within practical instrumentation limits any number of sectors of variable widths can be operated simultaneously and each can be rotated in azimuth.

A NEW TECHNIQUE FOR THE STUDY OF MAGNETO-IONIC DUCT PROPAGATION AT VERY LOW FREQUENCIES

Paper presented at IRE-URSI Symposium, Washington DC, 22nd-25th May 1957.
R.A. Helliwell, E. Gehrels,

An experiment has been performed to test the theory that signals from VLF transmitters can be propagated along lines of the earth's magnetic field in the manner of whistlers. The test was made using pulses of one-quarter second duration transmitted from station NSS at Annapolis on 15.5 kc. The signals were observed at Cape Horn, about 10,000 km from the transmitter, but close to the transmitter's magnetic conjugate point.

OBSERVATIONS OF MAGNETO-IONIC DUCT PROPAGATION USING MAN-MADE SIGNALS OF VERY LOW FREQUENCY

EE Abstr. 3813/1958; Proc. Inst. Radio Engrs., V. 46, No. 4, Pgs 785-7, April 1958.
R.A. Helliwell, E. Gehrels.

Echoes of radio signals from stations NSS, Annapolis, Md. (geomagnetic latitude $50^{\circ}N$) have been received near Cape Horn (latitude $45^{\circ}S$) with delays up to nearly 1 sec. These observations provide the first controlled test of the Ekersley-Storey theory of "whistler" propagation from one hemisphere to the other along the lines of force of the earth's magnetic field. There appears to be some evidence of an inverse correlation between the whistler rate and the occurrence of NSS echoes. A possible explanation of this is proposed. The results in general indicate the existence of a unique mode of v.l.f. propagation, for which the term "magneto-ionic duct propagation" is proposed. Since echoes were detectable on at least 80% of the days of observation, this mode of propagation may have useful application to v.l.f. communication, though magneto-ionic duct signals may be expected to interfere seriously with the operation of phase-sensitive navigation v.l.f. systems. It may, however, be of considerable use for the study of the outer regions of the ionosphere, since the duct may extend as much as 20,000 miles above the surface of the earth.

MAGNETO-IONIC DUCT OBSERVATIONS.

Abstract. Symposium on Whistlers, Programme of Joint IRE-URSI Meeting, Washington D.C., 2nd-5th May 1960, P. 115.
R.A. Helliwell

New observations of magneto-ionic duct, or whistler mode signals from station NSS on 15.5 kc are reported. Simultaneous recordings at Byrd Station, Antarctica, and Greenbank, West Va, show that the northern hemisphere echo delays are not twice those from the southern hemisphere. Quantitative comparison of these results with Cape Horn NSS data and extensive whistler data supports the interpretation that the observed time delay depends on the location of the receiver and that the Greenbank echoes are two-hop mode and not "hybrids". Echo intensities are compared with theoretical calculations of whistler-mode attenuation.

COUPLING BETWEEN THE IONOSPHERE AND THE EARTH-IONOSPHERE WAVEGUIDE AT VERY LOW FREQUENCIES

Phys. Abstr. 16258/1963. Ionosphere Conf., London 1962 (see Abstr. 11422 of 1963), Pgs 452-60.
R.A. Helliwell

At wave frequencies below the plasma and gyro-frequencies, electro-magnetic energy propagates freely in the ionosphere as a circularly polarized ordinary ray, in what is commonly called the whistler mode. This type of propagation is readily observed in the v.l.f. range (3 kc/s - 30 kc/s) as well as at somewhat higher and lower frequencies. The observed characteristics of the whistler mode can be explained in terms of a model ionosphere whose refractive index drops abruptly to zero at the lower boundary and is slowly varying elsewhere. Using Shell's law, a simplified theory of coupling between the ionosphere and the earth-ionosphere waveguide is developed. It is shown that transmission into the ionosphere occurs for any angle of incidence, but that transmission out of the ionosphere occurs only for angles of incidence less than a certain "critical" angle. At larger angles the energy is totally reflected at the boundary. A graphical method for the solution of this problem is outlined, and illustrative examples are given. The results of this theory are applied to the interpretation of whistler-mode propagation and ionospheric noise phenomena.

CONSTANT IONOSPHERE HEIGHT FOR AUDIO-FREQUENCY PROPAGATION

Phys. Abstr. 8425/1960; Nature (GB), V.85, P. 599, 1960.
F. Hepburn

Calculation of the height of reflection of audio frequency atmospherics originating from distant lightning flashes, gave a figure of 83 ± 2 km irrespective of the time of day. A slight diurnal variation of attenuation at frequencies in the range 4 - 14 kc has been noted, and source spectra have been constructed over this frequency range.

HEAVY-ION EFFECTS IN AUDIO-FREQUENCY RADIO PROPAGATION

J. atmos. terrest. Phys. (GB), V. 11, No. 36, 1957.

C.O. Hines.

No abstract

AN APPROXIMATE FULL WAVE SOLUTION FOR LOW FREQUENCY ELECTROMAGNETIC WAVES IN AN UNBOUNDED MAGNETO-IONIC MEDIUM

J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 1, 107-11, January-February 1962. Phys. Abstr. 16073/1962.

W.C. Hoffman

Maxwell's equations in an anisotropic inhomogeneous medium are transformed by means of the Stratton-Chu formula into a vector integral equation which couples the various electric field components. In case the hypotheses of far-zone field and low-frequency electromagnetic waves apply, this vector integral equation can be approximated by a system of uncoupled scalar integral equations. This implies an approximate equivalence between the original vector integral equation and a system of modified scalar inhomogeneous Helmholtz equations. The conditions under which the system of uncoupled scalar integral equations can be solved by Neumann series are discussed, and the first three terms of the Neumann series are given explicitly.

THE PROPAGATION OF EM WAVES FROM LAND TO SEA AND VICE VERSA: PART I.

Z. angew. Phys. (Germany), V. 3, Pgs 424-432, November 1951.

P. Holler.

An analytical approximation method of investigation is used in which the wave equation is first satisfied while neglecting the boundary conditions, and the boundary conditions are then satisfied while neglecting the wave equation. It is assumed that (a) the earth is flat, (b) sea and land are individually homogeneous and the boundary is sharp, (c) the sea is an ideal conductor, (d) the complex refractive index of land is not very large, so that the simple Weyl solution is applicable, (e) the transmitter height is sufficient for refraction and reflection at the earth's surface to be calculated by geometrical optics, (f) the distances of both transmitter and receiver from the coast are large compared with the wavelength.

AN EXPERIMENTAL INVESTIGATION OF SHORT-DISTANCE IONOSPHERIC PROPAGATION AT LOW AND VERY-LOW FREQUENCIES

EE Abstr. 760/1954; Proc. Instn. Elect. Engrs (GB), III, 101, Pgs 21-34, January 1954

H.G. Hopkins, L.G. Reynolds.

The properties of the lower portion of the ionosphere have been studied at selected lower and very-low frequencies by observations on commercial continuous-wave transmitters located at distances of about 200 km from the receiving point. Attention has, in general, been confined to the horizontally-polarized electric component of the ionospheric wave received by means of a vertical loop set normal to the plane of propagation. Using mainly twin-channel recording equipment, an outline description of which is given, the pick-up on this loop has been compared in phase and

magnitude with that on another vertical loop arranged in the plane of propagation. Changes in the apparent height and conversion coefficient of the reflecting layer have been studied, mainly at 16 and 70.8 kc, in terms of a simple model under both normal and disturbed conditions. The data serve generally to confirm the measurements of other observers, but some discrepancies are discussed. It is considered that the pulse-sounding technique has advantages over the continuous-wave method for ionospheric measurements in the frequency band under review, particularly at the higher frequencies.

VERY-LOW FREQUENCY PROPAGATION AND DIRECTION FINDING

EE Abstr. 2347/1957; Proc. Instn. Elect. Engrs (GB), Paper 2265R, V. 104B, Pgs 73-80, March 1957.
F. Horner

Studies of the propagation of 16 kc waves from the Rugby transmitter GBR have been made with the final objective of assessing the polarization errors to be expected in taking bearings on lightning flashes at similar frequencies. Measurements were made of the changes of the apparent bearing of the transmitter caused by changes in the amplitude and polarization of the ionospheric waves. A crossed-loop cathode-ray direction-finder was used for this work. Polarization errors were largest at distances of about 300 km from the transmitter, where median errors of the order of 10° in daylight and 30° at night were observed. The measurements have yielded further information on the reflecting properties of the ionosphere at 16 kc. Variations in bearings taken simultaneously at two stations at similar distances from Rugby, but in different directions, indicated that there were significant differences in the propagation along the two paths. It has been concluded that the polarization of the waves reflected by the ionosphere depends on the azimuthal direction of the propagation path, and this may be the explanation of apparent disagreements between the results of previous workers.

GROUNDWAVE PROPAGATION (MIXED PATH)

EE Abstr. 3814/1959; Tijdschrift Ned Radiogenoot (Netherlands), V. 24, No. 1, Pgs 1-10, 1959.
J. Houtsmuller

Propagation only over a flat earth is considered. The purpose of the investigation is to determine whether the way in which the transitions from one medium to another occur has any effect on field strength, the errors to be expected, and to study also phase and amplitude changes at the boundary between two media. Calculations, based on a method due to Bremmer (Abstr. 409/1955), are carried out for sharp transitions from sea water to dry sand, and for a gradual transition over 10 km, conductivity and permittivity values being obtained. It is shown that for some km from the boundary, no deviations occur in the second medium which could be attributed to the nature of the medium. Near the boundary, curves calculated for a flat earth are sufficiently accurate for application to a spherical earth surface.

MODE CALCULATIONS FOR VLF IONOSPHERIC PROPAGATION
VLF Symposium Paper No. 36, Boulder, Colorado, January 1957.
H.H. Howe, J.R. Wait.

No abstract

COMMENTS ON APPENDIX B, THE "WAVE-GUIDE MODE" THEORY OF THE PROPAGATION
OF VERY LOW FREQUENCY WAVES by K.G. BUDDEN

Publications Listing - July 54/Maroh 1963, Central Radio Prog. Lab.
Boulder Labs, Nat. Bur. Stand, Boulder, Colorado, V. 4, 96-98,
H.H. Howe,

No abstract

FURTHER COMMENTS TO "MODE CALCULATIONS FOR VLF IONOSPHERIC PROPAGATION"
Publications Listing - July 54/Maroh 63, Central Radio Prog. Lab.,
Boulder Labs, Nat. Bur. Stand., Boulder, Colorado, (Paper No. 36), v.4,
91-95.

H.H. Howe, J.R. Wait

No abstract

THE HEIGHT OF THE POLAR CAP ABSORPTION LAYER

Phys. Abstr. 20945/1961; Ark. Geofys. (Sweden), V.3, Paper 21,
Pgs. 419-26, 1961.
B. Hultqvist, J. Ortner.

"Polar cap absorption" symposium paper. Height determinations
based on disturbance-free records of the diurnal absorption occurring
during polar cap absorption events are reviewed, and evidence supporting
the interpretation of Hultqvist and Ortner (1959) is discussed.

SYMPOSIUM ON THE PROPAGATION OF VLF RADIO WAVES

Sponsored by the NBS Boulder Laboratories and IRE Professional Group
on Antennas and Propagation, held in Boulder, Colorado, 23rd-25th
January, 1957. Prepublication of papers 4 v.

PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON THE IONOSPHERE, LONDON,
JULY 1962.

London: The Inst. of Physics and the Physical Society (1963) 528 pp.
Phys. Abstr. 11422/1963.

The conference was held at Imperial College, under the auspices
of the Institute of Physics and the Physical Society. The proceedings
contain 81 articles, divided into 4 sections, each of which opens with
a review article and ends with a summary, within an additional section
giving preliminary results from the first Anglo-American satellite UK 1.
The titles of the sections are: Ionospheric constitution and ionizing
radiations; Geomagnetism and the ionosphere; Irregularities and drifts
in the ionosphere; The mathematics of the wave propagation through
the ionosphere. Abstracts of the articles will be found in this and
succeeding issues of Physics Abstracts.

IONOSPHERIC REFLECTION COEFFICIENTS AT VLF FROM SPHERICS MEASUREMENT
VLF Symposium Paper No. 31, Boulder, Colorado, January 1957.
A.G. Jean, L.J. Lange, J.R. Wait

A method for calculating the complex ionospheric reflection coefficients at vlf using spheric waveforms is presented. The mathematical analysis was carried out for a number of different waveforms to illustrate the method. Reflection coefficients determined from spherics observations were compared with reflection coefficients calculated using an ionospheric model. In most cases, the agreement with theory is only fair, and in some cases, reflection coefficients exceeding unity were obtained. The discrepancies are believed to result from horizontally polarized flashes rather than limitations in the ionospheric model. Plans for collecting more detailed information pertaining to the source are discussed. Attempts will also be made to completely characterize the downcoming sky wave in future measurements.

VLF PHASE CHARACTERISTICS DEDUCED FROM ATMOSPHERIC WAVE FORMS
Geophys. Res. (USA), V. 65, No. 3, Pgs 907-12, March 1960.
A.G. Jean, W.L. Taylor, J.R. Wait

The wave forms of the electric field of atmospherics recorded at four widely separated stations are analyzed to yield the phase characteristics of radio waves at very low frequencies. It is indicated that the relative phase velocity for propagation to great distances is about 3 per cent greater than c (velocity of light in a vacuum) at 4 ko. Above this frequency, it gradually decreases, being about 1 per cent greater than c at 8 kc. The form of dispersion curve is very close to that predicted by the mode theory.

OBSERVED ATTENUATION RATE OF ELF RADIO WAVES
J. Res. Nat. Bur. Stand. (USA), V. 65D, No.5, Sept.-Oct., 1961.
A.G. Jean, A.C. Murphy, J.R. Wait, D.F. Wasmundt.

Propagation attenuation rates for frequencies below 1 ko in the ELF region (30 cps to 3,000 cps) were calculated from the spectra of atmospherics observed at widely-spaced stations. Data are presented for east to west propagation under sunset approaching to eastern station. Under these conditions, the attenuation rates are about 1 db/1,000 km at 200 cps. The attenuation rates observed seem to be consistent with a two-layered ionosphere model with its lower region 90km above the earth.

VERY LOW FREQUENCY PHASE OBSERVATIONS ON THE IONOSPHERIC EFFECTS
OF THE SOLAR FLARE OF SEPTEMBER 28TH 1961
Phys. Abstr. 16264/1963. J. Geophys. Res. (USA), Vol. 67, No. 12,
Pgs. 4903-5, November 1962.
A.G. Jean, J.H. Crary.

This note describes the observation of large and sudden phase variations following a class 3+ solar flare.

SURFACE WAVE PHASE COMPUTATIONS

NBS Report 4C117, U.S. Nat. Bur. of Standards, Boulder, Colorado.

9th May 1955

J.R. Johler, W.J. Kellar, L.C. Walters

The special theoretical considerations pertinent to the computations of the phase of the surface wave at low frequencies are discussed. The formulas necessary for the numerical evaluation of the phase and the results of a numerical computation are presented.

PHASE OF THE LOW RADIO-FREQUENCY GROUND WAVE

NBS Circular 573, U.S. Government Printing Office, Washington, D.C.,

June 1956. Similar material was presented as a paper at IRE-URSI

Symposium, Washington D.C., 30th April, 1st-3rd May 1956.

J.R. Johler, W.J. Kellar, L.C. Walters.

The special theoretical considerations pertinent to the computation of the phase of the ground wave at low radio frequencies are discussed. The formulas necessary for the numerical evaluation of the amplitude and phase, and the results of the numerical computation are presented. The effects of frequency, conductivity of the earth, altitude above the surface of the earth, and vertical lapse of the permittivity of the atmosphere are evaluated.

PROPAGATION OF THE RADIO-FREQUENCY GROUND WAVE TRANSIENT OVER A FINITELY CONDUCTING PLANE EARTH

Geofis., pura e apply. 37, (1957/II), 116-126, May-August 1957.

J.R. Johler.

TRANSFER CHARACTERISTICS OF RADIO WAVES PROPAGATED BETWEEN THE IONOSPHERE AND THE EARTH AT VERY LOW FREQUENCIES

NBS Report 6002, U.S. Nat. Bur. Standards, Boulder, Colorado, 15th Sept. 1958. AD-212 085

J.R. Johler, L.C. Walters, C.M. Lilley

The transfer characteristics (amplitude and phase as a function of frequency) of the sky wave propagated between the D-region and the E-region of the ionosphere and the earth have been evaluated at low and very low frequencies by the geometrical-optical theory employing the quasi-longitudinal approximation of the ionosphere reflection coefficients. Distances, d/j , up to 1000 statute miles are considered and multiple hops or time-modes ($j = 1, 2, 3, \dots$) are evaluated for a vertical electric dipole source. The effects of the electron density, collision frequency, intensity of the earth's magnetic field and the geometrical parameters are illustrated. The effect of the vertical lapse of the permittivity of the earth's atmosphere is introduced into the computation.

PROPAGATION OF A GROUND WAVE PULSE AROUND A FINITELY CONDUCTING
SPHERICAL EARTH FROM A DAMPED SINUSOIDAL SOURCE CURRENT
EE Abstr. 5557/1959; Inst. Radio Engrs (USA), Trans. V. AP-7, No. 1,
Pgs 1-10, January 1959.
J.R. Johler, L.C. Walters

The form of the transient electromagnetic ground wave which has been propagated over a finitely conducting spherical earth from a source current dipole can be calculated by a direct quadrature evaluation of the Fourier integral. The method is illustrated by a calculation of the transient field radiated by the particular case of the damped sinusoidal current dipole. At short distances from the source, the earth was assumed to be a plane and the displacement currents in the earth were neglected. The pulse was then calculated by a direct evaluation of the Fourier integral and the integration was verified by special operational methods (inverse Laplace transformation). The form of this pulse was then predicted at great distances from the source by a direct evaluation of the Fourier integral in which the displacement currents in the earth and the earth's curvature were introduced into the Fourier transform. The form of the transient signal was found to be dispersed by the propagation medium. The most noteworthy attribute of this dispersion is a stretching of the period of the wave so that the form of the source is somewhat obscured by the filtering action of the medium.

LOW AND VERY LOW FREQUENCY RADIO-FREQUENCY TABLES OF GROUNDWAVE
PARAMETERS FOR THE SPHERICAL EARTH THEORY; THE ROOTS OF RICCATI'S
DIFFERENTIAL EQUATION
NBS Tech. Note 7, U.S. Dept. of Commerce, Office of Technical Services,
Washington D.C., 1st February 1959, PB 151366. \$2.25.
J.R. Johler, L.C. Walters, C.M. Lilley

The roots of Riccati's differential equation are tabulated in detail throughout the low- and very low radio-frequency part of the spectrum. The zeroes and certain other parameters used in the calculation of the amplitude and phase of the ground wave by the rigorous series of residues are also tabulated. This paper supplements NBS Circular 573.

AMPLITUDE AND PHASE OF THE LOW AND VERY LOW RADIO-FREQUENCY GROUND WAVE
NBS Tech. Note. No. 60, U.S. Dept. of Commerce, Office of Technical
Services, Washington DC, 1st June 1960. PB161561. \$.75.
J.R. Johler, L.C. Walters, C.M. Lilley

Graphs and tables of the low and very low radio-frequency ground wave are presented as a function of frequency, 100 c/s to 1000 ko.

ON THE THEORY OF REFLECTION OF LOW- AND VERY-LOW RADIO-FREQUENCY WAVES FROM THE IONOSPHERE

EE Abstr. 6957/1960; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 3, Pgs 269-85, May-June 1960.

J.R. Johler, L.C. Walters

The rigorous application of the magneto-ionic theory to the calculation of reflection coefficients for a sharply bounded ionosphere model is carried out, illustrated with computations applicable to the D or E-region of the ionosphere. The quasi-longitudinal approximation is derived from this theory and the range of validity of this approximation is illustrated. The restrictions imposed by the use of a sharply bounded model ionosphere are discussed.

LOW- AND VERY-LOW RADIO-FREQUENCY MODEL IONOSPHERE REFLECTION COEFFICIENTS

July 1960, NBS, Tech. Note No. 69, PB 161570, \$2.00

J.R. Johler, L.C. Walters, J.D. Harper

ON THE ANALYSIS OF L.F. IONOSPHERIC RADIO PROPAGATION PHENOMENA

J. Research NBS, Vol. 65D, No. 5, Pgs. 507-529, September-October 1961

J.R. Johler

Recent theoretical work which employs the classical magneto-ionic theory for a special model of the ionosphere applicable to transmission via the ionosphere at or close to grazing incidence is employed to analyze L.F. propagation data. The results of the analysis illustrate a practical model of the ionosphere by a detailed study of transmission via the first time-mode in particular.

MAGNETO-IONIC PROPAGATION PHENOMENA IN LOW- AND VERY-LOW RADIO FREQUENCY WAVES REFLECTED BY THE IONOSPHERE

EE Abstr. 2029/1961; J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 1, Pgs 53-65, January-February 1961.

J.R. Johler

Ionosphere reflection coefficients at l.f. - v.l.f. which illustrate the dependence of the amplitude and phase of the reflected wave on the propagation direction relative to the earth's magnetic field are presented. The calculations are based on a plane, sharply bounded, model ionosphere with plane-wave excitation, but make full use of the magneto-ionic formulae for complex directions of propagation in the ionosphere, so that the influence of the earth's magnetic field in the different directions of propagation is demonstrated. A special table of values applicable to v.l.f. is presented.

PROPAGATION OF THE LOW-FREQUENCY RADIO SIGNAL
Proc. Inst. Radio Engrs. (USA), Vol. 50, No. 4(I), Pgs 404-27,
April 1962. Phys. Abstr. 11807/1962.
J.R. Johler

The propagation of a radio signal and the propagation in the time domain is reviewed for linear amplitude systems. The particular case of the propagation of a ground wave pulse is considered in detail. A stretching in the form or shape of the pulse is noted as a result of the filtering action of the propagation medium. Theoretical transfer characteristics for the media of propagation of l.f. signals are introduced and methods of computation are considered. The particular case of a signal transmitted between two points on the earth's surface is considered from the view point of propagation in the time domain.

CORRECTION TO PROPAGATION OF THE LOW-FREQUENCY RADIO SIGNAL
Proc. IRE 50, 2092, October 1962.
J.R. Johler

PROPAGATION OF TERRESTRIAL RADIO WAVES OF LONG WAVELENGTH - THEORY OF ZONAL HARMONICS WITH IMPROVED SUMMATION TECHNIQUES
Phys. Abstr. 5855/1963. J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 6, Pgs 737-73, November-December, 1962.
J.R. Johler, L.A. Berry

Demonstrates that the field of the propagated long wavelength radio wave (frequencies less than approximately 50 kc/s) can be evaluated by a summation of a series of zonal harmonics. The detailed structure of the field in the absence of a concentric plasma is characterized by the quite regular behaviour of the ground wave as a function of distance. Indeed, the steady decrement of the groundwave field is modified only near the antipode. The series of zonal harmonics comprises individual waves which are travelling in the radial direction with respect to the centre of the sphere and standing in the direction of increased angular distance around the sphere. These waves, when summed, build up the wave progressing in the direction of increased angular distance. Under special circumstances, standing waves can be noted. This is especially obvious near the antipode of the transmitter. The results of the computations indicate that full rigour can be achieved with comparative ease at frequencies less than approximately 50 kc/s, leaving only the assumed model for the transmitter and the propagation medium and avoiding the complications of the Watson transformation.

CONCERNING LIMITATIONS AND FURTHER CORRECTIONS TO GEOMETRIC-OPTICAL THEORY FOR LF, VLF PROPAGATION BETWEEN THE IONOSPHERE AND THE GROUND
Radio Sci. Journ. Research NBS/USNC URSI, Vol. 68D, No. 1, January 1964, Pgs. 67-78.
J.R.Johler

Considerable use has been made of the geometric-optical propagation theory to describe long wavelength terrestrial radio waves between the ionosphere and the ground by Bremmer (1949), Wait and Murphy (1957), Wait (1961), Wait and Conda (1961), and Johler (1961, 1962). The physical interpretation of pulse signals propagated around the terrestrial sphere as an application of the theory has been described by Johler (1962, 1963a, 1963b). Indeed the use of the Loran-C radio navigation-timing system to study the propagation of LF ionospheric waves has given further impetus to such a study.

INVESTIGATION OF RADIO WAVE PROPAGATION, 10-500 KC AND STUDY OF LORAN SYSTEM OF HYPERBOLIC NAVIGATION
AD 106 351; University of Florida, Gainesville, Florida, 70 p., illus. 1948.
R.C. Johnson, R.S. Hoff.

No abstract.

INVESTIGATION OF RADIO WAVE PROPAGATION, 10-500 KC AND STUDY OF LORAN SYSTEM OF HYPERBOLIC NAVIGATION
AD 106 153; University of Florida, Gainesville, Florida, P. 25, illus., 1950.
R.C. Johnson, R.S. Hoff

No abstract

THE NON EXISTENCE OF THE SURFACE WAVE IN DIPOLE RADIATION ABOVE A PLANE EARTH
Arch. Elekt. Ubertragung (Germany), V. 5, Pgs. 25-32, January 1951
T. Kahan, G. Eckert

Sommerfeld's treatment of the radiation from a vertical hertzian dipole above a plane, finitely conducting, earth is discussed. Through the solution of Weyl is explained and modified. Comparison is made with the experimental work of Burrows (Abstr. 1048/1937). The final conclusion is that the surface wave does not exist. Objections by Ott are answered. (See Ott).

A NOTE ON THE STATISTICAL THEORY OF RADIOWAVE PROPAGATION OVER
AN IDEALLY CONDUCTING PLANE

EE Abstr. 474/1960; Dokl. Akad. Nauk SSSR, V. 127, No. 4,
Pgs 792-5, August 1959.
E.A. Kaner, F.G. Bass

Assumes a propagation medium with small chance fluctuations $\delta \epsilon$ of the dielectric constant $\epsilon = \langle \epsilon \rangle + \langle \delta \epsilon \rangle$, where $\langle \epsilon \rangle$ and $\langle \delta \epsilon^2 \rangle$ are assumed independent of time and the co-ordinates. The source is a dipole situated above the boundary plane. Only large scale fluctuations are considered, i.e. where the characteristic correlation radius is large compared with the wave-length. Starting from Maxwell's equation, the presence of the boundary is shown to lead to a sharp increase in the relative fluctuations as compared with the case of an infinite medium; these increases occur near the interference minima of the regular field component. The cases of a curved and a finitely conducting boundary are also discussed.

THE EXCITATION OF SURFACE WAVES IN MULTI-LAYERED MEDIA

AD 55911; Tech. Res. Grp., 56 West 45th Street, New York, N.Y.
October 1954.
A.F. Kay

The excitation of surface waves in three dimensional, multi-layered media with arbitrary electromagnetic parameters is related to the characteristics of the source antenna. The source field is first presented as a continuous spectrum of plane and evanescent waves, a Fourier integral which converges in a half space. A solution for a single incident wave is obtained in the usual fashion by postulating reflected and transmitted waves in each layer, uniquely determined by the boundary conditions at each interface and the radiation at infinity. Superposition of the solutions for each wave in the spectrum of the source field then is proved to yield the total field solution. The total field is examined at large distances ρ parallel to the layer interfaces for the asymptotically dominant terms as follows: the Fourier integral is transformed into an expression involving Hankel functions. The integration contours are deformed to embrace certain branch cuts thus crossing certain poles whose residues yield the surface waves. The branch cut integrals are roughly estimated and compared with the surface wave terms for large ρ . For this purpose, several results concerning the behaviour of the integrands for large ρ and large θ , the transform variable, are required. Examples of the excitation efficiency of dipoles and uniformly illuminated apertures are worked out. Some general results about the poles and residues for the cases of 1 and 2 interfaces are also given.

ELECTRICAL PROPERTIES IN THE DEEP CRUST

EE Abstr. 283/1964. IEEE Trans Antennas and Propagation (USA),
Vol. AP-11, No. 3, 344-57, May 1963.
G.V. Keller

Resistivities in the earth's crust have been evaluated by direct observation using dipole-dipole resistivity soundings and magneto-telluric resistivity methods, supplemented by laboratory measurements of the electrical properties of appropriate rock types at elevated temperatures. Assuming a three-layer crustal-model, the field observations indicate an attenuation of one to ten dB per km in the resistant middle layer. It is pointed out, however, that the resistivities in this zone are biased toward the lower side. Higher resistivities are expected on the basis of the laboratory experiments and if they occur to a significant extent, lower transmission losses would be obtained than are predicted by the field measurements.

SURFACE WAVE EXCITATION AND PROPAGATION

EE Abstr. 4138/1960; J. appl. Phys. (USA), V. 31, No. 6, Pgs 1039-46,
June 1960.
J.B. Keller, F.C. Karal, Jr.

A geometrical theory is developed for the analysis of surface-wave excitation and propagation. The surfaces along which the surface waves propagate may be either curved or flat, and may have either constant or variable properties. The theory is based on the concept of a complex or imaginary ray. The excitation coefficient which enters the theory is determined from the solution of a canonical problem - that of a line source over an impedance plane. Then the theory is applied to the surface wave excited by a line source, on a wedge with variable surface impedance. The result agrees precisely with the asymptotic form of the exact solution. Another application is made to the surface wave excited on a cylinder by a line source. The result also agrees with the exact solution.

PROPAGATION OF ACOUSTIC AND ELECTROMAGNETIC WAVES IN A HALF-SPACE

Akust. Zh. (USSR), V. 5, No. 4, Pgs. 464-71, 1959.
M.D. Khaskind

A half-space is considered in which the impedance at the boundary is given in the form of an arbitrary complex number, and a general solution of the wave equation is formulated by introducing a function which reverts to zero at the boundary. Expressions for the acoustic and e.m. potential are derived in terms of this function.

ENERGY SPECTRUM OF ATMOSPHERICS AND ATTENUATION OF DIFFERENT LOW FREQUENCIES WITH DISTANCE

EE Abstr. 2197/1962; Proc. Nat. Inst. Sci. (India), A, V.26, Suppl. No. 2, Pgs 58-66, December 1960.
S.R. Khastgir, R.S. Srivastava

Experiments were carried out to study the energy spectrum of different atmospheric and the attenuation of different frequencies (3-15 kc) over widely varying distances (150-1500 km) during the night hours. The method and experimental procedure are described. Considering only those atmospheric which gave smooth and continuous amplitude variations in the narrow-band amplifiers, and which showed at the same time return stroke pulses with successive ionospheric reflections in the automatic atmospheric recorder, the energy spectrum curves were drawn for the individual atmospheric originating at various distances, which were estimated from the time-intervals between successive ionospheric reflections in the wave-form records. The frequency for which the maximum amplitude was observed was found to increase almost linearly with distance. The attenuation curves were also drawn for 6, 7, 8, 9 and 10 kc relative to 12 kc over a distance ranging from Budden's theoretical curves.

A REVIEW OF PRESENT KNOWLEDGE OF THE IONOSPHERIC PROPAGATION OF VERY-LOW, LOW AND MEDIUM-FREQUENCY WAVES

Phys. Abstr. 2575/1953; Proc. Instn. Elect. Engrs (GB), III, 100, Pgs 100-8, March 1953.
F.A. Kitchen, B.G. Pressey, K.W. Tremellen

Deals with the ionospheric propagation of waves of frequencies < 3 Mc and is confined mainly to transmission over medium and long distances (> 500 km). The results of investigations on low and very-low frequencies (< 300 kc) are summarized under the headings of field strength, phase and polarization measurement, the effects of ionospheric disturbances, the study of local ionospheric characteristics and theoretical studies. Only work done since 1937 is considered. An important item of the recent work is the study of the ionospheric cross-modulation.

A METHOD OF INVESTIGATING AIR-TO-SUBSURFACE VLF PROPAGATION

IRE Trans. Antennas and Propagation (USA), Vol. AP-10, No. 5, 650-1, September 1962. E.E. Abstr. 980/1963.
S. Kowmacki

Uses geometrical optics. The radiating aerial is assumed to be in free space and the resultant field below the water surface is computed by summation of the contributions from individual rays. Each contribution is subjected to amplitude attenuation and phase change due to propagation through space and reflections from the ionosphere and water surface. The merits of horizontal and vertical polarization are compared.

THE BOUNDARY PROBLEM FOR THE PROPAGATION OF ELECTROMAGNETIC WAVES
IN A SPHERICALLY LAYERED, ANISOTROPIC, DISSIPATIVE MEDIUM
Doklady Akad. Nauk SSSR, Vol. 138, No. 4, Pgs 813-816, 1st June 1961.
Trans. in Sov. Phys. Doklady, Vol. 6, Pgs 466-9, December 1961.
P.E. Krasnushkin

Maxwell's equations are formulated in a matrix-operational form and a general case is considered, having immediate application to a spherical earth consisting of layers of different propagation constants and surrounded by an anisotropic ionosphere.

SOLUTIONS OF THE BOUNDARY VALUE PROBLEM FOR PROPAGATION OF RADIO WAVES ROUND THE EARTH, WHILE TAKING INTO ACCOUNT GENERAL GEOPHYSICAL FACTORS
EE Abstr. 488/1962; Dokl. Akad. Nauk SSSR, V. 138, No. 5, Pgs 1055-8, June 1961. Soviet-Physics-Doklady, V.6, No. 6, December 1961.
P.E. Krasnushkin

The total spectrum of such waves is derived for a three-layer model: (1) $0 \leq r \leq a$ ($a =$ earth's radius) with a complex dielectric constant; (2) $a \leq r \leq \infty$, ideal atmosphere with unity dielectric constant; (3) $0 \leq r \leq \infty$, ionosphere as an electric-ion plasma under the influence of steady magnetic field. Special cases are also considered: (1) Watson's case of a spherical waveguide; (2) plane waveguide model ($a \rightarrow \infty$); (3) diffraction model; (4) Sommerfeld model.

THE PROPAGATION LONG AND ULTRA-LONG RADIO WAVES ABOUT THE EARTH IN THE LOWER (C, D, AND E) LAYERS OF THE IONOSPHERE IN THE LIGHT OF INFORMATION
Theory, Doklady Akad. Nauk SSSR, Vol. 139, No. 7, Pgs 67-70 (July 1961). Trans. in Sov. Phys. Doklady, Vol.6, No.7, Pgs 576-9, Jan. 1962.
P.E. Krasnushkin

Using the solutions of two earlier papers for the earth ionosphere boundary value problem, propagation characteristics for frequencies below 100 kc are calculated. Experimental and theoretical models of the ionosphere are approximated using a multi-slab layered ionosphere.

THEORY OF TERRESTRIAL ATMOSPHERICS
EE Abstr. 14864/1962; Dokl. Akad. Nauk. SSSR, Vol. 144, No. 2, Pgs 334-7, 11th May 1962, in Russian.
P.E. Krasnushkin

The propagation of atmospheric waves is discussed in terms of idealized models. Mode theory is used to calculate field-strength versus time relationships at a distance from an impulsive source.

ON THE PROPAGATION OF LONG AND VERY LONG RADIO WAVES AROUND THE EARTH

Phys. Abstr. 19456/1963. Nuovo Cimento Suppl. (Italy), Vol. 26, No. 1, 50-112 (1962).
P.E. Krasnushkin

The problem of deriving functional relationships between E and ϵ is studied from the point of view of information theory. Solutions for the three layer medium are discussed for both mode and ray theories. An account is given of the ionization profile of the lowest ionosphere and of its dependence upon time of day, season and geomagnetic latitude. The features of the diurnal variation of the measured amplitude and phase of l.f. and v.l.f. waves are considered. There is good agreement between theory and experiment. An extensive list of references to both Russian and Western papers is given.

PROPAGATION OF RADIO PULSES OVER A FLAT HOMOGENEOUS EARTH

EE Abstr. 13875/1963; Radiotekhnika i Elektronika (USSR), Vol. 7, No. 4, 579-89 (April 1962). In Russian; English trans. in Radio Engng electronic Phys. (USA), Vol. 7, No. 4, Pgs 549-58 (April 1962).
G.N. Krylov

No abstract

ELECTROMAGNETIC WAVES: Proceedings of a Symposium Conducted by the Mathematics Research Centre, April 10-12, 1961.

University of Wisconsin Press, 1962.

R.E. Langer

LABORATORY SIMULATION OF VLF PROPAGATION AND UNDERGROUND ANTENNA PERFORMANCE

Inst. Radio Engrs (USA), Wescon Convention Records, Paper 31/1, 1961, T.C. Larter, M.E. Louapre, A.P. Stogryn

No abstract

PENETRATION OF THE IONOSPHERE BY VERY-LOW-FREQUENCY RADIO SIGNALS - INTERIM RESULTS OF THE LOFTI I EXPERIMENT

EE Abstr. 10101/1962; Proc. Inst. Radio Engrs (USA), Vol. 50, No. 1, 6-17, January 1962.
J.P. Leiphart, R.W. Zeek, L.S. Bearce, E. Toth

The LOFTI experiment was carried out by a satellite which carried v.l.f. receivers from which the telemetered outputs could be recorded. Signals at 18 kc/s transmitted by NBA (Panama), and NPG (Seattle) were received. It was shown that a considerable fraction of the transmitted energy penetrated into the ionosphere. The amplitude was much greater by night than by day, and the attenuation of the signal from NPG was less than that for NBA signal.

ELECTROMAGNETIC SURFACE WAVES ON A PLANE INTERFACE

Phys. Abstr. 13180/1961; J. appl. Phys. (USA), V. 32, No. 9,
Pgs 1758-63, 1961.

B.A. Lengyel, K.M. Mitzner

Surface waves are defined as waves exponentially decreasing on both sides of a plane interface. It is shown how all such waves can be generated from a single Hertz vector perpendicular to the interface. The relations between the propagation parameters of the waves and the material constants are derived in a general case which include media with different magnetic permeabilities. The condition for the existence of a surface wave is derived.

HYPERBOLIC DIRECTION FINDING WITH SPHERIC OF TRANSATLANTIC ORIGIN

Phys. Abstr. 16484/1960; J. geophys. Res. (USA), Vol. 65, No. 7,
Pgs. 1879-1905, July 1960.

E.A. Lewis, R.B. Harvey, J.E. Rasmussen

The experimental "hyperbolic direction-finder" consists of an array of sferio receivers in the New England area, connected by wideband data links so that microsecond differences in pulse arrival time can be measured. The hyperbolic directions can be determined from the time differences. In a series of co-ordinated runs, individual sferios originating in western Europe were observed by both the New England net and the sferics net of the British Meteorological Office. The British Meteorological Office furnished the geographic co-ordinates of the lightning strokes so that measurements of position could be compared. Tabulated results for 150 sferics show an average absolute deviation from the mean of only 31 nautical miles.

RELATIVE PHASE AND AMPLITUDE SHIFTS OF VLF SIGNALS RECEIVED ON TWO PATHS ALMOST PARALLEL WITH THE SUNRISE LINE

Phys. Abstr. 9946/1963; J. geophys. Res. (USA), Vol. 67, No. 12,
Pgs 4906-8, November 1962.

E.A. Lewis, J.E. Rasmussen

Comparison of the phases of 18 kc/s signals received along two paths almost parallel with the sunrise line, but about 120 km apart, shows a phase transient as the day-night interface sweeps across the two paths. The phase transient lasted about 13 mins. and the transit time from one path to the other was 6 mins., therefore the interface zone had an effective width corresponding to approximately 7 mins. i.e. 140 km. The maximum value of the phase shift was 30° , corresponding to a propagation time difference of 5μ sec. Such a phase shift could cause errors in direction finders of the "hyperbolic" or "time-difference" type. Amplitude changes were noticed 4 to 7 minutes after the beginning of the phase transient, whereas for single short paths the amplitude change occurs before the phase change.

PROPAGATION OF ELECTROMAGNETIC PULSES AROUND THE EARTH
EE Abstr. 4292/1957; New York Univ. (Inst. Math. Sci.), No. EM 102,
19 p., February 1957.
B.R. Levy, J.B. Keller

The pulses are assumed to be produced by a vertical electric or magnetic dipole. The earth is treated as a homogeneous sphere of either finite or infinite conductivity and the atmosphere is assumed to be homogeneous. It is found that very short pulses become longer the further they propagate, in addition to diminishing in amplitude. The duration of a pulse which is initially a delta-function increases as Θ^3 , where Θ is the angle between source and receiver. The results are represented as products of several factors, which we call the amplitude factor, the pulse-shape factor, the time-dependent height-gain factor for the source and receiver, and the conductivity factor. Graphs of these factors and of the pulse shape for several cases are given.

EXTREMELY LOW-FREQUENCY ELECTROMAGNETIC WAVES: I. RECEPTION FROM LIGHTNING

Phys. Abstr. 4571/1957; J. appl. Phys., V. 27, No. 12, Pgs 1473-6,
December 1956.
L. Liebermann.

Extremely low-frequency (ELF) radio waves (10-500 cps) originating in lightning were received over distances in excess of 15,000 km. Transmission conditions were equally good, day or night. Propagation distances were ascertained by analysis of higher frequency components (> 1700 cps) according to known methods. The receiving aerial employed an arrangement of grounded electrodes which uniquely determined the azimuthal direction of the source. Two distinct classes of ELF pulses are described which are attributed to different conditions of propagation.

EXTREMELY LOW-FREQUENCY ELECTROMAGNETIC WAVES: II. PROPAGATION PROPERTIES

Phys. Abstr. 4572/1957; J. appl. Phys. V. 27, No. 12, Pgs 1477-83,
December 1956.
L. Liebermann

Properties of electromagnetic propagation at extremely low frequencies (below 500 cps) are deduced from analysis of pulse distortion. The source of the transmitted pulse is lightning. Two distinct transmission types are analysed. Normal, or type I propagation is shown to behave as if the earth's surface and ionosphere constitute a wave guide composed of two parallel surfaces, with one surface partially conducting. This wave guide has no low-frequency limit on propagation; attenuation formulae are given. The transmission

properties of type II, or anomalous propagation, are derived and seen to be inexplicable by means of this wave-guide model. The analysis leads to a determination of the effective conductivity of the ionospheric reflector at these frequencies; the day-time reflecting layer (D-layer) conductivity is 10 e.s.u.; the night-time conductivity (E-layer) is 5×10 e.s.u.; both results are far lower than deduced by other means.

A VERY-LOW-FREQUENCY ANTENNA FOR INVESTIGATING THE IONOSPHERE
WITH HORIZONTALLY POLARIZED RADIO WAVES

J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 1, January-February 1960.
R.S. Macmillan, W.V.T. Rusch, R.M. Golden

The advantages of a horizontal half-wave resonant antenna for very-low-frequency propagation experiments lie in its relatively simple and inexpensive construction and in its radiation pattern which is maximum in the vertical direction. The radiation fields of this type of antenna located at the surface of a conducting earth consist of: (1) A horizontally polarized space-wave field radiated in the perpendicular bisector plane of the antenna. This vertically polarized field is zero at right angles to the antenna. These fields have been experimentally verified. The use of a 50-kilocycle horizontal half-wave antenna for vertical-incidence ionospheric sounding experiments is described. The radiation pattern of this antenna is well suited for ionospheric soundings since a receiver located in the groundwave null receives only the reflected skywave signal. Ground-resistivity measurements made at a number of locations in Central and Southern California were correlated with the geology of the terrain. This correlation showed that the ground resistivity is highest (a condition necessary for optimum antenna efficiency) in areas where the underlying rock formations are relatively unfractured. The amount of annual rainfall and other climatic conditions have little or no effect on the resistivity. Finally, a unique antenna system is presented which employs resonant loading circuits to convert a section of an existing power line into a horizontal half-wave very low-frequency transmitting antenna.

A THEORETICAL INVESTIGATION OF THE PROPAGATION PATH OF THE WHISTLING
ATMOSPHERICS

EE Abstr. 2512/1959; Rep. Ionosphere Space Res. (Japan), V. 10, No. 3,
Pgs 105-23, September 1956.
K. Maeda, I. Kimura.

By the ray-theoretical treatment based on Fermat's principle, formulae necessary for the exact calculation of the ray path of a whistler have been deduced, and ray paths starting from various geomagnetic latitudes have been calculated, under the appropriate assumption of distribution of electron density in the outer ionosphere. It is shown that the ray path does not in general follow the line of magnetic force and especially in lower latitudes the path is not

symmetric with respect to the magnetic equator. It is also shown that many of the facts so far observed at various latitudes can be explained by the results of this theoretical study. Some remarks are added on future experiments with a view to exploring the electrical and magnetic properties of the outer ionosphere.

CALCULATION OF THE PROPAGATION PATH OF WHISTLING ATMOSPHERICS
Phys. Abstr. 8428/1960; J. atmos. terrest. Phys., (GB), V. 15,
No. 1-2, Pgs. 58-65, September 1959.
K. Maeda, I. Kimura.

An approximate method is worked out of calculating the propagation path of a whistler by using Fermat's principle. The paths calculated under some appropriate assumption of the electron density distribution above the ionosphere shows an appreciable deviation from the line of magnetic force and are generally asymmetric with respect to the magnetic equator. As to the frequency characteristics of the whistler path, the higher the wave frequency is, the more the wave travels inside.

A CALCULATION OF THE PENETRATION OF VLF RADIOWAVE ENERGY THROUGH THE IONOSPHERE
EE Abstract 7746/1963; Ionosphere Conf., London 1962 (see Abstr. 5380 of 1963); Pgs. 461-6.
K. Maeda, H. Oya.

VLF radio waves must penetrate the ionosphere twice (for the whistlers) or once (for the hiss and the chorus) before they are received. The problem considered is the calculation of the penetration of the extraordinary mode waves through anisotropic dispersive media. It is anticipated that most of the radiowave energy will be reflected back at the ionospheric boundary, except for the case where the wave polarized in the plane of propagation is incident within a narrow band of angles corresponding approximately to Brewster's angle. In order to confirm this, the penetration energy was calculated as a function of the angle of incidence at a frequency of 10 kc/s. For the case in which the waves are incident upon the ionosphere from below, the calculation was based on a modification of Bremmer's theory (Terrestrial Radio Waves, New York: Elsevier (1949)), whilst a special theory was devised for the case in which the waves are incident from above. Numerical results and diagrams are presented for both cases.

PENETRATION OF ELF RADIO WAVES THROUGH THE IONOSPHERE
Phys. Abstr. 23613/1963; J. Geomagn. Geoelect (Japan), Vol. 14, No. 3,
Pgs 151-71, 1963.
K. Maeda, H. Oya

The rate of energy penetration of vlf (10 kc/s) radio waves through a sharp ionospheric boundary under a constant magnetic field is calculated and the directions of the ray and the wave normal at the boundary

are discussed. For the case in which the v.l.f. radio waves go up into the ionosphere from free space below, a rigorous calculation is performed using Bremmèr's method and the existence of a quasi-Brewster's angle is ascertained. In the case in which the waves come downwards from above, an approximate method is set up for the calculation and it is shown that the vlf waves can penetrate down to the earth's surface only when the wave normal lies in a narrow band of angle near the normal of the boundary. In this case the ray direction of the penetrating waves is close to the magnetic field.

WAVE-GUIDE MODE PROPAGATION OF VERY LOW FREQUENCY RADIO WAVES

EE Abstr. 3184/1962; J. atmos. terrest. Phys., (GB), V. 20, No. 2-3, Pgs 206-9, March 1961.
F.G. Martin.

A report of calculations of the attenuation of v.l.f. waves in W-E and E-W waveguide-mode propagation in an ionosphere in which the electron density is assumed to increase exponentially with height, while the magnetic field is inclined at 30° to the vertical in a plane perpendicular to the plane of propagation. The results thus apply to propagation in northern temperate latitudes, and use an ionospheric model probably closer to the true one than the sharply bounded homogeneous ionosphere considered by Budden and by Crombie. The values of the attenuation for the various modes were calculated by a method outlined by Budden, the earth being assumed flat, the ground perfectly conducting, the collision frequency 3×10^6 /sec, the gyro-frequency 1.28 Mc and the electron density $\bar{N} = \exp(\alpha z)$, where z is measured vertically upwards from a level near the base of the ionosphere. Pairs of curves relating attenuation of frequency are given for the case of a very sharp ionosphere defined by $\alpha = 2.36 \text{ km}^{-1}$ and for a more realistic model with $\alpha = 0.59 \text{ km}^{-1}$. In both cases the W-E propagation is the less attenuated. The results given apply to quasi-TM modes of least attenuation and to a value of 80 km for h , the distance between the ground and the level where the electron density $N = 3.175$. Pairs of curves are also given which relate h_1 to the attenuation for the frequencies 10, 12, 16 and 20 kc and in each case for the four least attenuated modes. These curves show that as h_1 decreases, the attenuation of the mode increases and the non-reciprocity becomes more apparent. It is noted that the attenuation curves for a vertically polarized wave propagated through a similar model of the ionosphere, but without an applied field, are very close to those given for E-W propagation.

STUDIES OF GEOMAGNETIC LATITUDE CONTROL OF VLF AND ELF PHENOMENA IN THE ANTARCTIC (VLF Air-Lifted Traverse), Final Report, National Science Foundation Grant 13532, Radioscience Laboratory, Stanford University, Stanford, Calif., 5th June 1961.
L.H. Martin

To determine the effect of increasing latitude on the characteristics of VLF and ELF phenomena at high geomagnetic latitudes the Radio Science Lab. of Stanford University with the assistance of co-operation of officers of the United States Antarctic Research Program, National Science Foundation,

planned an air-lifted VLF traverse to cover 20° of geomagnetic latitude along the magnetic meridian passing through Byrd Station. This work was planned for the 1960/61 Antarctic field season but unfortunately a long period of unsuitable flying weather delayed the start of the operation and it was only possible to set up three field stations before the season ended. Although the traverse covered only 7° of geomagnetic latitude, much interesting data were collected and the results demonstrate the desirability of completing this operation.

The traverse operation was funded through NSF Grant 13532. This grant also supported in part a conjugate point experiment carried out in January 1961 between Byrd Station and its geomagnetic conjugate area in the Canadian Arctic. This conjugate experiment was a joint and co-operative undertaking in which Stanford Radioscience Laboratory and the Pacific Naval Laboratory of the Canadian Defence Research Board combined to make simultaneous observations of naturally occurring ELF and VLF phenomena over a frequency range 0.002 cps - 15 kc/s. Preliminary analysis of the data from this experiment indicates that there is often great similarity between events at the opposite ends of a high latitude magnetic field line.

ON THE PROPAGATION OF THE WAVE FRONT IN A DISPERSIVE MEDIA
EE Abstr. 2569/1953; RC Accad. Naz. Lincei (Italy), V. 12,
Pgs 683-7, June 1952.
M. Marziani

The problem is investigated theoretically, by means of the Laplace transformation, for the general case of a plane electromagnetic wave in a homogeneous medium.

ON THE PROPAGATION OF THE WAVEFRONT IN HETEROGENEOUS DISPERSIVE MEDIA
Phys. Abstr. 2570/1953; RC Acad. Naz, Lincei (Italy), V. 13, Pgs.
127-31, September-October 1952.
M. Marziani

The wavefront propagates with velocity $(\epsilon(z)\mu)^{-1/2}$ for a plane wave perpendicular to the z-axis. An integral expression is also given for the electric field in the neighbourhood of the wavefront.

BIBLIOGRAPHY ON EM WAVE PROPAGATION

Technical Memorandum EDL-M186, Contract DA 36-039-sc-78281, Electronic Defense Lab., Sylvania Electric Products, Inc., Mountain View, California, 1st April 1959. AD-216 404.

The purpose of this bibliography is to provide an up-to-date (1947-1958) reference to publications from laboratories foremost in their respective fields of upper atmospheric research, wave propagation, and wave scattering phenomena. The laboratories whose work in these fields has comprised the basis for this report are: Cavendish Laboratory, University of Cambridge; Electrical Engineering Dept., Cornell University;

Ionospheric Research Laboratory, the Pennsylvania State University;
Radio Propagation Laboratory, Stanford University; Stanford Research
Inst. There are 814 references (including references to work from
other sources than the above).

A STUDY OF THE MORPHOLOGY OF IONOSPHERIC STORMS

J. Geophys. Research 64, 305-21, March, 1959.
S. Matsushita

PROPAGATION OF RADIO FREQUENCY ENERGY THROUGH THE EARTH

Phys. Abstr. 10361/1954; Geophysics (USA), V.19, Pgs. 459-77, July 1954.
F.M. McGehee, Jr.

Measurements were made of some propagation characteristics in the
earth of 1614 and 1700 kc energy. The experiments were conducted at
Carlsbad Caverns, New Mexico, and Mammoth Cave, Kentucky. Transmitters
were set up on the surface 710 ft above an unwired tunnel in Carlsbad
Caverns and the signal strength was measured at many points in the
tunnels. A similar series of measurements was made in Mammoth Cave
in a tunnel 270 ft below the surface. The data show that the atten-
uation constant is about 0.012 and 0.02 to 0.064 neper/m at the two
locations respectively. These values are in good agreement with
theory.

A NOTE ON THE DETECTION OF UNDERSEA CRAFT BY MEANS OF LOW FREQUENCY RADIATION FROM AIRCRAFT

Canad. J. Res., V. 23, Pgs 77-85, November 1945.
W.R. McKinley

A semiquantitative examination is made of the chief factors
affecting both the transmission of low-frequency radiation from an
aircraft to a submarine and the return of this energy to the aircraft
by scattering. A general expression is derived for the returning
field strength and graphs are shown for a representative set of
conditions. It is indicated that, even under the most favourable
conditions, the amount of energy returned is below the level of
detectability, if the submarine is submerged more than 10 ft.
However, it is also pointed out that communication between a shore
station and an undersea craft should be feasible under certain conditions.

THE PROPAGATION OF FADING WAVES

Phys. Abstr. 19948/1960; Phil. Mag. (GB), V.4, Pgs 763-76, June 1959.
R.P. Mercier

A scalar wave with random variations of amplitude and phase across
the wave-front is assumed as a simple model of a radio wave after it
has left the ionosphere. The second-order moments of the in-phase and

quadrature components of the fluctuating part of the field are found using the Fresnel diffraction formula. It is assumed that these two components have a joint Gaussian distribution, and a parameter ρ_N , called the intrinsic correlation of the fading, is introduced; this serves as a measure of the eccentricity of the ellipse of constant probability. It is shown that ρ_N is the amplitude of the diffraction pattern produced by a distribution of intensity proportional to the spatial correlation function of the fluctuations over the wave-front. As the wave propagates the correlation tends to zero. It is shown that for a given irregularity size and wavelength, the irregularities may be supposed to be situated at any height, up to a certain maximum height, at which $\rho_N = 1$. An analysis of day time fading on 16 kc was made. It appears that the intrinsic correlation of the wave at the ionosphere is very near one, and that the ionosphere imposes phase modulation on the wave.

INVESTIGATIONS ON THE PROPAGATION OF EM WAVES OVER AN ABSORBING SURFACE
Phys. Abstr. 12310/1963; Z. angew. Phys. (Germany), Vol. 15, No. 1,
31-9, January 1963. In German.
E. Meyer, D. Eisfeld.

Gives a detailed description of the results of experiments as well as of the apparatus and measurement devices. The waves were propagated over a channel filled with an absorbing liquid (glycol, $C_2H_4(OH)_2$). The measured field strengths and phase relationships (e.g. the direction of propagation vector) show good agreement with the quasi-optical theory outside a distance of one wavelength away from the absorbing surface. A very small and simple probe (fully described) was used to measure the component of magnetic field, while a dipole ($\lambda/2$) was used to obtain the electric field intensity. Special precautions were made to remove disturbances due to outside fields.

NIGHT-TIME IONIZATION IN THE LOWER IONOSPHERE. I. RECOMBINATION PROCESSES
Phys. Abstr. 763/1960; J. atmos. terrest. Phys. (GB), V. 10, No. 3,
Pgs 140-52, 1957.
A.P. Mitra

Both height and time variations of the effective recombination coefficient at night for the lower ionosphere are obtained from ionospheric data, including measurements on ionospheric absorption at 18.3 Mc and 150 kc; hourly values of the night-time E-region critical frequencies for Watheroo, phase height observation at 16 kc, and virtual height measurements at 50 kc and 150 kc. It is found that although at levels near 80 km the effective recombination coefficient increases appreciably immediately after sunset, at higher levels the coefficient decreases. Theoretical interpretation of these results is based on the idea put forward by Nicolet, that an appreciable number of atomic ions of low ionization potential exist in the ionosphere. While the positive molecular ions disappear rapidly through dissociative recombination with electrons, the positive atomic ions disappear very slowly.

VLF PROPAGATION EFFECTS OF A D-REGION LAYER PRODUCED BY COSMIC RAYS
Phys. Abstr. 15163/1960; J. geophys. Res. (USA), V. 65, No. 5,
Pgs 1459-68, May 1960.
W.F. Moler

The single-layered D-region model based only on Lyman α photoionization of nitric oxide is inadequate to explain certain aspects of v.l.f. radio propagation. Empirical evidence indicates the existence of a second and lower D-layer which is important for v.l.f. propagation. It is shown that normal cosmic rays produce sufficient ionization for such a layer. The electron-production and depletion process effective below 100 km and latitudinal distribution of cosmic-ray primaries due to the geomagnetic field are discussed. A series of electron-density profiles obtained from photoionization and cosmic-ray ionization processes is compared with the two-layered D-region model deduced from electromagnetic measurements. The calculated phase and amplitude characteristics of v.l.f. signals reflected from the lower cosmic-ray induced layer during the presunrise hour are in good agreement with those measured.

THE THEORY OF RADIO COMMUNICATION BETWEEN SUBMERGED SUBMARINES
A Thesis: Presented to the Faculty of the Graduate School of Cornell University for the Degree of Doctor of Philosophy, June 1951, microfilm, Cornell University Library.
R.K. Moore

No abstract

AN ISLAND AS A NATURAL VERY-LOW FREQUENCY TRANSMITTING ANTENNA
EE Abstr. 1629/1961; Instn. Radio Engrs. (USA), Trans., V. AP-8,
No. 5, Pgs 528-30, September 1960.
M.G. Morgan

It is suggested that an island, being as insulator in a conducting sea, could be excited as a resonant slot, Deception Island (63°S , 61°W) is ring-shaped broken by a narrow channel. It is proposed to excite the island by siting the transmitter opposite the channel with two feeders bridging the island from the sea. The island is 30 km long and should resonate at about 5 kc.

VERY-LOW-FREQUENCY PROPAGATION BELOW THE BOTTOM OF THE SEA
EE Abstr. 1228/1964. IEEE Trans Antennas & Propagation (USA),
Vol. AP-11, No. 3, 323-9, May 1963.
H. Mott, A.W. Biggs

Radio-wave propagation at very low frequencies v.l.f. in the stratified rock below the bottom of the sea is studied. A reasonable assumption of extremely low electrical conductivity in the stratified rock is based upon available geological data. The surface wave travelling along the interface between this region of low conductivity and the highly conducting sea is compared with the vertically polarized ground wave found in v.l.f. radio-wave propagation at the surface of the earth. When extremely low frequencies e.l.f. are transmitted, the highly conducting layer found at greater depths below the bottom of the sea forms the lower surface of a spherical waveguide. This waveguide at elf supports a propagation mode similar to the mode existing at v.l.f. between the surface of the earth and the lower boundary of the ionosphere. The similarity in propagation mechanisms leads to the name "inverted ionosphere" described by Wheeler (see Abstr. 2701 of 1961) for the underground region. The sea or relatively highly conducting soil at the surface of the earth is an almost impregnable shield against atmospheric noise and effects from sudden ionospheric disturbances or solar flares. In addition to providing a noise-free medium, the sea has the advantage that construction costs are much less than those of a v.l.f. transmitter at the earth's surface.

CONFERENCE ON PROPAGATION OF ELF ELECTROMAGNETIC WAVES
National Bur. Stands (US), Tech. News Bull. 44, 74-5, May 1960,

THE OMEGA LONG-RANGE NAVIGATIONAL SYSTEM
AD 254 519; U.S. Navy Electronics Lab., San Diego, Calif. Rept.
No. 958, 16 p., illus., 1960.

The Omega Long-Range Hyperbolic Navigation System promises to provide a continuous flow of accurate position-fix information to all U.S. Fleet units, whether they operate under, on, or over the seas. The system has unique capabilities: (1) it is capable of blanketing the world with but seven transmitting stations; (2) it is the only secure means whereby submarines can obtain position fixes while completely submerged in any sea, including the seas beneath polar ice fields; and (3) it is the only system that can be adapted at low cost to transmit communication as well as navigational information, thereby at least doubling the Navy's v.l.f. facilities. Its high relative accuracy makes it uniquely valuable for station keeping, for co-ordinating Fleet manoeuvres, for stationing ships in the far reaches of the oceans, and for pinpointing locations of submarine and aircraft contacts.

ON THE PROPAGATION OF ELECTRIC WAVES FROM A HORIZONTAL DIPOLE OVER THE SURFACE OF THE EARTH SPHERE
Sci. Rep. Res. Inst. Tohoku Univ. Ser. B, V. 1/2, Pgs 25-49, January 1951.
Y. Nomura

The electromagnetic field generated by a horizontal electric or magnetic dipole on or over a finitely conducting spherical surface is considered, and formulas for the magnitude of each of the spherical-co-ordinate components of the electric and magnetic forces are obtained. The field of the horizontal dipole is calculated from that of the vertical dipole. An approximate expression based on optical ray theory is also given.

ON THE THEORY OF ELECTRIC WAVES OVER A PLANE SURFACE OF THE INHOMOGENEOUS EARTH
EE Abstr. 3813/1959; Rep. Res. Insts Elect. Commun. Tohoku Univ., Ser. B, V. 6, No. 1, Pgs 19-30, 1954.
Y. Nomura.

Solves Maxwell's equation for the case of propagation over a land-sea boundary for the general case where receiver and transmitter are not both at ground level. The special case where transmitter and receiver are at ground level is considered and it is shown that the formula derived by Millington is not entirely accurate. The results are generalized to cover the case of propagation over many such boundaries.

ELECTROMAGNETIC-WAVE PROPAGATION OVER A PLANE HOMOGENEOUS EARTH'S SURFACE
Phys. Abstr. 11234/1954; J. Inst. Elect. Commun. Engrs. (Japan), V. 37, Pgs 160-5, March 1954.
Y. Nomura

The saddle-point method is applied to show that the Sommerfeld surface-wave term due to the residue of the pole of the integrand is just cancelled by the part of the integral along the steepest descent through the saddle-point, also that the remaining part of the integral gives the same formula as that of Van der Pol and Niessen, which is the extension of Weyl's solution. The non-existence of the surface wave is attributed to the fact that the ratio of the propagation constants of the air and earth, $|k/k_2|$, is so small that the pole of the integrand lies in the neighbourhood of $\lambda = k$, which is the branch point of $\sqrt{\lambda^2 - k^2}$.

THEORY OF ELECTROMAGNETIC WAVE PROPAGATION OVER PLANAR, INHOMOGENEOUS EARTH'S SURFACE

EE Abstr. 2097/1957; J. Inst. Elect. Commun. Engrs. (Japan), V. 37, No. 6, Pgs 416-20, June 1954.

Y. Nomura

A mathematical analysis for cases such as propagation over sea and land having different propagation constants k_1 and k_2 . A set of formulae is derived consisting of 3 terms which represent, respectively, the ground wave, the sky wave and the refracted wave due to the boundary. These formulae differ according to whether the receiving and transmitting points P and Q are on the same side or on opposite sides of a plane (Q'O) defined by the boundary line O and the image Q' of the point Q. When the receiving point P is on the plane Q'O, the two expressions become identical and give a result equal to the arithmetic mean of the values for the two cases when the surface of the earth consists of homogeneous substances with propagation constants, respectively of k_1 and k_2 . The same holds good when P and Q are both on the surface of the earth and on different sides of the boundary. The results obtained differ from those given by Millington who holds the geometric mean, rather than the arithmetic, to be correct.

THE SUBMERGED RECEPTION OF RADIO FREQUENCY SIGNALS

AD 121 322; U.S. Naval Research Lab., Washington, D.C., Rept. R-1669, 49 p., illus. 1940.

O. Norgorden

No abstract

THE PROPAGATION OF ELECTROMAGNETIC WAVES IN IONIZED GASES (WITH SPECIAL REFERENCE TO "WHISTLERS"). I-II.

Phys. Abstr. 15157/1960; J. atmos. terrest. Phys. (GB), V. 17, No. 1-2, Pgs 158-69, 170-8, 1959.

F. H. Northover

Recent studies lend support to the theory that whistling atmospherics are caused by lightning flashes, the electromagnetic energy radiated by these being guided along discrete columnar ionic irregularities which follow approximately the lines of force of the earth's magnetic field. In Pt. I the theoretical problems arising are set forth and a general wave theory developed which is first applied to the problem of propagation through homogeneous compound streaming media. In Pt II the simplest case of "standard Type" propagation along stationary columns is carefully examined, both for columns with a central ionic surplus and for columns with a central ionic deficiency. Although both types of column, when sufficiently well developed, can guide electromagnetic energy, it appears that the former type is a much more likely mechanism for the whistler propagation than the latter.

TRANSMISSION LOSS IN RADIO PROPAGATION

Proc. IRE, Vol. 41, No. 1, Pgs 146-152, January 1953. Similar material was published as NBS Report 2044, Central Radio Propagation Lab., Nat. Bureau of Standards, 31st October 1952, AD-4970, and Part II, NBS Report 5092, Boulder Laboratories, 25th July 1957, AD-200 639. K.A. Norton

The utility of the concept of the transmission loss in radio propagation analysis is explored. The transmission loss of a radio system is defined to be the ratio of the power radiated from the transmitting antenna to the resulting signal power available from a loss-free receiving antenna. After discussing some methods of measuring transmission loss, its calculation for representative systems is discussed. It is shown that a measure of transmission loss often adopted, namely the attenuation relative to the free-space value, sometimes leads to errors and confusion in the presentation of the results of measurements and in application to radio systems; the use of the over-all transmission loss of a system avoids these pitfalls.

A discussion is given of the expected variation with time (fading) of the transmission loss expected for radio systems involving ionospheric or tropospheric propagation. This discussion involves the theory of Rayleigh distribution and its limitations in such applications.

A definition is then derived for the effective noise figure of a radio system which includes the external noise pickup on the receiving antenna. This definition is used to explain the method of determining the maximum range of a radio system.

Finally a discussion is given of the maximum range of a radio system as limited by interference from other radio signals plus noise rather than from noise alone.

SYSTEM LOSS IN RADIO WAVE PROPAGATION

EE Abstr. 6765/1959; J. Res. Nat. Bur. Stand.(USA), V. 63D, No. 1, Pgs 53-73, July-August 1959. K.A. Norton

A summary is presented of the ways in which the concept of system loss and the closely concepts of transmission loss, basic transmission loss, propagation loss and path aerial gain may be used for precise, yet simple, description of some of the characteristics of radio wave propagation which are important in the design of radio systems. Definitions of various terms associated with the concept of system loss are given which introduce a greater flexibility into its use, without any loss in precision. It is shown that the use of these terms and concepts makes feasible the extension of the use of this method of description to any portion of the radio spectrum. A more general formula for the system loss is given which may be used for aerials with an arbitrary small separation. Using this formula it is shown that the system loss between small electric or magnetic dipoles

separated by a distance $d \ll \lambda$ can be made arbitrarily small even though the individual aeri-als have large circuit losses. Formulae are developed for the percentage of time that a desired signal is free of interference, and these are used to demonstrate methods for the efficient use of the spectrum. In particular, contrary to general belief, it is shown that efficiency is promoted by the use of higher power and high aeri-als and, in the case of a broadcast service, sufficiently small separations so that there is appreciable mutual interference. An analysis is made of the variance of the path aerial gain in ionosphere scatter propagation. Methods are given for the calculation of the transmission loss for the ground wave and tropospheric scatter modes of propagation through a turbulent model atmosphere with an exponential gradient. Examples of such calculations are given which cover a wide range of frequencies and aerial heights. Finally, examples are given of the expected range of various tropospheric point-to-point scatter systems such as an f.m. multichannel system, a television relay or an f.m. broadcast relay.

SYSTEM LOSS IN RADIO-WAVE PROPAGATION

IRE 47, 1661-2, September 1959.
K.A. Norton

POSSIBLE APPLICATION OF THE SYSTEM LOSS CONCEPT AT ELF (EXTREMELY LOW FREQUENCY)

EE Abstr. 5207/1960; J. Res. Nat. Bur. Stand, V. 64D, No. 4, Pgs 413-14, July-August 1960.
K.A. Norton

The system loss L_s is defined as the dimensionless ratio p_t/p_a expressed in decibels, where P_t is the radiofrequency power input to the terminals of the transmitting aerial and p_a is the resultant r.f. signal power available at the terminals of the receiving aerial. A simple T network is described which represents the complete system and it is shown how L_s can be minimized by simultaneous matching of complex input and output impedances. The possible applications of the system loss concept to extremely low-frequencies is described and a method for allowing for the effect of external noise level is outlined.

VLF SPECTRA OF ATMOSPHERICS PROPAGATED THROUGH THE IONOSPHERE

Reports Ionosphere Research Japan, Vol. 12, No. 4, Pgs 478-82 (1958).
T. Obayashi

This note presents results obtained with a radio spectroscop-
e which provides continuous swept-frequency recordings over the ranges
1-10 kc/s and 5-70 kc/s. The statistical distribution of amplitude
with frequency is determined by observation of a large number of
atmospherics, but the spectra of individual atmospherics are not studied.
Examples of the records are reproduced. The daytime spectrum has a

peak at about 15 kc/s; the night spectrum has a main peak at 8-10 kc/s and subsidiary peaks at higher frequencies. An "absorption band" exists at 2-4 kc/s. The observations support the "waveguide mode" theory of ionospheric VLF propagation. Some diurnal variations, and effects observed during a solar flare and associated "SEA", are discussed in terms of mode theory.

AN EXPERIMENTAL PROOF OF THE MODE THEORY OF VLF IONOSPHERIC PROPAGATION
EE Abstr. 4888/59; J. Geomagn. Geoelect. (Japan), V. 10, No. 2,
Pgs. 47-55, 1959.
T. Obayashi, S. Fujii, T. Kidokoro

A new spectroscopy for recording continuously the amplitude-frequency spectrum of v.l.f. atmospherics has been developed. The sweep-frequency receiver gives complete coverage of the band 5-70 kc and the output is displayed on an intensity-modulated cathode-ray tube, which is photographed on a slowly moving film. Observations have been carried out and it appears that the result provides an excellent experimental basis for the mode theory of v.l.f. ionospheric propagation. It is found that the frequency spectrum of distant atmospherics shows a broad intensity maximum around 10 kc and decreases in intensity towards higher frequencies with undulating peaks. Marked selective absorption bands appear in the spectrum and are variable according to the time of day, and they may be associated with cut-off frequencies of the waveguide bounded by the earth and ionosphere. The solar flare effect on v.l.f. atmospherics propagation is also revealed, which indicates a sudden shift of the spectrum to higher frequencies owing to increase of ionization and lowering of reflecting height of the ionosphere.

VERY-LOW-FREQUENCY SPECTRA OF ATMOSPHERICS PROPAGATED THROUGH
THE IONOSPHERE

Phys. Abstr. 2010/1960; Nature (GB), V. 184, Pgs. 34-6, 4th July, 1959.
T. Obayashi

An investigation of very low frequency atmospherics using radio-spectrometers covering the band 1-70 kc/. Observations indicate a region of strong absorption around 2-4 kc and it is noted that a night-time atmospherics have a maximum spectral intensity at about 8-10 kc while the day spectrum has its maximum near 15 kc. These and other data appear to confirm the mode theory of propagation enunciated by Budden and elaborated by Wait.

A NEW SPORADIC LAYER PROVIDING VLF PROPAGATION

EE Abstr. 2023/1961; Inst. Radio Engrs (USA) Trans., V. AP-8,
No. 6, Pgs 621-8, November 1960.

J. Ortner, A. Egeland, B. Hultqvist

During two periods in May and July 1959, following strong solar flares, the signal strength of receptions at Kiruna of v.l.f. transmissions from Rugby (16 kc) showed no, or only slight, diurnal variation. It is proposed that the change of the diurnal variation is due to the production by solar protons of an ionized layer very deep in the atmosphere, the electron density of which is sufficient for reflection of very long waves, but too low to cause measurable non-deviative absorption in the h.f. band at geomagnetic latitudes lower than approximately 60° .

DOES THERE EXIST A ZENNECK WAVE IN THE FIELD OF A TRANSMITTER?

Arch. elekt. Ubertragung (Germany), V. 5, Pgs 15-24, January 1951.
H. Ott.

A thorough mathematical analysis of an old problem concerning the radiation from a dipole placed above a plane earth. Formerly the field was separated into two parts, a "space" wave and a "surface" (Zenneck) wave. After some general remarks, the Hertzian vector of the field is written down and evaluated by a modified saddle-point method (idem, Ann. Phys. Lpz. 43, 393, 1943). Then various properties of the field are deduced, including the tangential and normal components of the electric field. The present treatment is compared with that of previous writers.

NUMERICAL STUDY OF TWEEDS BASED ON THE WAVE-GUIDE MODE THEORY

Proc. Research Inst. Atmospherics, Nagoya Univ. (Japan), Vol. 7,
p. 58, (1960).

J. Outsu

Assuming that the ionospheric reflecting layer is a sharply bounded and imperfect conductor, attenuation factors and group velocities are calculated from the waveguide mode theory developed by Wait.

Results are obtained mainly for the first order mode for four frequencies between 1.8 kc and 2.2 kc with various values of the ionospheric parameter ω_r . And in the case of zero and second order modes calculations are performed only for ω_r of $5 \times 10^7 \text{ sec}^{-1}$ and for wave frequencies less than 2.0 kc and between 3.6 kc and 5.0 kc, respectively. Differences which are caused by regarding an imperfectly conducted layer as a perfectly conducted one, in the determination of distance and height, are discussed.

THE APPROXIMATE LIMITING CONDITION IN THE THEORY OF PROPAGATION OF
RADIO WAVES ALONG THE EARTH

EE Abstr. 4773/1961; Radiotekhnika i Elektronika (USSR), V. 5, No. 3,
Pgs 385-8, March 1960.

A.D. Petrovskii, E.L. Feinberg.

The complex dielectric constant of soil is presented in a modified mathematical form, which makes it possible to extend the existing theories of propagation to soils with comparatively small dielectric constant. This modification is also applicable for rigorous analysis of cases of oblique angle of arrival of the waves. 6 references.

THE PROPAGATION OF RADIO WAVES OF FREQUENCY LESS THAN 1 KC.

Phys. Abstr. 7234/1960; Proc. Inst. Radio Engrs. (USA), V. 48,
No. 3, Pgs 329-31, March 1960.

E.T. Pierce

The simplified mode theory of propagation in a waveguide formed by the earth and a concentric ionosphere of constant height is applied to the experimental observation of Chapman and Macario for the frequency range between 100 and 1000 cps. It is demonstrated that discrepancies between theory and night-time experimental results may be explained by modifying the theory and postulating an effective increase in ionospheric height as frequency decreases. This concept is also shown to be not necessarily incompatible with results for day-time.

ATTENUATION COEFFICIENTS FOR PROPAGATION AT VERY LOW FREQUENCIES (VLF)
DURING A SUDDEN IONOSPHERIC DISTURBANCE (SID)

Phys. Abstr. 5491/1962; J. Res. Nat. Bur. Stand. (USA), V. 65D,
No. 6, Pgs 543-6, November-December 1961.

E.T. Pierce

Attenuation coefficients for propagation under SID conditions are deduced, from records of atmospheric noise, for the frequency range of 3.5 to 50 kc. These are compared with the values under normal day-time circumstances. It is shown that the advent of SID implies little change in attenuation between about 12 and 20 kc; above this range there is a markedly decreased attenuation, while below 12 kc there is an even more pronounced increase in the attenuation coefficients. The principle of an improved recorder of the changes in atmospheric noise associated with SID conditions is outlined; this recorder would discriminate between source effects independent of the SID and propagation influence solely attributable to the SID.

THE DIURNAL CARRIER-PHASE VARIATION OF A 16 KILOCYCLE TRANS-
ATLANTIC SIGNAL

Proc. IRE, Vol. 43, No. 5, Pgs 584-8, May 1955.

J.A. Pierce

The diurnal variation of the time of arrival of a 16 kc signal traversing a transatlantic path has been found to be about 40 microseconds. This variation is presumably caused by a day to night change in the equivalent height of reflection of 10 to 12 km and appears to be very predictable.

The great phase stability of very low frequency transmission permits intercontinental frequency comparison to a precision of at least one part in 10^{10} .

VLF PHASE SHIFTS ASSOCIATED WITH THE DISTURBANCE OF 23RD FEBRUARY 1956.

Phys. Abstr. 4569/1958; J. geophys. Res. (USA), V. 61, No. 3,
Pgs 475-83, September 1956.

J.A. Pierce

During the magneto-ionic disturbances following a solar flare at about 03h 34 min U.T. on 23rd February 1956, the phase of a signal received at Cambridge, Mass., at 16 kc from a transmitter at Rugby, England, was advanced by about 44 μ sec or 250° . The peak Doppler effect on the received frequency occurred at 03h 47 min, and corresponded approximately to a falling of the effective height of reflection at 1km/min, assuming that the phase change was produced solely by a change in height. The record of this phenomenon is contrasted with those made during daytime sudden ionospheric disturbances. It is shown that in the latter case an increase in signal amplitude is observed at 60 kc but not at 16 kc, and that there must be changes in the phase shift at reflection from the ionosphere, as well as changes in the height of reflection. Some comparisons are given between the time of occurrence of this phenomenon and the times of various other effects of this disturbance that have already been reported.

INTERCONTINENTAL FREQUENCY COMPARISON BY VERY LOW-FREQUENCY RADIO
TRANSMISSION

EE Abstr. 4973/1957; Proc. Inst. Radio Engrs (USA), V. 45, No. 6,
Pgs 794-803, June 1957.

J.A. Pierce

Studies of signals from Rugby, England, at 16 kc and 60 kc have given evidence that a single source of standard frequency can be made available at v.l.f. on a world-wide basis. At a distance of 5200 km the Doppler effects in transmission seldom exceed ± 3 parts in 10^9 , and measurements can be made to 1 part in 10^9 in a few minutes. Accuracies exceeding 1 part in 10^{10} are consistently obtained by observation over several hours. Data by Allan, Crombie and Penton, of the New Zealand Dominion Phys. Lab., indicate that at 16 kc the

the diurnal Doppler effects at 18,700 km have normal maxima of the order of $1/10^8$, and that a measurement to 3 Or 4 parts in 10^9 can be made in an hour or less. These results are described and some of the effects of solar flares and magnetic disturbances are discussed. In addition, a brief description is given of four mechanisms that have been found useful in comparing the frequency of a local oscillator with that of a v.l.f. standard transmission.

LOW-FREQUENCY REFLECTION IN THE IONOSPHERE, I.
Phys. Abstr. 1219/1960; J. atmos. terrest. Phys. (GB), V. 12,
No. 2-3, Pgs 126-39, 1958.
H. Poeverlein

A theory of low-frequency reflection in the ionosphere is developed. At wavelengths long compared to the layer of thickness, the ionospheric layer is considered as a thin conductive sheet, that leads to a discontinuity of the electromagnetic field. A thicker layer is subdivided into many thin (or differential) sub-layers. The field is then thought of a superposition of many partial waves, each of which is reflected by an individual sub-layer. An additional penetrating wave must be assumed. At the lowest frequencies (in the case of thin-sheet reflection) the currents in the layer are horizontal E-component. Dielectric-type reflection with sign or phase transition at the Brewster angle is obtained at higher frequencies, if vertical and horizontal current density components are of comparable magnitude. The frequencies under consideration are roughly 1-100kc.

LOW-FREQUENCY REFLECTION IN THE IONOSPHERE. II.
Phys. Abstr. 1220/60; J. atmos. terrest. Phys. (GB), V. 12, No.4,
Pgs 236-47, 1958.
H. Poeverlein

See preceding abstract. Various ranges of data are specified and their reflection characteristics are investigated. Metallic-type reflection is found at high electron concentration and dielectric-type reflection at medium electron concentration above a certain frequency limit. In this latter case, the currents in the ionospheric layer have the direction of the terrestrial magnetic field and the propagation in the layer is very peculiar. Some consequences of the theory are discussed with references to observations where possible. Among them there are statements about phase, sign, and Brewster case and possibilities of transmission through a layer. The final section brings some remarks on the theory, mainly on the field-strength quantities introduced. These quantities allow an interpretation which points at a close relationship to Budden's theory.

LOW AND VERY LOW FREQUENCY PROPAGATION

Fortschritt der Hochfrequenztechnik, Vol. 4, Pgs. 47-101, 1959.
In German. A translation of the paper appears as AFCRC-TR-60-106,
January 1960. AD-237 269.
H. Poeverlein

Observational results and theoretical studies in the field of low and very low frequency propagation are presented. Among the topics covered are propagation between transmitter and receiver, and various types of low and very low frequency noises like spherics, whistlers, and other audio frequency noises. The lower ionosphere and noises at extremely low frequencies are briefly treated. Presentation of the more intricate theories is beyond the scope of this paper, but in several instances the explanation of some phenomenon or propagation characteristic is given in a relatively simple formation.

RESONANCE OF THE SPACE BETWEEN EARTH AND IONOSPHERE

EE Abstr. 6095/1962; J. Res. Nat. Bur. Stand (USA), V. 65D,
No. 5, Pgs 465-73, September-October 1961.
H. Poeverlein

When noise radiation of roughly one or a few kc is emitted in the higher atmosphere, part of it (an extraordinary wave) is propagated downward into the space between earth and ionosphere. Reflection at the earth and ionosphere leads then to a standing wave in this space, whose intensity for a given incident power flux varies very much with frequency. Maximum field strength of the standing wave is derived for the resonance frequencies of the space. The incident wave fronts are assumed to be horizontal. Only clearly defined wave fronts being of sufficiently wide extension and showing no noticeable irregularities will lead to a definite resonance. The space between earth and ionosphere is comparable to an air gap between two parallel plane reflectors. The lower ionosphere is, however, only a partial reflector, allowing radiation to enter the resonance space and causing at the same time loss of energy out of the resonance space (leakage). Stratification of the lower ionosphere has some influence on the resonance phenomena. With a D layer, an additional resonance at a lower frequency is obtained. It seems too early to decide whether in any observed noises the resonance spectrum of the space between earth and ionosphere becomes apparent, but it is expected that noise spectra observed on the ground are modified by the resonances. In case of monochromatic emissions, the received intensity depends on the position in the resonance spectrum. The resonance spectrum should be received in case of emission of a white-noise spectrum, provided the wave fronts are appropriate.

SPACE AND TIME ISOTROPY OF WAVE PROPAGATION

EE Abstr. 2823/1963; Z. angew. Phys. (German), Vol. 14, No. 12,
Pgs 748-51, December 1962, in German.
H. Poeverlein

Study of wave propagation in isotropic and anisotropic media of four dimensions in terms of the four-dimensional propagation vector which represents the group propagation direction in the space-time medium. It is shown that in this case the dispersion equation is also Lorentz invariant.

THE NON-EXISTENCE OF SOMMERFELD'S SURFACE WAVE

CR Acad. Sci. (France), V. 235, Pgs 350-2, 2nd August 1952
P. Poincelot

A source of error in Sommerfeld's analysis is noted, from which it is concluded that the surface wave does not exist.

SCHUMANN RESONANCES OF THE EARTH-IONOSPHERE CAVITY - EXTREMELY LOW FREQUENCY RECEPTION AT KINGSTON, R.I.

EE Abstr. 11352/1962; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 3, 313-8, May-June, 1962.
C. Polk, F. Fitchen.

Since June 1961 magnetic fields of natural origin in the 5 to 20 c/s frequency range have been recorded in Kingston, R.I. The experimental equipment is described briefly, and results are presented. Variations with time of the first resonant frequency of the earth-ionosphere cavity are indicated, and effects of solar activity are discussed. An analysis of the envelope of recorded wave trains shows only fair agreement with existing theory.

THE MEASUREMENT OF THE PHASE VELOCITY OF GROUND-WAVE PROPAGATION AT LOW FREQUENCIES OVER A LAND PATH

EE Abstr. 1682/1953; Proc. Instn Elect. Engrs. (GB), III, V. 100, Pgs 73-84, March 1953.
B.G. Pressey, G.E. Ashwell, C.S. Fowler

Describes the measurement of the change of phase with distance of a 127.5 kc wave over a particular inhomogeneous land path and the deduction of the mean velocity. The measuring system made use of transmissions from stations of the English chain of the Decca Navigator System. It was possible to plot a curve showing the deviation of the measured phase from that calculated on the assumption of a velocity equal to that in free space. The mean velocity deduced for the path was 299230 ± 12 km/sec. The measured change of phase along the path was measured in relation to the profile and geological structure. A high velocity over ground of good conductivity and a low velocity over ground of poor conductivity was clearly shown. Comparisons between the measurements and the phase changes

derived by a method based on theoretical curves of phase lag over homogeneous ground showed good correlation. They also confirmed the theoretical predictions of a characteristic phase disturbance at the boundary between sections of differing conductivity.

THE PHASE VARIATION OF VERY LOW FREQUENCY WAVES PROPAGATED OVER LONG DISTANCES

EE Abstr. 2686/1961; Proc. Inst. Elect. Engrs (GB), Paper 3456E, V. 108B, Pgs 214-26, 1961.

B.G. Pressey, G.E. Ashwell, J. Hargreaves

The proposed use of very low frequency waves (10-20 kc) for navigational aids of the phase-comparison type has led to the study of the phase variations of these waves when propagated over distances up to 6000 km. The particular aspect of this study described in the paper is the relative phase variations over a pair of adjacent paths. Measurements have been made of the variations in the phase difference between the signals received from a single transmitter at two spaced receiving stations. The two principal transmitters used were Varberg, Sweden, on a frequency of 17.2 kc and at a range of 1000 km, and Annapolis, United States, on 15.5 kc at a range of 6000 km. Receiver base-lines, up to 280 km in length, were situated in England and orientated both transverse to, and along the direction of propagation. The observations were made at various seasons, and the results show the extent of the systematic diurnal changes and the random fluctuations; the former were of the order of 30° at the shorter range and 5° at the longer, and the latter had standard deviations at both ranges of the order of 4° in the daytime and 10° at night. It is shown that the magnitude of the random phase fluctuations can be calculated from measurements of the corresponding amplitude fluctuations. In this way data on phase fluctuations at night at intermediate ranges and for receiver spacings up to 2000 km have been obtained. The relationship between the receiver separation and the correlation between fluctuations on two paths has been examined, and is shown how the results of the phase measurements may be applied to the other receiver arrangements.

ATTENUATION OF RADIO FREQUENCY WAVES THROUGH THE EARTH

EE Abstr. 2194/1953; Geophysics (USA), V. 17, Pgs 193-217, April 1952.

W.C. Pritchett

Evidence has been presented by several investigators indicating the possibility that radio waves penetrate sufficiently deep into the earth to be useful in prospecting for oil. Conventional electromagnetic theory used with normal values of the earth constants indicates, however, that the attenuation is too great to allow the signal to be used after propagation through significant distances of shale. To settle the above question the signal level in the earth was measured at various distances from a battery-operated transmitter operating at 1652 kc suspended in an uncased, mud-filled hole by a mud-saturated rope. The mud resistivity was matched to that of the 40-foot thick

shale section used in order that the entire immediate region would be as nearly as possibly homogeneous. The receiver was also battery-operated and suspended by a cable in other similar mud-filled holes at various distances from the first hole. The attenuation constant in shale was found to be 0.231 nepers/ft, (2.31 db/ft), which is much too large to give any hope of deep penetration. A few measurements in a limestone section gave a value of 0.086 nepers/ft, which is also too large to be useful. Although these values are quite high, they are lower than the theory predicts for these earth resistivities by a factor of about two.

SUDDEN CHANGES IN AMPLITUDE AND PHASE OF THE VERY-LOW-FREQUENCY SIGNAL FROM STATION BBR AT SALISBURY, SOUTH AUSTRALIA.

Phys. Abstr. 14780/1963; Nature (GB), Vol. 197, 783, 23 February 1963
P. Rohan, L.L. Anderson, D.J. Cooke

The 16 kc/s GBR transmission was mixed with a local standard frequency to determine frequency drift of the latter over 24-hour periods. On several occasions a marked increase in the beat frequency occurred for approximately half an hour.

A POLAR CAP ABSORPTION ROCKET EXPERIMENT

Phys. Abstr. 20950/1961; Ark. Geofys (Sweden), V. 3, Paper 21, Pgs 455-6, 1961.
D.C. Rose

"Polar cap absorption" symposium paper.

SENSOR CONDUCTIVITY AND ELF/VLF INDICES OF REFRACTION FOR D-REGION
Applied Research Lab., Sylvania Electronic Systems, Waltham 54, Mass.,
Engineering Note dates 31 July 1961.

R.V. Row

No abstract

ON THE ELECTROMAGNETIC RESONANT FREQUENCIES OF THE EARTH IONOSPHERE CAVITY

Phys. Abstr. 7718/1963; IRE Trans Antennas and Propagation (USA), Vol. AP-10, No. 6, Pgs 766-9, November 1962.
R.V. Row

The earth ionosphere cavity is capable of supporting resonant electro-magnetic modes (Schumann modes) at extremely low frequencies. The usual formula for the frequencies of these resonances is deduced from the waveguide mode theory in which propagation is essentially tangential to the earth's surface. Here an alternative formulation in terms of outwardly and inwardly propagating radial waves is presented and shown to result in the same formula as found from the waveguide mode theory for all reasonable D-region ionosphere parameters.

RESULTS OF MEASUREMENT OF FIELD INTENSITY OF VLF WAVES OVER GREAT DISTANCES

J. Radio Res. Lab. (Japan), Vol. 8, No. 40, Pgs 425-39, November 1961. Phys. Abstr. 5391/1963.

A. Sakurazawa, J. Asai, T. Ishii

Field intensities of 18.6 kc/s transmissions from Oso, Washington, were continuously recorded over a period of $1\frac{1}{2}$ years at the Inubo Radio-wave Observatory, and 19.8 kc/s transmissions from Maui, Hawaiian Is., were also recorded during the latter half year. The results obtained are presented graphically and discussed. Minimal intensities were noted at sunrise and at sunset; the intensity was approximately constant at night, increased gradually from the sunrise minimum to a maximum and then decreased to the sunset minimum. In the summer there was an enhancement of intensity about an hour before the sunrise minimum. The fluctuation of intensity during a month was generally < 3 db. The seasonal variations differed for the two transmission paths. The variations can be roughly explained by the attenuation values obtained by integrating the attenuation coefficients along the propagating path on the basis of the waveguide theory in the sharply bounded ionosphere, but various other factors must be considered to explain the sunrise and sunset minima and the enhancement of intensity before sunrise.

INFLUENCE OF SOLAR FLARE ON THE FIELD OF VLF RADIO WAVES PROPAGATED OVER LONG DISTANCES

EE Abstr. 6433/1963; J. Radio Res. Lab. (Japan), Vol. 9, 385-400, September 1962.

A. Sakurazawa, T. Ishii

The strength of NPG signals has been continuously measured at Inubo Radio-Wave Observatory since January 1960. An account is here given of the characteristics of sudden field anomalies observed during 1960. A marked feature of the long-distance propagation considered is that the occurrence and magnitude of the anomalies are related to the time of day. The relation between the occurrence of solar flares and that of anomalies is not good, but when flares and anomalies occur at the same time, there appears to be certain relation between the strength of the flare and the magnitude of the anomaly. If the magnitude of the anomaly is calculated on the basis of the mode theory of vlf ionospheric propagation, the result is obtained that an increase of the ionosphere electron density due to a flare will be of the order of two or three times as much as normal in the case where only the density varies and the reflection height does not vary, but will be of the order of four to seven times greater in the case when the reflection height falls several kilometres.

PRELIMINARY OBSERVATIONS OF ELF ATMOSPHERIC WAVEFORMS

Phys. Abstr. 4774/1964; J. Geomagn. Geoelect. (Japan), Vol. 15, No. 1, 43-5, 1963.

K. Saegusa, H. Jindo, M. Yamashita

The apparatus used for tape-recording and playing back the atmospheric is described briefly and some preliminary records are displayed.

REFLECTION OF ATMOSPHERICS FROM THE IONOSPHERE
Nature (GB), V. 143, No. 3630, 27th May 1939.
Schonland and others

No abstract

THE PROPAGATION OF VERY LONG RADIO WAVES ROUND THE EARTH AND
SIGNALS FROM LIGHTNING

EE Abstr. 750/1954; Nuovo Cimento, (Italy), V. 9, Pgs 1116-38,
December 1952
W.O. Schumann

The theory of the propagation of very long radio waves between
the earth and the ionosphere is developed using Sommerfeld's
"singular eigen-functions". Fourier integration is then applied
to the formulae for the case of electromagnetic radiation from
lightning discharges of various forms.

ON THE PROPAGATION OF VERY LONG ELECTRIC WAVES AND THE WAVE SPECTRUM
OF THE LIGHTNING DISCHARGE

Phys. Abstr. 1787/1953; Note in Naturwissenschaften (Germany), V. 39,
No. 20, Pg. 475; 1952.
W.O. Schumann

Assuming a rectangular impulse, representing the lightning
current, being radiated from an antenna, the propagation of the
resulting waves is evaluated by using Watson's formula (1919)
under consideration of reflections from the ionosphere. This
results in a signal intensity the amplitude of which decreases with
the cube of the distance and which is broadened proportionally to
the square of the distance.

ON THE PROPAGATION ALONG THE EARTH'S SURFACE OF VERY LONG ELECTRIC
WAVES AND THE LIGHTNING DISCHARGE

Phys. Abstr. 6155/1953. Z. angew. Phys. (Germany), V.4, No. 12,
Pgs. 474-80, 1952.
W.O. Schumann

A detailed mathematical derivation is given of the steps
leading to the conclusions previously reported in abstract 1787/1953.
(See abstract immediately above).

ON THE HIGH FREQUENCY FIELD PRODUCED DURING THE PROPAGATION AROUND THE
WORLD OF LONG ELECTRICAL WAVES AND LIGHTNING SIGNALS

EE Abstr. 754/1954; Naturwissenschaften (Germany), V. 40, No. 19,
Pgs 504-5, 1953.
W.O. Schumann

No abstract

ON THE ADDITIONAL FIELD PRODUCED BY PROPAGATION IN THE SYSTEM EARTH-AIR-IONOSPHERE OF LONG ELECTRIC WAVES WITH TWO EXAMPLES (HORIZONTAL AND PERPENDICULAR DIPOLES)

Phys. Abstr. 6744/1954; Z. angew. Phys. V. 6, No. 1, Pgs 35-43, 1954.
W.O. Schumann

A theoretical treatment in which the earth and the ionosphere are treated as poor conductors for wave-lengths greater than 3 km. It is shown that the system has a series of eigenvalues and that waves propagated in this way are heavily attenuated.

ON THE PROPAGATION OF LONG ELECTRIC WAVES ROUND THE EARTH AND CERTAIN APPLICATIONS TO TRANSMITTER INTERFERENCES AND STATIC SIGNALS

EE Abstr. 412/1955; Z. angew. Phys. (Germany), V. 6, No. 3, Pgs 346-52, August 1954.
W.O. Schumann

While the relations for long-wave propagation are well-known, the types received under various meteorological conditions are still largely unknown and, for their elucidation, extensive practical analysis is still required. In an attempt to explain the large value of attenuation occurring, very small admittances of the atmosphere are taken into account for signals having "slow tails", while signals consisting of a long series of reflected impulses require high admittances of the atmosphere and, partly, totally different reflection level. It is shown how on the basis of observed signals, conclusions regarding the nature of electrical discharges can be drawn.

ON THE RADIATION OF LONG WAVES OF A HORIZONTAL DIPOLE IN THE AIR CAVITY BETWEEN EARTH AND IONOSPHERE. I.

Phys. Abstr. 8455/1954; Z. angew. Phys. (Germany), V. 6, No. 5, Pgs 225-9, 1954.
W.O. Schumann

The wave length is considered so long that the ionosphere may be treated as a conductor with known resistance. The mathematical solution of this problem, treating the earth as having finite conductivity, is derived with the aid of the Hertzian potential.

ON THE RADIATION OF LONG WAVES OF A HORIZONTAL DIPOLE IN THE AIR CAVITY BETWEEN THE EARTH AND IONOSPHERE. II.

Phys. Abstr. 10358/1954; Z. angew. Phys. (Germany), V. 6, Pgs 267-71, June 1954.
W.O. Schumann

Continuation of Pt I (see immediately above) and concludes with a comparison of the results of this more general treatment with those obtained by Sommerfeld for the simple case of perfect conducting boundaries.

ON THE INFLUENCE OF THE EARTH'S MAGNETIC FIELD ON THE PROPAGATION
OF VERY LONG ELECTRIC WAVES
EE Abstr. 2933/1955; Naturwissenschaften (Germany), V. 42, No. 4,
Pgs. 91-92, 1955.
W.O. Schumann

A brief note indicating the modifications necessary to previous
work if a radial magnetic field is assumed to exist in the ionosphere.

THE INFLUENCE OF THE EARTH'S MAGNETIC FIELD ON THE PROPAGATION OF
VERY LONG ELECTRICAL WAVES
Z. angew Physik, Vol. 7, pp. 284-90, June 1955. In German.
W.O. Schumann

Analysis is presented in which the ionosphere is regarded as
an anisotropic poor conductor. Ordinary and extraordinary wave
components penetrate the ionosphere travelling normal to the
boundary, with resulting attenuation of and interference with the
components travelling in the waveguide formed by the earth and the
ionosphere. To satisfy the boundary conditions, both an E mode
and an H mode must be propagated in the guide; an original E mode
gives rise to an auxiliary H mode, and vice versa. The ratio of
the horizontal components at the earth's surface of magnetic field
strength perpendicular to and parallel to the propagation direction
is a measure of the relative intensities of the E and H modes.

INFLUENCE OF THE EARTH'S HORIZONTAL MAGNETIC FIELD ON ELECTRIC WAVES
BETWEEN THE EARTH AND IONOSPHERE, WHICH RUN OBLIQUELY TO THE
MAGNETIC MERIDIAN
Z. angew. Physik, Vol. 8, No. 3, pp. 126-7, 1956, in German.
W.O. Schumann

In a continuation of earlier work with waves along and perpend-
icular to the magnetic Meridian it is shown that two independent
waves are possible which, through the two wave types, E and H, are
coupled on account of boundary conditions. Expressions are obtained
for the two waves and their phases and intensities are discussed.
On this theory, the observations of Ratcliffe and others, on thunder-
storms to SE and SW having different wave forms, are attributed, not
to a special property of the distribution, but to the character of
the electric charge, which is different over the ocean from over
the continent.

ON THE CHARACTERISTIC ELECTRIC OSCILLATIONS OF THE CAVITY EARTH-
AIR-IONOSPHERE EXCITED BY LIGHTNING FLASHES
Z. angew. Physik, Vol. 9, No. 8, pp. 373-8, August 1957, in German.
W.O. Schumann

Previous work is continued. Allowance is made for the effect
of the earth's magnetic field and it is shown that signals due to
this cause will be much weaker by night than by day.

ON THE PROPAGATION OF ELECTRICAL WAVES ALONG A DIELECTRICALLY
BOUNDED PLASMA LAYER WITH A LONGITUDINAL MAGNETIC FIELD
Z. angew. Physik, Vol. 10, No. 1, pp. 26-31, January 1958, in
German.
W.O. Schumann

When the electron cyclotron freq. ω is smaller than the plasma
freq. ω_0 , a possible wave-type is found which starts at $w = 0$ with
the phase velocity c and ends at $w^2 = (\omega^2 + w^2)/2$ with the phase
velocity zero. If $\omega > w$ this type remains unchanged, from $w = 0$
to $w = \omega_0$; for $w > \omega_0$ there can be no propagation.

SHORT TERM PHASE PERTURBATIONS OBSERVED AT 18 KC/S
J. Geophys. Research, Vol. 66, No. 10, pp. 3601-3602, October 1961.
C.F. Sechrist, Jr. and K.D. Felperin

The purpose of this letter is to report on the observation at
State college of small, short-term phase fluctuations, on the 18 kc/s
signal transmitted from NBA, Balboa, Panama Canal Zone, a north-south
propagation path length of 3500 km.

Apart from the usual sunrise and sunset changes of phase, our
records show quasi-sinusoidal phase changes with periods in the range
10 to 20 secs. and amplitudes of 2° to 6° . These have been observed
in the daytime but not during the night, making it extremely unlikely
that they are produced by instrumental variations.

VERY LOW FREQUENCY PHASE PERTURBATIONS OBSERVED DURING GEOMAGNETIC
STORMS
Phys. Abstr. 20162/1962. J. geophys. Res. (USA), Vol. 67, No. 4,
1685-6 (April 1962)
C.F. Sechrist, Jr.

Reports observations of short-term phase perturbations in a signal
received at 18 kc/s. These only seem to occur during geomagnetic
storms and could be due to ionospheric height changes of between
200 and 500m.

A LOW FREQUENCY LONG RANGE PROPAGATION PROBLEM
Paper presented at IRE-URSI Symposium, Washington DC, 2-5 May, 1955.
J. Shmoys

With the variation of electron density and collision frequency
assumed exponential, the propagation constants of the first few modes
of propagation of low frequency radio waves have been calculated.
A simple relation between group velocity and angle of arrival has
been derived. The validity of this analysis in the case of vertically
polarized waves will be discussed. Similarities and differences
between ray and wave treatment of the problem will be pointed out.

LONG RANGE PROPAGATION OF LOW FREQUENCY RADIO WAVES BETWEEN THE
EARTH AND THE IONOSPHERE

Proc. IRE, Vol. 44, No. 2, pp. 163-70, February 1956.

J. Shmoys

The problem of modes of propagation of electromagnetic waves between a perfectly conducting earth and a gradually varying ionosphere is considered. The case of exponentially varying ionospheric parameters is solved in terms of Bessel functions. The propagation constant, the angle of arrival and the group velocity are calculated for the first few modes of propagation. It is shown that the order modes obtained when the ionosphere is assumed to be a perfectly conducting sheet at a height simply related to ionospheric parameters are very close to the true values. An application of this theory to the propagation of "tweeks" is discussed.

SOME STATISTICAL THEORY FOR THE ANALYSIS OF RADIO PROPAGATION DATA

Phys. Abstr. 502/63; J. Res. Nat. Bur. Stand. (USA), Vol. 66D,
No. 5, 571-80, September-October 1962.

M.M. Siddiqui

The statistical theory of stationary processes has wide applications in the analysis of radiowave propagation data. Assuming knowledge of the basic concepts of probability theory, characteristics of stationary processes such as covariance and spectral density functions were developed, problems of estimating these characteristics were tackled, and numerous examples were worked out to illustrate the theory.

TRANSMISSION COEFFICIENTS FOR ELECTROMAGNETIC PLANE WAVE RADIATION
INTO A CONDUCTING HALF-SPACE

AD 268 424; University of New Mexico, Albuquerque, New Mexico.
Technical Report EE-60, November 1961.

E.B. Simmons

This paper deals with the transmission of uniform plane waves from the air into a highly conductive medium such as sea-water. Exact and approximate equation describing the transverse electric and transverse magnetic cases are derived and results interpreted. Graphs of the transmission coefficients versus the angle of incidence at specific frequencies are included.

CALCULATION OF THE ELECTRON DENSITY OF THE OUTER IONOSPHERE
USING WHISTLERS

To be submitted to: J. Res. Nat. Bur. Stand (USA), Section D,
Radio Propagation

R.L. Smith, R.A. Helliwell.

No abstract.

MODE CALCULATIONS FOR VLF PROPAGATION IN THE EARTH-IONOSPHERE
WAVEGUIDE

Nat. Bur. Stand. (USA), Technical Note No. 114, 17th July 1961.
K.P. Spies, J.R. Wait.

The concept that radio waves are channeled between the earth and the ionosphere as in a waveguide has been very useful at VLF (Budden, 1953; Al'pert, 1956; Wait, 1957). Unfortunately, the computational aspects of the problem are quite complicated even when the model is highly idealized. The difficulty stems from the grazing nature of the modes of lowest attenuation. Some progress has been made recently by utilizing higher order approximations for the various spherical wave functions which enter into the problem. In this way the influence of earth curvature has been fully accounted for. The detailed theoretical aspects and essential derivations have been presented elsewhere (Wait 1960-61). Here the actual computational procedure is outlined and some numerical results are presented. It is believed that the methods used are of general interest and also have possible application to propagation of acoustic and seismic waves in curved layered media.

LAYERED EARTH PROPAGATION IN THE VICINITY OF POINT BARROW, ALASKA.

J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 95, January 1960.
G.M. Stanley

The relative field strength of a vertically polarized low frequency radio signal was measured as a function of distance over several radial paths in the vicinity of Point Barrow, Alaska. The attenuation of the recorded signal was very much less than predicted by the theory of propagation of a ground wave signal over a plane, homogeneous, infinitely conducting earth. The analysis of these data in terms of a plane, layered, finitely conducting earth appears to resolve the anomaly.

THE IONOSPHERIC PROPAGATION OF RADIO WAVES OF FREQUENCY 16 KC OVER
SHORT DISTANCES

EE Abstr. 789/1955; Proc. Instn. Elect. Engrs. (GB), Monogr.
No. 114R, 12 p., January 1955.
T.W. Straker

A continuation of earlier investigations by Best, Budden, Ratcliffe, and Wilkes (1936-9) on the ionospheric propagation of radio waves of frequency 16 kc emitted from the Post Office sender GBR at Rugby, and observed at Cambridge, 90 km away. The apparent height of reflection usually varied regularly and predictably with the zenith angle of the sun. The total change of height in passing from midday to midnight was 16.8 km in summer and 13.5 km in winter. There was a marked seasonal variation of the amplitude of the downcoming wave, the variation of the daytime amplitude being different from that

of the night-time amplitude. There was no clear evidence of waves reflected twice from the ionosphere. During and after great magnetic storms the diurnal variation of the height of reflection was markedly abnormal, the abnormality lasting for as long as 10 days after the end of the magnetic disturbance. Anomalous behaviour of a less violent nature was frequently observed both by day and by night.

SWEEP-FREQUENCY PULSE-TRANSMISSION MEASUREMENTS OVER A 2400 km PATH
J. Geophys. Research 60, 411-420, December 1955.
P.G. Sulzer

VERY LOW FREQUENCY RADIO PROPAGATION IN THE IONOSPHERE
Phys. Abstr. 5859/63, J. Res. Nat. Bur. Stand (USA), Vol. 66D,
No. 6, 663-80, November-December 1962.
D.W. Swift

Equations describing the propagation of radio waves in a horizontally stratified anisotropic ionosphere were developed by considering the limiting case of a large number of infinitesimally thin slabs of constant electron density and collision frequency. The quasi-longitudinal approximation was used. The propagation equations appeared as four coupled first-order linear differential equations, coupled by gradients in electron density and collision frequency. The quasi-longitudinal approximation permitted use of particularly simple forms for the coupling coefficients, these forms being amenable to simple analysis. Coupling between two ordinary or two extraordinary modes was found to be considerably stronger than cross coupling between ordinary and extraordinary modes. Cross coupling was related to the rate of change of the direction of the phase normal. It was found that the reflection of vlf radio waves from the daytime ionosphere is relatively insensitive to the angle of incidence on the ionosphere except for highly oblique propagation. Whistler penetration was also found to be insensitive to the angle of incidence on the ionosphere.

PROPAGATION OF ELECTROMAGNETIC WAVES IN A SEMI-INFINITE CONDUCTING MEDIUM
EE Abstr. 7608/1960; Arch. Elektrotech. (Poland), V. 8, No. 1,
Pgs 103-21, 1959.
P. Szulkin

Examines the problem of radiation of a vertical electric dipole in a conducting medium along a boundary plane with a lossless medium. The electromagnetic field is calculated explicitly for the assumed propagation model and the defined boundary values.

SOME CHARACTERISTICS OF VLF PROPAGATION USING ATMOSPHERIC WAVEFORMS

In recent advances in atmospheric electricity; Proceedings of the Second Conference on Atmospheric Electricity, held at Portsmouth, N.H., 20th-23rd May 1958, pp. 609-17. New York, Pergamon Press, 1958. W.L. Taylor and L.J. Lange

VLF ATTENUATION FOR EAST-WEST AND WEST-EAST DAY-TIME PROPAGATION USING ATMOSPHERICS

Phys. Abstr. 16488/1960; J. Geophys. Res. (USA), V. 65, No. 7, Pgs. 1933-8, July 1960. W.L. Taylor

Day-time attenuation characteristics were computed by comparing the amplitude spectra of atmospheric waveforms recorded at four widely separated stations. The results of these attenuation measurements are presented for the band of frequencies from 3 to 30 kc and involving distances of 1,000 to 10,000 km. Non-reciprocity is evident from this study. Attenuation rates over sea water for east-to-west propagation were about 3 db/1000 km greater for frequencies below 8 kc, and about 1 db/1000 km greater for frequencies above 10 kc than for west-to-east propagation. East-to-west attenuation rates over land were about 1db/1000 greater than for over sea water.

DAY-TIME ATTENUATION RATES IN THE VERY LOW FREQUENCY BAND USING ATMOSPHERICS

Phys. Abstr. 12716/1960; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 4, Pgs 349-55, July-August 1960. W.L. Taylor

Day-time attenuation characteristics have been computed by comparing the amplitude spectra of atmospheric waveforms recorded at four widely separated stations. The results of these attenuation measurements are presented for the band of frequencies from 3 to 30 kc and involving distances of 1,000 to 10,000 km. It was found from these data that attenuation was about 7 to 9 dB per 1,000 km at 6 kc and decreases to about 1 to 3 dB per 1,000 km at frequencies greater than 10 kc. The difference in attenuation rate of west-to-east propagation relative to east-to-west propagation was about 3 dB per 1,000 km less for frequencies lower than 8 kc and about 1 dB per 1,000 km less from frequencies higher than 10 kc.

A LAYERED MODEL APPROACH TO THE EARTH-IONOSPHERE CAVITY RESONANCE
PROBLEM

Project NR-371-401, 15th June 1963, Geophysics Lab., Massachusetts
Inst. of Technology.

W.B. Thompson

The purpose of this investigation is to define a satisfactory mathematical model to predict the character and propagation properties of the ELF resonant waves in the spherical cavity bound by the earth and ionosphere. The study of the modes of this cavity offers a useful geophysical tool for observation of the gross properties of the lower ionosphere, which comprises one wall of the cavity. The model uses real ionospheric parameters in the presence of the earth's geomagnetic field, which makes the conductivity anisotropic. The mode structure as observed at the earth's surface is affected by the conductivity of the ionosphere to varying heights.

THE PROPAGATION OF EM WAVES IN A PARALLEL PLATE MEDIUM, THE PLATES
OF WHICH ARE ARBITRARILY THICK AND LOSSY

EE Abstr. 9256/1962; Arch. elekt. Ubertragung (Germany), Vol. 16,
42-50, January 1962, in German.

P. Thust

From the basic equation for the propagation coefficient various approximations and sets of curves for different frequency bands and geometrical dimensions are derived. The basic equation also gives the case of "free space propagation", "guided waves" and "skin effect in an infinite sheet of metal" if proper conditions and values are used. Attenuation-frequency characteristics of the various modes are also considered. 10 references.

ON DISCONTINUOUS ELECTROMAGNETIC WAVES AND THE OCCURRENCE OF A
SURFACE WAVE

Trans. Inst. Radio Engrs (USA), V. AP4, p. 288, 1956.

B. van der Pol

No abstract.

ON THE PROPAGATION OF A DISCONTINUOUS ELECTROMAGNETIC WAVE

Proc. Ned. Akad. Wetensch. (Netherlands), V. 53, No. 3, Pgs. 254-265,
1960.

B. van der Pol, A.H.M. Levelt

A treatment of a variant of Sommerfeld's problem is made in which the oscillating dipole is replaced by a dipole whose moment jumps from zero to one. A solution for the general case in terms of complete elliptic integrals is given.

MODES IN LOSSY STRATIFIED MEDIA WITH APPLICATION TO UNDERGROUND PROPAGATION OF RADIO WAVES

EE Abstr. 1189/1964. IEEE Trans Antennas & Propagation (USA), Vol. AP-11, No. 3, Pgs 318-23, May 1963.
M.E. Viggh

The problem considered is that of determining the complex propagation constant of a plane wave on a flat layer of lossy dielectric with a loss-tangent of less than one, and of uniform thickness, surrounded on both sides by identical layers having a loss-tangent greater than one, and thicknesses much larger than the skin depth. A formula given, relates this propagation constant to the path loss between two aeri-als provided their excitation efficiencies are known. As an example, curves showing attenuation and wavelength are given for the following properties of the layers:

$$\begin{aligned} \text{Middle layer} &= \sigma = 10^{-6} \text{ (ohm meter)}^{-1}, \epsilon_r = 10, \mu_r = 1. \\ \text{Surrounding layers} &= \sigma = 10^{-2} \text{ (ohm meter)}^{-1}, \epsilon_r = 10, \mu_r = 1. \end{aligned}$$

Frequencies between 1 kc/s and 10 Mc/s are covered, as well as values on thickness of the middle layers ranging from 10m-200m.

ON THE THEORY OF PROPAGATION OF VLF WAVES

Technischer Bericht 33, Heinrich-Hertz-Institute, Berlin-Charlottenburg (1959), Trans. 945, Royal Aircraft Establishment, Gt. Britain, May 1961, AD-259 788
H. Volland

After a discussion of the usefulness of a model ionosphere having a sharply limited lower edge and constant conductivity for the propagation of very long radio waves (λ of an order of magnitude of 10km) and an estimate of the effect of the earth's magnetic field the wave theory and the ray theory of the propagation of very long waves are developed and compared. The effect of the earth's curvature is discussed and by means of an example the agreement of both theories is shown in the region of overlapping of their areas of validity (300-2000 km distance from the place of transmission).

ON THE DIURNAL PROPAGATION OF VLF WAVES AT A DISTANCE OF 1000 KM

Technischer Bericht 37, Heinrich-Hertz-Institut, Berlin-Charlottenburg (1960). Trans. 944 Royal Aircraft Establishment, Great Britain, May 1961, AD-259-787.
H. Volland.

The one-year measured results of the recording of the field intensity of the British VLF transmitters GBZ (19.6 kc) and GBR (16 kc) are summarized. An attempt is made to interpret their behaviour during the day by means of propagation theories. The anomalies in the VLF field intensity in the case of solar eruptions are quantitatively compared with Moegel-Dellinger effects and solar radio radiation, and a profile of the electron density of the lower limit of the ionosphere is derived.

COMPARISON BETWEEN MODE THEORY AND RAY THEORY OF VLF PROPAGATION
EE Abstr. 4789/1961; J. Res. Nat. Bur. Stand. (USA), Vol. 65D,
No. 4, Pgs 357-61, July-August 1961.
H. Volland

It is shown that the field strength according to mode theory and ray theory in the v.l.f. band are derivable from the same expression of the original vector potential, and the result of one theory is the analytic continuation of the other one in another range of convergence. In fact, both ranges of convergence overlap. Estimates of these ranges are made and an example shows that within this overlapping region (between distances of 300 and 2000 km) both theories give the same result. Using this fact calculations of frequency spectra are possible which in the case of a white noise dipole show some similar features to measured frequency spectra of lightning discharges.

AUSBREITUNG ELEKTROMAGNETISHER FELDER IN SEEWASSER (PROPAGATION OF ELECTROMAGNETIC FIELDS IN SEA WATER)

ATI No. 38427, Microfilm, 13 p., 1944; an English translation; copies obtainable from Air Documents Division, attn: MCLDXD, Wright Patterson Air Force Base, Dayton, Ohio.
K.W. Wagner

As a basic step in research covering the propagation of electromagnetic fields in bodies of sea water, the propagation of sine waves with a theoretically limitless space was analyzed. Dipole movements were analyzed by means of Maxwell's electromagnetic equation and expressed in vector notations. The Biot-Savart law was applied to the electromagnetic field of the coil, and the intensitivity of the magnetic field was determined. It was found that when dipoles and coils are used to produce an electromagnetic field only very low frequencies of simple impulses are practical, while high frequencies, showing too much damping, cannot be used for telecommunications in sea water. The wave reflected from the water surface was not calculated exactly but was estimated for simplification. Further research is necessary before final conclusions can be drawn.

EFFECT OF A LARGE DIELECTRIC CONSTANT ON GROUND-WAVE PROPAGATION
Canad. J. Phys., V. 31, Pgs 456-457, March 1953
J.R. Wait, L.L. Campbell

Curves relating field strength and distance from transmitter at 200 kc are given for values of permittivity between 2 and 200. For ground conductivities of $< 1.0 \times 10^{-14}$ e.m.u. the field strength can vary by a factor of as much as 100 according to the value of permittivity taken.

PROPAGATION OF RADIO WAVES OVER A STRATIFIED GROUND
Geophysics, (USA), V. 18, Pgs 416-422, April 1953.
J.R. Wait

The propagation of vertically polarized radio waves over a horizontally stratified medium is investigated. A general expression for the "wave tilt" is derived for the case of any number of layers with arbitrary properties in each layer. Numerical calculations are carried out for the special case of only two layers which show that the conductivity and dielectric constant variations of the lower layers will affect the magnitude and phase of the wave tilt.

TRANSMISSION CURVES FOR GROUND WAVE PROPAGATION AT LOW RADIO
FREQUENCIES
Def. Res. Tele. Est., Radio Physics Lab., Ottawa, Canada, rept. R-1,
April 1953.
J.R. Wait, L.L. Campbell

A study is made of the propagation of radio waves over the surface of the earth in relation to the electrical constants of the ground. The work of Norton and Bremmer is applied and extended in making charts showing the field strength at distances up to 2000 miles from a transmitter for frequencies in the range 15 to 500 kc. A wide range of values for the conductivity and dielectric constant of the ground is chosen. The effect of a large dielectric constant of the ground is seen to modify considerably the magnitude of the field strength. The effect of raising the transmitting or receiving antenna above the ground is illustrated by curves of a height-gain function. The phase of the ground wave is also considered.

AN EXTENSION TO THE MODE THEORY OF VLF IONOSPHERIC PROPAGATION
J. Geophys. Res., (USA), V. 63, No. 1, Pgs 125-135, March 1954.
J.R. Wait

The wave-guide mode theory of VLF propagation for a sharply bounded homogeneous ionosphere is defined to include stratification at the lower edge of the ionosphere. The numerical results for a two-layer model are discussed in detail. By choosing the upper medium to have

a conductivity with a factor of 10 greater than the lower medium, the attenuation vs. frequency characteristic of the model is consistent with experimental data from 1.0 to 20 kc. The effect of the finite thickness of E layer, important for frequencies less than 1.0 kc, is treated by an ionospheric model which has a sharp lower edge and an exponential taper to zero at greater heights.

NOTE ON THE THEORY OF RADIO PROPAGATION OVER AN ICE COVERED SEA
Def. Res. Tele. Est., Radio Physics Lab., Ottawa, Canada, Project
rept. 18-0-7, 31st March 1954.
J.R. Wait

A preliminary theoretical analysis is outlined for the problem of a vertical dipole radiating over a two layer medium where the upper stratum is a low-loss dielectric. It is shown that a zero-order T.M. wave guide mode can be set up in the dielectric. The possibility of such a phenomenon occurring over an ice-covered sea is discussed. It is pointed out that the attenuation due to dielectric losses in the ice and the finite conductivity of the sea water would be at least 10db per kilometer at 15 Mc for a three foot thickness of ice.

ON ANOMALOUS PROPAGATION OF RADIO WAVES IN EARTH STRATA
Geophysics (USA), V. 19, April 1954.
J.R. Wait

No abstract

THEORY OF ELECTROMAGNETIC SURFACE WAVES OVER GEOLOGICAL CONDUCTORS
Geof. p. e Appl. (Italy), V. 28, Pgs 47-56, 1954.
J.R. Wait

The radiation fields of a vertical electric antenna situated on a horizontally stratified ground are discussed. The attenuation and "wave-tilt" of the surface wave and the "height-gain" factor are shown to be a function of the horizontal stratification in the ground. It is possible that the results have application to an airborne geophysical exploration scheme.

MULTIPLE REFLECTIONS BETWEEN THE EARTH AND THE IONOSPHERE IN VLF
PROPAGATION
Geof. p. e. Appl. (Italy), V. 35, Pgs 61-72, 1956.
J.R. Wait, A. Murphy

Treating the ionosphere as a sharply bounded medium, sky wave field intensities are calculated by geometrical-optical methods for very low radio frequencies. The reflection coefficients are discussed in some detail and the numerical data are compared with experiment.

AMPLITUDE AND PHASE CURVES FOR GROUND-WAVE PROPAGATION IN THE BAND 200 CYCLES PER SECOND TO 500 KILOCYCLES
Nat. Bur. Stand. (USA), Circular No. 574, May 1956.
J.R. Wait, H.H. Howe.

After making several extensions to the formulas of van der Pol and Bremmer, field strength and phase values of the very low frequency ground wave from a short vertical antenna are computed. The ground conductivity values chosen are 4, 0.01, and 0.001 mho per meter. The distances considered range from 1 to 1,500 miles.

MIXED PATH GROUND WAVE PROPAGATION: 1. SHORT DISTANCES
J. Res. Nat. Bur. Stand (USA), V. 57, No. 1, Pgs 1-15, July 1956.
J.R. Wait

An expression is derived for the mutual impedance between two short vertical antennas on a flat earth with a straight boundary separating two media of differing electrical constants. After making some approximations that are valid at low and medium frequencies and where the antennas are not near the boundary, the integral formula for the field is evaluated for a wide range of parameters. The numerical results computed in this paper are shown to be in reasonably good agreement with experiment. Finally, the effect of the obliqueness of the boundary is considered by a refinement of the stationary phase evaluation of the integrals.

ON THE THEORY OF REFLECTION FROM A WIRE GRID PARALLEL TO AN INTERFACE BETWEEN HOMOGENEOUS MEDIA.

Appl. Sci. Research B. 6, Pgs 259-275, 30th July 1956.
J.R. Wait

No abstract

THE WAVEGUIDE MODE THEORY OF VLF IONOSPHERIC PROPAGATION
EE Abstr. 4293/1957; Proc. Inst. Radio Engrs (USA), V. 45, No. 1,
Pg 95, January 1957.
J.R. Wait, H.H. Howe

Assuming that for frequencies of the order of 16 kc and less the ionosphere can be regarded as a sharply bounded isotropic medium, if only the vertically polarized field at large ranges is considered, an equation is obtained for finding the possible modes in the parallel-plate waveguide bounded by the earth and the ionosphere. Calculations based on this equation enable the attenuation rate to be plotted as a function of the reciprocal of the ionospheric conductivity for the first four modes, particular values being assigned to various ionospheric and ground parameters. The attenuation for the zero-order mode becomes

prohibitively high for the larger values of L , a factor proportional to the reciprocal of the conductivity of the ionosphere. At 16 kc L is of the order of 0.4 for the daytime and somewhat less for the night. In the range from $L = 0.1$ to 4 and higher the dominant mode is of order one and not zero, as is commonly supposed. The effect of ground conductivity is shown in a diagram giving the attenuation rate for the mode of order one as a function of L for 3 different values of ground conductivity. Detailed calculations of the attenuations and phase constants of the modes for larger orders and for a range of ionospheric heights and frequencies are to be published later.

THE GEOMETRICAL OPTICS OF VLF SKY WAVE PROPAGATION

VLF Symposium Paper No. 5, Boulder, January 1957, Proc. Inst. Radio Engrs (USA), V. 45, No. 6, Pgs. 754-760, June 1957.

J.R. Wait, A. Murphy

At distances not exceeding 1500 km, it is convenient to calculate the field strength of a vlf transmitter by geometrical optics. In such computations, it is usual to assume some equivalent height for the (ionospheric) reflecting layer with a reflection coefficient that does not vary with angle of incidence. In the present paper, the ionosphere is taken to be a homogeneous ionized medium with a sharp lower boundary. The reflection coefficient, which is a function of angle incidence, is utilized to compute the strength of the single and multiple hop sky waves. Combining these with the numerical results of the amplitude and phase of the ground wave, the total field is obtained. The theoretical field-strength-vs-distance curves compare favourably with the experimental data of Heritage for frequencies of 16.6, 18.6 and 19.8 kc over daytime paths in the Pacific Ocean. Finally, diffraction by the earth's bulge of the first hop sky wave is considered. This effect is important at ranges greater than 1200 km or so.

THE MODE THEORY OF VLF IONOSPHERIC PROPAGATION FOR FINITE GROUND CONDUCTIVITY

VLF Symposium Paper No. 6, Boulder, January 1957. Proc. Inst. Radio Engrs (USA), V. 45, No. 6, Pgs. 760-767, June 1957.

J.R. Wait

The space between the earth and the ionosphere is considered as a waveguide with sharply bounded walls. Employing a representation in terms of spherical wave functions of complex order, the field of a vertical dipole source is calculated for very low frequencies. It is shown that the effect of the finite conductivity of the ground is quite important for propagation to great distances. Good agreement is obtained with the experimental results of J. Heritage.

CALCULATIONS OF IONOSPHERIC REFLECTION COEFFICIENTS AT VERY LOW RADIO FREQUENCIES

J. geophys. Res. (USA), V. 62, No. 1, Pgs 43-56, March 1957.
J.R. Wait, L.B. Perry

A set of calculated curves are presented for the reflection coefficients at a sharply bounded homogeneous ionized medium with a superimposed magnetic field. The results are plotted parametrically to permit general comparisons with experimental data. Both steady-state and transient cases are considered.

AMPLITUDE AND PHASE OF THE LOW-FREQUENCY GROUND WAVE NEAR A COASTLINE.

J. Res. Nat. Bur. Stand (USA), V. 58, No. 5, Pgs 237-242, May 1957.
J.R. Wait

A theoretical analysis is given for the amplitude and the phase of the ground wave, originating from a distant transmitter on land, as it crosses a coastline. The land and sea are assumed to be smooth, and homogeneous with a sharp boundary of separation. Attenuation is focused on the effects that take place near the coastline when it is not permissible to employ arguments based on the principle of stationary phase. A limited comparison is made with the recent experimental work of Pressey, Aswell, and Fowler.

MIXED-PATH GROUND WAVE PROPAGATION: 2. LARGE DISTANCES

J. Res. Nat. Bur. Stand (USA), V. 59, No. 1, Pgs 19-26, July 1957.
J.R. Wait, J. Householder

The theoretical results are given in part I (NBS Research Paper No. 2687) for ground wave propagation over a mixed path on a flat earth are generalized to a spherical earth. The problem is formulated in terms of the mutual impedance between two vertical dipoles which are located on either side of the boundary of separation. Extensive numerical results are given in graphical form for a mixed land-sea path at frequencies of 10, 20, 50, 100, and 200 kilocycles per second.

THE ATTENUATION VS FREQUENCY CHARACTERISTICS OF VLF RADIO WAVES

Proc. Inst. Radio Engrs (USA), V. 45, No. 6, Pgs 768-771, June 1957.
J.R. Wait

The theoretical dependence on frequency of the attenuation of the wave guide modes in vlf propagation is discussed in some detail. It is indicated that most of the published experimental data between 1 and 30 kc was compatible with the sharply bounded model of the ionosphere with a reflecting height of about 70 km during the day and 90 km during the night.

ON THE MODE THEORY OF VLF IONOSPHERIC PROPAGATION
Geof. p. a Appl. (Italy), V. 37, Pgs 103-115, 1957.
J.R. Wait

The space between the earth and the ionosphere is considered as a wave-guide with sharply bounded walls. Employing a representation in terms of spherical wave functions of complex order, the field of a vertical dipole source is calculated for very low frequencies. It is shown that the dominant mode for 16 kc is of order one and not zero as has been commonly supposed. Good agreement is obtained with the experimental results of J. Heritage.

A NOTE ON THE PROPAGATION OF THE TRANSIENT GROUND WAVE
Canad. J. Phys. V. 35, Pgs 1146-1151, 1957
J.R. Wait

No abstract

PROPAGATION OF A PULSE ACROSS A COAST LINE
Proc. Inst. Radio Engrs (USA), V. 45, No. 11, 1 p., November 1957.
J.R. Wait

No abstract

ON THE THEORY OF PROPAGATION OF ELECTROMAGNETIC WAVES ALONG A CURVED SURFACE
Canad. J. Phys., V. 36, Pgs 9-17, 1958.
J.R. Wait

The problem of propagation of vertically polarized waves along a surface whose curvature and electrical properties have a discontinuity is considered. The mutual impedance Z between two short vertical antennas on either side of the boundary of separation is considered to be the fundamental quantity which is sought. By utilizing the principle of stationary phase and the concept of surface impedance, an approximate expression is derived for Z . It is shown that to a first order of magnitude, the effects of the conductivity contrast and curvature change are additive corrections to the mutual impedance between dipoles over a single homogeneous spherical surface.

TRANSMISSION AND REFLECTION OF ELECTROMAGNETIC WAVES IN THE PRESENCE OF STRATIFIED MEDIA
J. Res. Nat. Bur. Stand. (USA), V. 61, No. 3, Pgs 205-232, September 1958.
J.R. Wait

A general analysis is presented for the electromagnetic response of a plane stratified medium consisting of any number of parallel

homogeneous layers. The solution is first developed for plane-wave incidence and then generalized to both cylindrical and spherical-wave incidence. Numerical results for interesting special cases are presented and discussed. The application of the results to surface-wave propagation over a stratified ground is considered in some detail.

A STUDY OF VLF FIELD STRENGTH DATA: BOTH OLD AND NEW
Geof. p. a Appl. (Italy), V. 41, Pgs 73-85, 1958/III.
J.R. Wait

Employing some old data of Round et al, and the recent data of Heritage et al, attenuation rates at VLF are deduced. For middle latitudes, daytime rates of less than 2 db per 1000 km of path length are not uncommon. These are in general accord with values derived from spheric waveforms and they are compatible with mode theory. An extensive bibliography is appended.

TRANSMISSION LOSS CURVES FOR PROPAGATION AT VERY LOW RADIO FREQUENCIES
Inst. Radio Engrs (USA) Trans. on Communications Systems, Pgs 58-61,
December 1958.
J.R. Wait

Curves of the transmission loss are presented for the propagation to great distances at frequencies in the range 10 to 20 kc. The theoretical model of the ionosphere assumed is a sharply bounded homogeneous ionized medium. The working formula for the field is a sum of waveguide type modes. The calculated results compare favourably with experimental data at 16.6 kc over the Pacific Ocean.

DOWNCOMING RADIO WAVES
Electronic and Radio Engr (GB), V. 36, No. 3, Pgs, 106-107, March 1959.
J.R. Wait

No abstract

TRANSMISSION OF POWER IN RADIO PROPAGATION
Electronic and Radio Engr. (GB), V. 36, No. 4, Pgs 146-150, April 1959.
J.R. Wait

Some remarks concerning the theoretical foundations of the transmission loss concept are made. It is emphasized that the influence of the ground on the input resistances of the transmitting and receiving aerials must be accounted for.

DIURNAL CHANGE OF IONOSPHERE HEIGHTS DEDUCED FROM PHASE VELOCITY
MEASUREMENTS AT VLF

EE Abstr. 5565/1959; Proc. Inst. Radio Engrs (USA), V. 47, No. 5(I),
P. 998, May 1959.

J.R. Wait

Recent v.l.f. propagation results indicate that the carrier phase-shift occurring is directly proportional to the length of the path which is in daylight. Calculations based on a simple theoretical model indicate corresponding diurnal changes of effective reflection height which are in agreement with observation.

PREPUBLICATION OF PAPERS ON SURFACE WAVES TO BE PRESENTED AT (URSI)
SYMPOSIUM ON ELECTROMAGNETIC WAVE THEORY, JUNE 1959.

Compiled by J.R. Wait, March 1959.

Most of these papers were published in the IRE Trans. on Ant. Prop.
AP-7, Special Supplement, December 1959, including:

- (1) Preface to the Surface Wave Papers
- (2) Guiding of Electromagnetic Waves by Uniformly Rough Surfaces, Part I.
- (3) Guiding of Electromagnetic Waves by Uniformly Rough Surfaces, Part II.

RADIO WAVE PROPAGATION IN AN INHOMOGENEOUS ATMOSPHERE

Nat. Bur. Stand. (USA), Technical Note No. 24, 10th September 1959,
J.R. Wait

A self-contained treatment of the theory of radio waves in an inhomogeneous atmosphere is given. The refractive index is assumed to vary with height above the earth in a monotonic fashion. Variation according to an exponential law is used for illustration of general principles. For this case, rigorous series formulas are developed for the distance to the horizon for an elevated point in the atmosphere.

ON THE PROPAGATION OF ELF RADIO WAVES AND THE INFLUENCE OF A NON-HOMOGENEOUS IONOSPHERE

J. geophys. Res. (USA), V. 65, No. 2, Pgs 597-600, February 1960.
J.R. Wait

The mode assumed consists of a spherical earth surrounded by a concentric ionosphere whose electron density increases exponentially with height. This elaboration of the usual homogeneous model appears to explain the observed attenuation for terrestrial propagation as a function of frequency in the range 100 cps to 1 kc.

FIELD STRENGTH CALCULATIONS FOR ELF RADIO WAVES
Nat. Bur. Stand. (USA), Technical Note No. 52, March 1960.
J.R. Wait, N.F. Carter

The mode theory of propagation of electromagnetic waves at extremely low frequencies (1.0 to 3000 cps) is briefly reviewed in this paper. Starting with the representation of the field as a sum of modes, approximate formulas are presented for the attenuation and phase constants. At the shorter distances, where the range is comparable to the wavelength, the spherical-earth mode series is best transformed to a series involving cylindrical wave functions. This latter form is used to evaluate the near field behaviour of the various field components. The effect of the earth's magnetic field is also evaluated using a quasi-longitudinal approximation which is particularly appropriate for propagation in the magnetic meridian. In general it is indicated that if the gyrofrequency is comparable or greater than the effective value of the collision frequency, the presence of the earth's magnetic field may be important for ELF. In this case the attenuation may be increased somewhat. The influence of a purely transverse magnetic field is also considered.

TERRESTRIAL PROPAGATION OF VERY-LOW-FREQUENCY RADIO WAVES
J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 2, Pgs 153-204, March-April 1960.
J.R. Wait

A self-contained treatment of the waveguide mode theory of the propagation of very-low-frequency radio waves is presented. The model of a flat earth with a sharply bounded and homogeneous ionosphere is treated for both vertical and horizontal dipole excitation. The properties of the modes are discussed in considerable detail. The influence of earth curvature is also considered by reformulating the problem using spherical wave functions of complex order. The modes in such a curved guide are investigated and despite the initial complexity of the general solution, many interesting and limiting cases may be treated in simple fashion to yield useful and convenient formulas for calculation. Other factors considered are the influence of the earth's magnetic field, antipodal effects, resonator type oscillations, and the influence of stratification at the lower edge of the ionosphere.

PROCEEDINGS OF THE 1960 CONFERENCE ON THE PROPAGATION OF ELF RADIO WAVES
Nat. Bur. Stand. (USA), Technical Note No. 61, 6th June 1960.
J.R. Wait (Editor)

No abstract

ON THE EXCITATION OF ELECTROMAGNETIC SURFACE WAVES ON A CURVED SURFACE
Inst. Radio Engrs (USA), Trans., V., AP-8, July 1960.
J.R. Wait

The excitation and propagation of surface waves on a spherical inductive boundary is considered. The source is taken to be a vertical electric dipole. The circumferential attenuation rate of the various modes are discussed where it is indicated that the dominant mode is very similar to the trapped surface wave for a plane inductive boundary. The results appear to conflict with those of Barlow, but are in sympathy with some numerical data of Elliott for the circumferential attenuation rate of the dominant mode.

INFLUENCE OF SOURCE DISTANCE ON THE IMPEDANCE CHARACTERISTICS OF ELF RADIO WAVES
EE Abstr. 8273/1960; Proc. Inst. Radio Engrs (USA), V. 48, No. 7, Pgs 1338-9, July 1960.
J.R. Wait

Quantitative results for the wave impedance at extremely low frequencies, (e.l.f.) are presented for the case of a flat perfectly conducting earth and a plane ionospheric reflecting layer at height h . The source is assumed to be equivalent to a vertical electric dipole located on the ground plane. Curves are plotted which show: (a) the normalized impedance ratio, (b) the phase lag of the ratio, as a function of distance from 50 to 2000 km, for frequencies from 50 to 1600 cps. The value of ω_r , an ionospheric conductivity parameter involving the electron density, collision frequency and the earth's magnetic field, is taken as 5×10^5 and $h = 90$ km. The shape of the curves is not appreciably modified if other values of ω_r and h are chosen. A method of utilizing these curves for determining the distance of a lightning flash from an observing station is suggested.

PREFACE TO ELF PAPERS
J. Research (D. Radio Propagation) Nat'l Bur. Standards 64D, 381, July-August 1960
J.R. Wait, editor.

No abstract

MODE THEORY AND THE PROPAGATION OF EXTREMELY LOW FREQUENCY RADIO WAVES
J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 4, July-August 1960.
J.R. Wait

The mode theory of propagation of electromagnetic waves at extremely low frequencies (ELF) (1.0 to 3,000 cycles per second) is treated in this paper. Starting with the representation of the field

as a sum of modes, approximate formulas are presented for the attenuation and phase constants. Certain alternate representations of the individual modes are mentioned. These are used as a basis for describing the physical behaviour of the field at large distances from the source, particularly near the antipode of the source. At the shorter distances, where the range is comparable to the wavelength, the spherical-earth mode series is best transformed to a series involving cylindrical wave functions. This latter form is used to evaluate the near field behaviour of the various field components. The effect of the earth's magnetic field is also evaluated using a quasi-longitudinal approximation. In general it is indicated that if the gyro-frequency is less than the effective value of the collision frequency, the presence of the earth's magnetic field may be neglected for ELF. When this condition is not met the attenuation may be increased somewhat. The influence of an inhomogeneous ionosphere is also briefly considered, and finally, the propagation of ELF pulses is treated. It is suggested that certain observed characteristics of ELF waveforms may be attributed to the inclination of the current channel in the lightning discharge.

INFLUENCE OF EARTH CURVATURE AND THE TERRESTRIAL MAGNETIC FIELD ON VLF PROPAGATION

J. geophys. Res. (USA), V. 65, August 1960.
J.R. Wait, K. Spies

An account is given of some recent work on the mode theory of VLF ionospheric propagation. Attention is confined to the behaviour of the attenuation coefficient of the dominant mode. The ionosphere is assumed to be a sharply bounded and homogeneous ionized medium. It is indicated that earth curvature increases the attenuation rate by as much as a factor of 2 as compared with the corresponding attenuation for a flat earth. The influence of the earth's magnetic field is also shown to be important. In fact propagation paths from east-to-west suffer much greater attenuation than for west-to-east paths. The theoretical results in the present paper appear to agree quite well with the experimental data of W.L. Taylor.

A CONFERENCE ON THE PROPAGATION OF ELF ELECTROMAGNETIC WAVES
Proc. IRE 48, Pgs 1648-1649, September 1960
J.R. Wait, letter.

No abstract

A SUMMARY OF VLF AND ELF PROPAGATION RESEARCH

EE Abstr. 6076/1962, J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 6,
Pgs 647-9, December 1960.

J.R. Wait

URSI National Committee Report, London, 1960 (see Abstr. 2183/1962). Applications of v.l.f. and e.l.f. to long distance communications, world-wide frequency standards, navigational aids, and detection of storms are providing incentive for further research in this field. This paper is a review of the published work relating to terrestrial propagation which has been carried out in the USA since January 1957. Closely related work carried out in the other countries is also mentioned.

PROPAGATION OF ELECTROMAGNETIC WAVES ALONG A THIN PLASMA SHEET

Can. J. Phys. 38, 1586-1594, December 1960.

J.R. Wait

No abstract

A NEW APPROACH TO THE MODE THEORY OF VLF PROPAGATION

Phys. Abstr. 7769/1962; J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 1,
Pgs 37-46, January-February 1961.

J.R. Wait

An attempt is made to present a concise derivation of the mode theory of v.l.f. propagation. Taking note of the fact that the important modes for long-distance propagation are near grazing, suitable approximate forms of the wave-functions are introduced at the outset, rather than at the end, of the analysis. It is thus possible to account for the influence of earth curvature in a relatively concise manner. The influence of the earth's magnetic field is also discussed. Finally, numerical results for the attenuation and the phase velocity of the dominant mode are presented.

THE PROPAGATION OF ELECTROMAGNETIC WAVES ALONG THE EARTH'S SURFACE

Phys. Abstr. 7761/1962; Electromagnetic Waves Symposium, Madison,
Wisconsin, 1961.

J.R. Wait

A rigorous solution is obtained for the following boundary value problems: (a) vertical electric and magnetic dipoles placed above a flat, vertically stratified earth; (b) an electric dipole above a spherically stratified earth. It is assumed for the spherical earth that the effect of stratification can be described by introducing a surface impedance. The boundary value problems (a) are solved by employing the standard Sommerfeld integral representation and the nature of the solution is examined in detail. The boundary value problem (b)

is also solved by standard methods and Watson's method is employed to transform the solution into a form more suitable for computation at high frequencies. Approximate methods are also developed for mixed path propagation over a flat and spherical earth. Graphs of several quantities of physical interest are included.

A NOTE ON PHASE VELOCITY OF VLF RADIO WAVES

J. geophys. Res. (USA), V. 66, No. 3, Pgs 992-993, March 1961.

J.R. Wait, K. Spies

No abstract

THE PROPAGATION OF ELECTROMAGNETIC WAVES ALONG THE EARTH'S SURFACE

Preprint from Proc. of Symposium on Electromagnetic Waves, Pub. No. 6, Math. Res. Centre, (U.S. Army), Madison, Wisconsin, April 1961.

J.R. Wait

No abstract

A COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL DATA ON PHASE VELOCITY OF VLF RADIO WAVES

EE Abstr. 3191/1962; Proc. Inst. Radio Engrs (USA), V. 49, No. 6, Pgs 1089-90, June 1961.

J.R. Wait

The experimental data were obtained by transmitting 1-sec signal bursts of unmodulated carrier from a master station and following it with similar bursts from slave stations. The master and receiving stations were at Hawaii and the slave station in California. Later a further slave station was located in New York State and a second receiving station in California. Frequencies employed ranged from 9.2 to 15.2 kc. The data obtained were applied as follows. Possible values for phase-velocity (v) deviation (from that of light) were plotted against frequency and on the same sheet curves were drawn which had been derived from waveguide-mode theory, taking account of the earth's curvature. Both perfect and imperfect reflection from the ionosphere were assumed. A good fit was achieved when values of 70 km and 90 km are assumed for the height of the ionosphere for day and night respectively, reflection being imperfect.

ON THE THEORY OF MIXED-PATH GROUND-WAVE PROPAGATION ON A SPHERICAL EARTH

J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 4, Pgs 401-410, July-August 1961

J.R. Wait

The problem formulated concerns the mutual impedance between two vertical dipole antennas A and B located near the surface of a spherical smooth earth. The path between A and B is made up of a number of homogeneous segments where the surface impedance is constant. Various formulas are developed, for two- and three-section paths, which are suitable for computation. Certain limiting cases are discussed and where possible a physical interpretation of the results is given. Comparisons with previous work are made.

ON THE POSSIBILITY OF REJECTING CERTAIN MODES IN VLF PROPAGATION

Proc. Inst. Radio Engrs (USA), V. 49, No. 9, P. 1429, September 1961.

J.R. Wait

Long-distance propagation of VLF radio waves is characterized by only a few low-order waveguide modes. This results from the excessive attenuation of the higher-order modes. In navigational systems, this is a desirable characteristic since the phase velocity approaches a constant at very great ranges when only one mode is predominant. Unfortunately, the second-order mode still exerts its influence for ranges as great as 4000 km. The possibility that this second-order mode could be discriminated against at the transmitting antenna is an intriguing one. We will discuss this problem from an analytical viewpoint. At the same time it is hoped that this might shed some light on the behaviour of antenna rays at VLF.

A NOTE CONCERNING THE EXCITATION OF ELF ELECTROMAGNETIC WAVES

J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 5, September-October 1961.

J.R. Wait

Previous solutions for the ELF mode series are discussed briefly. Particular attention is paid to the height-gain function. The excitation of the modes for vertical and horizontal dipole excitation is also considered.

EXPECTED INFLUENCE OF A LOCALIZED CHANGE OF IONOSPHERE HEIGHT ON VLF PROPAGATION

Phys. Abstr. 1607/1962; J. geophys. Res. (USA), V. 66, No. 10, Pgs 3119-3123, October 1961.

J.R. Wait

An approximate analysis is carried out for mode propagation in the earth/ionosphere waveguide with the height of the boundary varying with distance. Particular attention is paid to the phase anomaly produced by a localized depression of ionosphere height.

AVERAGE DECAY LAWS OF VLF FIELDS

Proc. Inst. Radio Engrs (USA), V. 50, No. 1, Pgs 53-56, January 1962.
J.R. Wait

A simplified discussion of propagation in the earth-ionosphere waveguide is given. It is shown that, if the square of the field amplitude is averaged over the width of the waveguide, a very simple formula for the averaged intensity is obtained. This result is used to describe some of the broad features of VLF propagation in a relatively concise fashion.

ON THE PROPAGATION OF VLF AND ELF RADIO WAVES WHEN THE IONOSPHERE IS NOT SHARPLY BOUNDED

Phys. Abstr. 16071/1962; J. Res. Nat. Bur. Stand. (USA), V. 66D, No. 1, January-February 1962, 53-61.
J.R. Wait

Employing an idea of Brekhovskikh, an expression for the reflection coefficient of a continuously stratified ionized medium is derived. The result is in the form of a series whose first term is a Fresnel-type coefficient and succeeding terms account for the finite thickness of the transition layer. This result is then fitted into previously developed theory for propagation between a spherical earth and a concentric ionosphere.

THE PROPAGATION OF ELECTROMAGNETIC WAVES ALONG THE EARTH'S SURFACE

EE Abstr. 10927/1962; EM Waves Symposium, Madison, 1961 (see abstr. 9255 of 1962); Pgs 243-90.
J.R. Wait

A rigorous solution is obtained for the following boundary value problems: (a) vertical electric and magnetic dipoles placed above a flat, vertically stratified earth; (b) an electric dipole above a spherically stratified earth. It is assumed for the spherical earth that the effect of a stratification can be described by introducing a surface impedance. The boundary value problems (a) are solved by employing the standard Sommerfeld integral representation and the nature of the solutions is examined in detail. The boundary value problem (b) is also solved by standard methods and Watson's method is employed to transform the solution into a form more suitable for computation at high frequencies. Approximate methods are also developed for mixed path propagation over a flat and spherical earth. Graphs of several quantities of physical interest are included.

COMMENTS ON PAPER BY W.D. WESTFALL "PREDICTION OF VLF DIURNAL PHASE BY CHANGE AND SOLAR FLARE EFFECT"

J. Geophys. Res. (USA), Vol. 67, No. 2, Pgs 916-917, February 1962
Phys. Abstr. 13032/1962

J.R. Wait

Criticises the use of a formula taken from Wait (Abstr. 5565B of 1959; Proc. Inst. Radio Engrs., Vol. 47, No. 5(1), 998, May 1959), and used to determine the height of reflecting layers and their diurnal change.

VERY LOW FREQUENCY PROPAGATION IN THE EARTH-IONOSPHERE WAVEGUIDE OF NON-UNIFORM WIDTH

Int. Conf. on the Ionosphere, Imperial College, London, July 1962.
Proceedings 446-451, London, Institute of Physics and the Physical Soc., 1963.
J.R. Wait

No abstract

INTRODUCTION TO THE THEORY OF VLF PROPAGATION

EE Abstr. 13541/1962; Proc. Inst. Radio Engrs (USA), Vol. 50, No. 7, 1624-47, July 1962.

J.R. Wait

This paper is a self-contained exposition of the conventional theory of propagation of vlf radio waves. The model is a spherical earth surrounded by a concentric ionosphere. Although the model is highly idealized, the theory is still quite involved. The complexities arise from the long wavelengths inherent in such problems. In Section I the elementary geometrical or hop theory for vlf is considered. In Section II, the diffractive corrections near the caustics of the ray systems are obtained. In Section III, the waveguide mode theory is expounded. Finally, in Section IV, the influence of a stratified ionosphere is treated by using a two-layer model.

AN ANALYSIS OF VLF MODE PROPAGATION FOR A VARIABLE IONOSPHERE HEIGHT

Phys. Abstr. 16077/1962; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 4, Pgs 453-61, July-August 1962.

J.R. Wait

An approximate treatment of modes in a waveguide width is presented. It is assumed that the boundaries satisfy impedance-type boundary conditions. The model consists of two parallel-plate waveguide regions connected by a linearly tapered section. The results have application to the theory on VLF radio wave propagation when the ionospheric heights are not constant along the path.

WAVE PROPAGATION AROUND A CURVED BOUNDARY WHICH CONTAINS AN OBSTACLE
Phys. Abstr. 17956/1962; Canad. J. Phys. Vol. 40, No. 8, Pgs 1010-16,
August 1962.
J.R. Wait

The problem is to calculate the field of an electric dipole on a smooth spherical or cylindrical surface which contains a localized obstruction. An approximate solution is obtained by combining the rigorous theory of diffraction by a sphere and the approximate Kirchhoff diffraction theory for black screens. The application to ground wave propagation is briefly indicated.

EXCITATION OF MODES AT VERY LOW FREQUENCY IN THE EARTH-IONOSPHERE
WAVE GUIDE
Phys. Abstr. 9953/1963; J. Geophys. Res. (USA), Vol. 67, No. 10,
Pgs 3823-8, September 1962.
J.R. Wait

The concept of vlf radio waves propagating between the earth and the ionosphere in the manner of a wave guide has proved very useful. A much neglected aspect of the subject, however, is the manner in which the modes are excited. A valid analysis of this effect requires that the earth's curvature and the grazing nature of the modes be properly accounted for. By using the Airy integral or third-order approximations for the spherical wave functions, an expression for the excitation factor is obtained. It is indicated that the modes of very low attenuation may be accompanied by excitation factors much less than unity. There is evidence of this phenomenon in some of the old experimental data of Round et al. (1925) at frequencies of the order of 25 kc/s. A mode of this type can be imagined as becoming "detached" from the lower boundary of the earth-ionosphere waveguide. In this situation, the height-gain functions increase with height and the modal characteristics depend only slightly on ground characteristics.

ON THE PROPAGATION OF ELF PULSES IN THE EARTH-IONOSPHERE WAVEGUIDE
Phys. Abstr. 22346/1962; Canad. J. Phys. Vol. 40, No. 10, Pgs 1360-9,
October 1962.
J.R. Wait

The paper is concerned with the connection between frequency domain and time domain for propagation in the earth-ionosphere waveguide. Attention is focused on the extremely low frequency (elf) range. It is assumed that the propagation constant is proportional to f^{ν} , where f is the frequency and ν is a fraction between 0 and 1. For such a frequency law, the corresponding transient responses are computed. These illustrate a number of important points. In particular, it is indicated that the frequency dependence of the propagation constant could be estimated directly from the waveforms themselves without resorting to conventional spectral analysis.

THE PROPAGATION OF ELECTROMAGNETIC WAVES ALONG THE EARTH'S SURFACE
Electromagnetic Waves, edited by R.E. Langer, the University of Wisconsin
Press, Pgs 243-290, 1962
J.R. Wait

No abstract

ELECTROMAGNETIC WAVES IN STRATIFIED MEDIA
Pergamon Press, Oxford, 1962
J.R. Wait

No abstract

CURVES FOR GROUND WAVE PROPAGATION OVER MIXED LAND AND SEA PATHS
EE Abstr. 5362/1963. IEEE Trans. Antennas & Propagation (USA),
Vol. AP-11, No. 1, Pgs 38-45, January 1963.
J.R. Wait, L.C. Walters

Specific numerical results are presented for ground wave propagation over paths which are part sea and part land. The problem is idealized to the extent that the earth is a smooth spherical surface. The method is based on a previous formulation in terms of mutual impedance between two vertical electric dipoles on an inhomogeneous spherical earth. Amplitude and phase of the ground wave are given for various combinations of the following parameters; frequency 1000, 100, and 20 kc/s; land conductivities 100 and 10 mmhos/meter; and a sea conductivity of 4 mhos/meter. Most of the curves exhibit the well-known recovery effect which occurs beyond the coast line for propagation from land towards the sea.

VERY LOW FREQUENCY PROPAGATION IN THE EARTH-IONOSPHERE WAVE GUIDE OF NON-UNIFORM WIDTH
Phys. Abstr. 16257/1963; Ionosphere Conf., London, 1962 (see Abstr. 11422 of 1963), pgs. 446-51.
J.R. Wait

An approximate theory for propagation of electromagnetic waves in a curved waveguide of variable width is outlined. The method is based on a direct application of the Lorentz reciprocity theorem. The final result is in the form of a line integral which involves the profile of the ionospheric reflecting layer as a function of the horizontal distance. By making a number of simplifications, valid for small perturbations, the physical consequences of non-uniform reflecting height are evident. In particular, it is indicated that perturbations at the reflecting level will introduce higher-order modes in the waveguide.

A NOTE ON DIURNAL PHASE CHANGES OF VERY LOW FREQUENCY WAVES FOR LONG PATHS

EE Abstr. 13890/1963; J. geophys. Res. (USA), Vol. 68, No. 1, Pgs. 338-40, 1st January 1963.

J.R. Wait

Some of the new experimental results on the phase of very-low-frequency transmissions are discussed in terms of the waveguide mode theory of propagation using as an ionospheric model a sharply bounded isotropic ionosphere and neglecting the effects of the earth's magnetic field. Both theory and experiment show the existence of an interference region due to the effects of different waveguide modes.

THE MODE THEORY OF VLF RADIO PROPAGATION FOR A SPHERICAL EARTH AND A CONCENTRIC ANISOTROPIC IONOSPHERE

Phys. Abstr. 7715/1963; Canad. J. Phys. Vol. 41, No. 2, Pgs 299-315, February 1963.

J.R. Wait

The theory of the propagation of electromagnetic waves in the space between a spherical conducting earth and a concentric ionospheric reflecting layer is treated. The problem is idealized to the extent that, at the boundaries of this spherical waveguide, the tangential field components are related in a prescribed way. In the case of the ground, the relation involves a scalar surface impedance while, for the ionosphere, it is necessary to employ a reflection coefficient or surface impedance while, for the ionosphere, it is necessary to employ a reflection coefficient or surface impedance in the form of a matrix. On this basis a solution is sought for the total field produced by a vertical electric dipole. Explicit results are obtained under the assumption of azimuthal symmetry. By applying the Watson transformation a representation in terms of guided waves is obtained. This form of the solution was used previously by the author to obtain specific results.

HEIGHT-GAIN FOR VLF RADIO WAVES

EE Abstr. 5396/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 2, 183-7, March/April 1963.

J.R. Wait, K.P. Spies

The height dependence of the field strength of vlf radio waves is considered. Using a previously developed theory, the height-gain function of the first two modes is calculated in terms of Airy functions of complex argument. It is indicated, for frequencies of the order of 25 kc/s that the height-gain function reaches a maximum value at a height of the order of 40 km when the reflecting layer is about 70 km. The form of the height-gain function is also shown to be dependent on the finite conductivity of the ground. An experimental curve for 18.0 kc/s based on a rocket measurement shows some agreement with the theory.

THE POSSIBILITY OF GUIDED ELECTROMAGNETIC WAVES IN THE EARTH'S CRUST
EE Abstr. 703/1964; IEE Trans. Antennas and Propagation (USA), Vol.
AP-11, No. 3, Pgs 330-5, May 1963.

J.R. Wait

A natural waveguide for electromagnetic waves may exist in the earth's crust. Choosing an idealized model, the attenuation in such a guide is calculated under more or less optimum conditions. By choosing certain dimensionless parameters the results may have rather broad applications to problems of this type.

CONCERNING SOLUTIONS OF THE VLF MODE PROBLEM FOR AN ANISOTROPIC CURVED IONOSPHERE.

EE Abstr. 12289/1963; J. Res. Nat. Bur. Stand. (USA), Vol.67D, No.3, Pgs 297-302, May-June 1963.

J.R. Wait

The influence of earth curvature in the theory of reflection from the ionosphere is considered. By choosing a rather idealized model, the significance of usual earth-flattening procedures can be displayed quite readily. To simplify the analysis, it is assumed that the earth's magnetic field is vertical everywhere. It is shown that the curved ionosphere may be represented by homogeneous planar slabs, provided the local value of layer curvature is used. The results are compared with some corresponding expressions obtained by Johler and Berry. (Abstr. 4391 of 1963).

INFLUENCE OF THE LOWER IONOSPHERE ON PROPAGATION OF VLF WAVES TO GREAT DISTANCES

Phys. Abstr. 1964/2255; J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 4, Pgs. 375-81, July-August 1963.

J.R. Wait

Theoretical attenuation and phase characteristics at vlf are presented for a number of idealized models of the lower ionosphere. The results indicate the limitations of the sharply bounded model.

REFLECTION OF VLF RADIO WAVES FROM AN INHOMOGENEOUS IONOSPHERE.

I. EXPONENTIALLY VARYING ISOTROPIC MODEL

EE Abstr. 12290/1963; J. Res. Nat. Bur. Stand. (USA), Vol.67D, No.3, Pgs 361-7, May-June 1963.

J.R. Wait, L.C. Walters

The oblique reflection of vlf radio waves from a continuously stratified ionized medium is considered. The profile of the effective conductivity is taken to be of an exponential form. This is a fair representation for the actual D layer of the ionosphere. It is shown that the gradient of the conductivity change has a marked effect on the reflection characteristics.

REFLECTION OF VLF RADIO WAVES FROM AN INHOMOGENEOUS IONOSPHERE

II. PERTURBED EXPONENTIAL MODEL

EE Abstr. 1265/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 5, Pgs 519-23, September-October 1963.

J.R. Wait, L.C. Walters

The oblique reflection of radio waves from a continuously stratified medium is considered. The medium is assumed to be isotropic. The height profile of the effective conductivity is a Gaussian curve superimposed on the (undisturbed) exponential form. The reflection coefficient is shown to be influenced by the vertical location of the Gaussian perturbation. In some cases the magnitude of the reflection coefficient is increased while, in other situations, it is decreased. In nearly all cases, insofar as phase is concerned, the presence of the perturbation corresponds to a lowering of the reflection height.

REFLECTION OF VLF RADIO WAVES FROM AN INHOMOGENEOUS IONOSPHERE

III. EXPONENTIAL MODEL WITH HYPERBOLIC TRANSITION

Journal of Research of Nat. Bur. of Standards, D. Radio Propagation, Vol. 67D, No. 6, November-December 1963.

J.R. Wait, L.C. Walters

This is a continuation of two earlier papers on the subject of reflection of waves from inhomogeneous isotropic media. In this particular paper an exponential conductivity profile is perturbed in such a manner that the conductivity is increased for all heights above a certain level. A hyperbolic tangent transition is employed in order to avoid discontinuities in the conductivity versus height profile.

REVIEW OF MODE THEORY OF RADIO PROPAGATION IN TERRESTRIAL WAVEGUIDES

Rev. of Geophysics, Vol. 1, November 1963, No. 4.

J.R. Wait

This paper is an expository review of the theory of guided waves that occur in the earth's atmosphere. We introduce the subject by treating the problem of radio propagation around the surface of an airless spherical earth.

It is shown, for frequencies less than about 10 kc/s, that the field may be described in terms of flat-earth modes analogous to those in a straight rectangular microwave guide. At higher frequencies, however, the earth curvature plays a major role and the character and excitation of the modes are changed drastically. Complications resulting from the anisotropy of the ionosphere are also considered. A critical discussion of the recent work on the subject is given.

OBLIQUE PROPAGATION OF GROUNDWAVES ACROSS A COASTLINE, I.
EE Abstr. 15861/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 6,
Pgs 617-24, November-December 1963.
J.R. Wait

The amplitude and phase of the groundwave are calculated for oblique propagation across a flat lying coastline. The land and sea are assumed to be smooth and homogeneous. Attention is focused on the effects which take place near the coastline. It is shown that the reflected wave depends critically on the angle of incidence, θ_0 , while the transmitted wave has only a weak dependence on θ_0 .

OBLIQUE PROPAGATION OF GROUNDWAVES ACROSS A COASTLINE, II.
EE Abstr. 15862/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 6,
Pgs 25-30, November/December 1963.
J.R. Wait, C.M. Jackson

The amplitude and phase are calculated for oblique propagation across a coastline with a sloping beach. In this case, the land and sea are taken to be plane surfaces and the beach slope is constant. It is shown that the reflected wave may be quite significant and it has a fundamentally different character from the reflected wave in the case of a flat-lying coastline.

TWO-DIMENSIONAL TREATMENT OF MODE THEORY OF THE PROPAGATION OF VLF RADIO WAVES
Radio Sci. Journal of Research NBS/USNC-URSI, Vol. 68D, No. 1, January 1964,
Pgs 81-93
J.R. Wait.

This paper is partly of a tutorial nature. The intended purpose is to exploit the essential two-dimensional nature of wave propagation in the earth-ionosphere waveguide. It is shown that without resorting to erudite arguments in the complex plane, the usual working formulas of VLF mode theory may be derived directly from orthogonality considerations. Furthermore, the physical insight gained by the present development immediately suggests how the formulas may be generalized to an earth-ionosphere waveguide of non-uniform width.

SOME REMARKS ON MODE AND RAY THEORIES OF VLF RADIO PROPAGATION
Radio Sci. Journal of Research NBS/USNC-URSI, Vol. 68D, No. 1, January 1964,
pgs. 79-80.
J.R. Wait

Some of the assumptions used in treatment of the mode theory of VLF radio propagation are discussed briefly. The connections with geometrical-optical theories are also pointed out.

CALCULATED DIFFRACTION EFFECTS AT VLF FROM A LOCALIZED IONOSPHERIC DEPRESSION

Nat. Bur. Stands., Tech. Note 208, 16th January 1964.
J.R. Wait

Propagation of VLF radio waves in the earth-ionosphere waveguide of non-uniform width is considered. The disturbed region is permitted to be of finite extent. It is assumed that the height variations may be locally represented in terms of a propagation function $S(x,y)$ which is a function of both x and y . Using first-order scattering theory, calculations are presented for a disturbed region which is approximately rectangular in the horizontal plane.

NUMERICAL CALCULATIONS FOR REFLECTION OF ELECTROMAGNETIC WAVES FROM A LOSSY MAGNETOPLASMA

Tech. Note. 205, November 21st 1963. Nat. Bur. Stands, Boulder, Colorado.
L.C. Walters, J.R. Wait

No abstract

LOW-FREQUENCY PROPAGATION PATHS IN ARCTIC AREAS

J. Research (D. Radio Propagation); Nat. Bur. Stands, 63D, Pgs 99-112, July-August 1959.
A.D. Watt, E.L. Maxwell, E.H. Whelan

No abstract

POWER REQUIREMENTS AND CHOICE OF AN OPTIMUM FREQUENCY FOR A WORLD-WIDE STANDARD-FREQUENCY BROADCASTING STATION

EE Abstr. 6747/1959; J. Res. Nat. Bur. Stand. (USA), V. 63D, No. 1, Pgs. 35-44, July-August 1959.
A.D. Watt, R.W. Plush

Calculations are presented for the expected transmission characteristics and atmospheric noise levels in the 8-100 kc band. When these are combined with carrier-to-noise requirements for a given precision of frequency comparison, it is indicated that a minimum radiated power in the order of 10 to 100 kw for frequencies in the vicinity of 20 kc will be required to provide worldwide coverage. Minimum observation times of 15 to 30 min. appear to be required for these transmitter powers in order to obtain a precision of frequency comparison of 1 part in 10^9 for typical transmission paths. Carrier-to-noise requirements and the factors determining this ratio are considered for typical receiving systems.

WORLDWIDE VLF STANDARD FREQUENCY AND TIME SIGNAL BROADCASTING

J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 6, November-December 1961.
A.D. Watt, & Others

Recent studies and measurements have shown that the phase stability of the signals in VLF region is very much higher than in the HF spectrum. This fact, along with its excellent coverage characteristics, has caused considerable interest in employing this medium for the wide distribution of standard frequencies and time reference. Basic limitations in stability of the received signals are discussed, including path phase distortion, carrier-to-noise and envelope delay variations as related to precise synchronisation of clocks, and highly accurate frequency calibrations. Also included is a discussion of the present services of standard frequency and time signals stations throughout the world at HF, LF and VLF.

COMPARISON OF OBSERVED VLF ATTENUATION RATES AND EXCITATION FACTORS WITH THEORY

Radio Sci. Journal of Research NBS/USNC-URSI, Vol. 68D, No. 1, January 1964, Pgs 1-9.
A.D. Watt, R.D. Croghan

The properties of VLF propagating modes are briefly reviewed and simplified equations are presented which can be employed in calculating the fields produced. Experimentally determined excitation factors are compared with theoretical curves obtained by Wait and found to agree rather closely. Attenuation rates are shown as a function of frequency and found to agree rather closely with calculated values using a proposed simplified perturbation solution for attenuation rates based on reflection coefficients at the ground and ionosphere. When employing values of ionospheric reflection coefficients recently presented by Wait and Walters, the non-reciprocal effects in attenuation rate are found both theoretically and experimentally, to be much greater in the 10 kc/s region than in the 20 to 30 kc/s region. Finally, experimental field strength versus distance data are compared with mode calculations and found to compare well all the way from 1 megameter out to and including fields at the antipode (20 megameters).

EFFECT OF EXTERNAL CONDITIONS ON THE PHASE OF RADIO SIGNALS

Nature (GB), Vol. 191, 1286, 23rd September 1961.
Phys. Abstr. 11798/1962
D.E. Watt-Carter, R.L. Corke

Reports on phase aberrations of radio signals investigated with the aid of 16 kc/s emissions from the GBR transmitter at Rugby. Observed causes of aberration are mentioned.

HYDROMAGNETIC WAVES AND ELF OSCILLATIONS IN THE IONOSPHERE
EE Abstr. 6074/1962; J. Res. Nat. Bur. Stand. (USA), Vol. 64D,
No. 6, Pg. 650, November-December 1960.
J.M. Watts

URSI National Committee Report, London 1960. A brief review of the researches performed in the triennium 1957 to 1960 into hydromagnetic waves and e.l.f. oscillations in the ionosphere. The hypothesis of hydromagnetic waves has been extended to explain certain geophysical phenomena. However, this does not seem to explain other classes of electromagnetic disturbances and emphasis has been placed on the theory of travelling wave amplification. It has been possible to create hydromagnetic waves in the ionosphere by means of nuclear explosions and to observe these with rockets and satellites. The magnitude of these effects is comparable with the magnitude of natural occurrences.

THE PRESENT STATE OF KNOWLEDGE CONCERNING THE LOWER IONOSPHERE
Proc. Inst. Radio Engrs (USA), V. 45, Pg. 741, June 1957.
A.H. Waynick

No abstract

ON A REFINEMENT OF THE THEORY OF THE PROPAGATION OF LONG ELECTRIC WAVES
ROUND THE EARTH
Z. angew. Phys. Vol. 7, No. 2, Pgs. 77-82, 1955. In German.
J. Weidner

The author considers a second term in the theory of Schumann. This is shown to be negligible for wavelengths greater than 180 km and inadequate for wavelengths less than 40 km.

PREDICTION OF VLF DIURNAL PHASE CHANGES AND SOLAR FLARE EFFECTS
Phys. Abstr. 19044/1961; J. geophys. Res. (USA), V. 66, No. 9, Pgs 2733-6,
September 1961
W.D. Westfall

VLF diurnal phase shift data are compared with predictions resulting from the waveguide equations for the first order mode. The effects of higher order mode energies appear to exist out to 2700 km, and may at times affect measurements beyond this range. A relation is given for the prediction of diurnal phase shift for 10-20 kc radio waves. Expressions are given for relating observed VLF phase perturbations caused by both small and large solar flares to the resulting apparent decreases in ionospheric reflecting height.

RADIO WAVE PROPAGATION IN THE EARTH'S CRUST

J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 2, March-April 1961.

H.A. Wheeler

There is a reasonable basis for postulating the existence of a useful waveguide deep in the earth's crust, of the order of 2 to 20 km below the surface. Its dielectric is basement rock of very low conductivity. Its upper boundary is formed by the conductive layers near the surface. Its lower boundary is formed by a high-temperature conductive layer far below the surface, termed the "thermal ionosphere" by analogy to the well-known "radiation ionosphere" far above the surface. The electrical conductivity of the basement rock has not been explored. An example based on reasonable estimates indicates that transmission at 1.5 kc might be possible for a distance of the order of 1500 km. This waveguide is located under land and sea over the entire surface of the earth. It may be useful for radio transmission from the shore to a submarine on the floor of the ocean. The sending antenna might be a long conductor in a drill hole deep in the basement rock; the receiving antenna might be a vertical loop in the water.

VL F PROPAGATION UNDER THE IONOSPHERE IN THE LOWEST MODE OF HORIZONTAL POLARIZATION

Radio Sci. Journ. of Research NBS/USNC-URSI, Vol. 68D, No. 1, January, 1964, Pgs. 105-113.

H.A. Wheeler

In the lower part of the VLF band, around 4 kc/s, it appears that the lowest rate of attenuation is obtainable by horizontal polarization in the TE-01 mode. This offers a substantial advantage relative to vertical polarization in the usual TM-01 mode and the simple TM-00 or TEM mode. Some types of antennas are found to be suitable for the TE-01 mode, namely, a horizontal wire above ground or a vertical loop, either one located in a plane perpendicular to the direction of transmission. A theoretical study is summarized leading to the conclusions that this mode offers some unique features and is suitable for transmission to distances of the order of 4,000 km.

RESEARCH ON VLF PROPAGATION IN ARCTIC REGIONS - GEOPHYSICAL EFFECTS

Final Report, SRI Project 3176, Contract AF 19(604)-7250, Stanford Research Inst., Menlo Park, California, February 1961. AD-256062

A.L. Whitson

During the arctic winter of 1958-59, Stanford Research Inst. recorded atmospheric waveforms, direction of arrival, and rates of occurrence and atmospheric noise levels from 12 to 30 kc at Fairbanks, Alaska, at Thule, Greenland, and at St. John's Newfoundland. The bulk of the data recorded has been reported in AFCRC-TR-60-118(A), "Arctic Atmospheric Noise and Propagation Studies, Part A - Arctic Sferic Data - August 1958 to March 1959".

The atmospheric noise data collected in the Arctic have been used to determine certain geophysical effects on VLF propagation between 3 and 30 kc in arctic regions. The effect of sudden ionospheric disturbances in the form of a sudden enhancement of atmospheric noise is defined in the 3- to 30-kc frequency band. Very-low-frequency propagation along the Fairbanks-Thule great-circle path, as measured by Fourier analysis of atmospheric noise, is non-reciprocal but disagrees with non-reciprocal measurements at mid-latitudes. The influence of a polar-cap-absorption even on atmospheric noise is shown, along with variations in atmospheric noise spectrum that are related to some unexplained VLF propagation phenomena.

SOME RESULTS OF A SWEEP-FREQUENCY PROPAGATION EXPERIMENT OVER AN
1150-KM EAST-WEST PATH

J. Geophys. Research 60, Pgs 395-409, December 1955.
B. Wieder

No abstract

TWO HOP 18.6-KC/S WHISTLER-MODE ECHOES RECEIVED AT SEATTLE

J. Geophys. Research, Vol. 66, No. 6, Pgs 1976-1977, June 1961.
H.R. Willard.

This note describes briefly the reception at Seattle of whistler-mode echoes from U.S. Navy Station NPG. This station, operating at 18.6 kc/s, has been providing special keying sequences consisting of a series of quarter-second pulses spaced three seconds apart. Echoes from these transmissions, believed to be propagated by two-hop whistler mode, have been received occasionally during the night-time hours. Echoes have been heard up to approximately local sea-level sunrise.

SUBTERRANEAN COMMUNICATION BY ELECTRIC WAVES

J. Brit. Instn Radio Engrs (GB), V.11, Pgs 101-111, March 1951.
H.P. Williams

The possibility of communications directly through the ground to imprisoned miners is studied. A formula for the propagation of a plane wave through a conducting medium is derived and it is shown that because of the changing relative values of σ and ϵ , where σ is the conductivity and ϵ the dielectric constant of the medium, the best propagation will be achieved at very low frequency, i.e. 500 cps. This, however, introduces the difficulty of obtaining an efficient radiator considering first the case of two buried stations and assuming the use of lw transceivers each with two radiating electrodes spaced 100 m apart, it is shown that up to ≈ 450 m, the electrostatic field will predominate and will give with favourable orientation of the electrodes, ≈ 0.3 mv. input voltage unaffected by frequency over the range 0.5 - 3.0 kc. Desirable electrodes would be 1 mm rods surface buried. For communication between a central station and a portable transceiver, more efficient propagation would be achieved with one electrode buried at the bottom of the main shaft and the other 1 - 2 miles away. Taking noise level into accord and assuming a transmitter power of 50 the range should be $\ll 1$ km. To permit a narrow transmission band,

communication solely by means of a key, battery and buzzer is recommended. Full analysis on propagation and electrode design are given.

THE TRANSMITTED AND REFLECTED FIELDS DUE TO A PLANE WAVE INCIDENT ON
A DIELECTRIC HALF-SPACE FROM A CONDUCTING HALF-SPACE
AD 251 680; University of New Mexico, Albuquerque, New Mexico, Technical
Rept. EE-42, February 1961.
R.H. Williams

The problem considered in this paper assumes (a) that all space is composed of a conducting half-space separated by a plane boundary from a dielectric half-space; (b) that a uniform (homogeneous) electromagnetic plane wave is incident upon the boundary from sources in the conducting half-space. This problem was motivated by consideration of the more general problem of a radiating antenna in a highly conducting medium such as the sea. It is shown that Snell's law and Fresnel formulas are not adequate to obtain a unique solution of the reflected and transmitted fields; a radiation condition is introduced as a remedy. The relative efficiencies between the TE and the TM cases in transmitting an electric field from the conductor to the dielectric is studied under the assumption that the incident electric fields are constant in magnitude as the angle of incidence is varied. It is shown that the TM case is more efficient by only a factor of $\sqrt{2}$ except at very small angles of incidence where the TE and TM become essentially the same. Finally, an investigation is made showing the errors and misinterpretations that can occur if one tries to consider this problem in the light of power reflection coefficients.

THE TRANSMISSION OF A PARTICULAR NON-UNIFORM PLANE WAVE ACROSS A FLAT
BOUNDARY
AD 256 213; University of New Mexico, Albuquerque, New Mexico, Technical
rept. No. EE-47, March 1961.
R.H. Williams

The formal solution is presented for the reflected and transmitted electromagnetic fields caused by a particular class of non-uniform plane waves which are incident on a plane boundary separating two infinite half-spaces. The specific class of non-uniform plane waves is characterized by plane waves having planes of constant amplitude parallel to the boundary and planes of constant phase with arbitrary angles of incidence. A specific example is studied in which the medium that contains the incident plane wave is highly conductive and the medium that contains the transmitted field is non-conductive. Almost all the discussion is confined to the transmission coefficients; in particular it is confined to the transmission coefficient for the transverse magnetic case where a phenomenon appears that suggests a pseudo-Brewster angle. It is suggested that this pseudo-Brewster angle can account for some of the properties of the fields in air originated by a dipole submerged in a conducting medium.

PROPAGATION BETWEEN CONDUCTING AND NON-CONDUCTING MEDIA
AD 263 277; University of New Mexico, Albuquerque, New Mexico,
Technical rept. No. EE-50, September 1961.
R.H. Williams

No abstract

LOW-FREQUENCY RADIO PROPAGATION INTO A MODERATELY ROUGH SEA
EE Abstr. 13876/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 67D,
No. 5, Pgs 551-62, September-October 1963.
D.F. Winter

Radiation from primary current sources above or at the interface of a homogeneous conducting dielectric half-space has been studied extensively in connection with various communication problems. In many cases of practical interest, however, the surface bounding the conducting medium is irregular in configuration, the local deviation of the interface from the average being a function of position and time. The present paper describes a method for determining the effect of interface irregularities upon low-frequency electromagnetic fields propagated within such a conductor. The electric field at a point within the medium is expressed as a stochastic integral over the bounding surface using the method of Stratton and Chu. As a consequence of certain restrictions which are principally geometric in character, a perturbation technique can be employed to simplify the integrand. Following the introduction of assumptions regarding the statistical properties of the local surface deviations, approximate expressions are developed for the expectation of the sub-surface field and the mean square deviation of the field amplitude. Numerical results for this latter quantity are obtained for the case of a vertical electric dipole as the radiating source on the interface between free space and a moderately rough sea. It is shown that sea surface irregularities can produce a pronounced effect upon sub-surface fields in some instances; a tentative physical interpretation of the numerical results is advanced.

SOME ASPECTS OF A RIGOROUS SCALAR TREATMENT OF ELECTROMAGNETIC WAVE PROPAGATION

In: Electromagnetic Wave Propagation, See Page 30.
E. Wolf

THE REFRACTION OF RADIO WAVES BY A SPHERICAL IONIZED LAYER
J. atmos terrest. Phys. (GB), Vol. 16, No. 1-2, Pgs 124-35, October 1959.
E. Woyk

A general expression is derived for the refraction of radio waves passing completely through a spherical ionized layer, using a simple ray treatment. A similar formula is derived for the ray-path length.

REFLECTION AT A SHARPLY-BOUNDED IONOSPHERE

Proc. Inst. Radio Engrs (USA), V. 45, P. 750, June 1957.

I.W. Yabroff

A quantitative description of the waves transmitted into and reflected from a sharply-bounded, anisotropic ionosphere with losses is given. Given curves show the effects of the earth's field and losses for a particular model of the night-time E-layer at VLF.

COMPUTATION OF WHISTLER RAY PATHS

SRI Project 2241, Final Letter Report, Part II, Contract AF 18(603)-126, Stanford Research Inst., Menlo Park, Calif., December 1959. AFOSR-TN-60-71.

AD-233 130.

I.W. Yabroff

This is the second of two reports covering the work done on the theory and application of ray tracing techniques to whistler propagation in the outer ionosphere. (See Brandstatter for Pt. 1 - "The Theory of Propagation of Rays in an Inhomogeneous and Anisotropic Medium").

The work reported here is an attempt to demonstrate some of the complex phenomena of "magneto-ionic duct" propagation. The set of computations described here is in no sense complete or comprehensive; it is meant only to demonstrate a few interesting details of this mode of propagation and to stimulate further thought and work.

COMPUTATION OF WHISTLER RAY PATHS

J. Research NBS, Vol. 65D, No. 5, Pgs 485-505, September-October 1961.

I.W. Yabroff

Calculations of whistler ray paths in the outer ionosphere are shown for a variety of electron density profile models including exponential, constant, and columnar profiles. The Haselgrove formulation of the ray equations was used with the magneto-ionic representation of the wave refractive index to develop a set of differential equations for ray tracing suitable for inhomogeneous; anisotropic medium. The variation of paths with frequency, latitude, initial wave-normal angle, and other variables are examined for the purpose of providing a preliminary basis for comparison of the theoretical with some of the experimental results.

RECEIVING AND TAKING BEARINGS IN SEA-WATER ON ELECTRO-MAGNETIC WAVES

Telefunken Ztg., Germany, V. 33, No. 128, June 1960.

G. Ziehm

Very low frequency electromagnetic waves are characterized by their ground-wave being attenuated only moderately during propagation round the earth. Furthermore, the drop in amplitude of the wave penetrating the ground, and particularly sea-water, is lower than at higher frequencies. Especially in view of the latter property VLF

waves are suitable for establishing communications with submerged submarines. If the wave penetrating sea-water is examined closer the superiority of receiving antennas responding to the magnetic field over other types can be perceived. When the magnetic receiving antenna is above the water surface and its main lobe directed to the distant transmitter, reception will be possible in general if the signal field strength equals the interfering field strength. In reception in sea-water the situation is quite different. Reception is no longer limited solely by interference picked up by the antenna but also by the receiver's inherent noise. Since noise and interfering voltages can be added quadratically, it can easily be shown that reception below water is limited by receiver noise (predominantly Nyquist noise) almost exclusively when the signal field strength above water is more than five times higher than the average interference field strength. Some formulae are derived for the depths at which reception or direction finding is possible. If bearing shall be taken below water on a transmitter the type of direction finder used plays a part as regards the maximum depth at which reliable results can be expected. When both aural minimum and instantaneous reading direction finders are employed the maximum depths are less than when signals are received only.

THEORY AND APPLICATIONS OF SURFACE WAVES

Phys. Abstr. 3685/1954; *Nuovo Cimento* (Italy), V. 9, Suppl. No. 3, Pgs 450-73, 1952.

F.J. Zucker

"Free" waves are defined as those whose propagation constant is independent of the source. The nature of such waves in open guides - dielectric cylinders, wires with dielectric beads, dielectric-filled spirals, etc. - are discussed. In general both transmission and radiation modes may exist, their forms depending on the transverse propagation constants of the guide. An outline is given of the theoretical treatment which provides the required discrete and continuous eigenvalues. Examples are given of open guides in which transmission is observed in the microwave region. Analogous optical waves are discussed and it is suggested that Zenneck waves on flat metallic sheets are free waves and may yet be observed experimentally.

PART II

PART II

CALCULATION OF DC AND EM FIELDS, ANTENNAS

DIE INDUKTION VON WECHSELSTROMEN IN EINER EBENEN LEITENDEN SCHICHT
Z. angew. Math. Mech. (Germany), V. 2, Pg. 109, 1922.
M.V. Abraham

No abstract

FIELD OF ELECTRIC DIPOLES IN SEAWATER - THE EARTH - ATMOSPHERE -
IONOSPHERE PROBLEM
Phys. Abstr. 16061/1962; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 1,
Pgs. 63-72, January-February 1962.
W.L. Anderson

The theory of extremely-low-frequency radiowave propagation from vertical and horizontal electric dipoles in a half-space, separated by an infinite slab from another half space, is discussed and application is made to the specific case of the seawater - atmosphere - ionosphere problem, with dipoles located in the seawater. Each of the media is assumed homogeneous and isotropic. When attention is restricted to the frequency range 1 to 1000 c/s, integration in the complex plane leads to consideration of the pole corresponding to the TEM mode of transmission and two branch cut integrals. One of these (that giving rise to propagation of energy along and in the ionosphere) is found to be important in the case of the horizontal dipole.

THE HORIZONTAL ELECTRIC DIPOLE IN A CONDUCTING HALF SPACE
Scripps Instn. of Oceanography, La Jolla, Calif., Ref. 53-33,
September 1953.
A. Banos, Jr., J.P. Wesley

This report gives a complete and thorough account of the mathematical problems involved in the determination of the electromagnetic field components generated by a horizontal electric dipole embedded in a conducting half-space whose plane boundary is also horizontal. The problem is formulated by introducing the Herizian vectors or polarization potentials and employing the technique of tripole Fourier transforms in Cartesian coordinates, in configuration space as well as in transform space. Suitable integral representations are obtained for the components of the Herizian vectors.

THE HORIZONTAL ELECTRIC DIPOLE IN A CONDUCTING HALF-SPACE
Scripps Instn. of Oceanography, La Jolla, Calif., Ref. 54-31,
August 1954.
A. Banos, Jr., J.P. Wesley

This report, Part II, constitutes the culmination of a research study which was described initially in a paper of the same title, Part I, that appeared as SIO reference 53-33, September 1953, and provides a further account of the mathematical theory involved in the determination of the electromagnetic field components generated by a horizontal electric dipole embedded in a conducting half-space separated from the non-conducting medium above by a horizontal plane. In particular, a detailed account is given of the computations involved for points of observation in the non-conducting medium when the depth of the source and the height of the point of observation are small in comparison with the horizontal range.

CONDUCTING ANALOGS OF A MAGNETIC FIELD
EE Abstr. 623/1960; Amer. J. Phys., (USA), V. 28, No. 2, Pgs 139-44,
February 1960.
J.R. Barker

The distribution of electric current in a conducting medium has a close analogy with the distribution of magnetic flux in a geometrically similar magnetic field. There is a second form of the analogy, when the field is two-dimensional, in which the electric equipotentials correspond with the magnetic flux lines.

RADIATION OF ELECTROMAGNETIC WAVES FROM A POINT SOURCE IN A GYROTROPIC MEDIUM WITH A BOUNDARY SURFACE
EE Abstr. 6187/1961; Radiotekhnika i Elektronika (USSR), V. 4, No. 11,
Pgs 1759-64, November 1959.
K.A. Barsukov

The Sommerfeld problem of the field of a point source in a system of two media with a boundary of separation is generalized to the case of gyromagnetic media. The final formulae obtained for the field components are complex but take a simple form under certain conditions. As a particular case the field of a vertical radiator located at the boundary of the ionosphere and the atmosphere is considered taking the earth's magnetic field into account.

THE MAGNETIC FIELD OF A PLANE CIRCULAR LOOP
J. appl. Phys. (USA), V. 21, No. 11, Pgs. 1108-1114, 1950.
C.L. Bartberger

No abstract.

LIMITING CONDITIONS FOR THE ELECTROMAGNETIC FIELD ON THE SURFACE WITH AN ARBITRARY VALUE OF DIELECTRIC CONSTANT

See Section I, Page 9.

F.G. Bass

LOW-FREQUENCY EDDY-CURRENT LOSSES IN A CYLINDRICAL ROD

Phys. Abstr. 9183/1960; Bull. Acad. Roy. Belgique Cl. Sci., V. 45, No. 9, Pgs 870-5, 1959.

O. Beaufays

A general formula, giving the eddy current loss in cylindrical rods of arbitrary section, was derived. It is found that the loss is independent of the permeability of the material forming the cylinder.

FERROMAGNETISM

Springer-Verlag, Berlin, 440 p., illus., 1939.

R. Becker and W. Doring

ON THE DIRECT ELECTROMAGNETIC EFFECT OF AN A.C. EMITTER ON THE SURFACE OF A HOMOGENEOUS EARTH

Phys. Abstr. 2325/1955; Ann. Geophys. (France), V. 7, No. 3, Pgs 415-40, July 1954.

A. Belluigi

A brief discussion of Sommerfeld's classical theory of a horizontal dipole is followed by a discussion of the Horton-Lewis theory. The theory is then extended to include the variation of the dielectric constant of the earth with frequency and finally generalized to include other types of oscillator. Graphs and tables are included to assist in the application of this theory to electrical prospecting.

INPUT RESISTANCES OF HORIZONTAL ELECTRIC AND VERTICAL MAGNETIC DIPOLES OVER A HOMOGENEOUS GROUND

EE Abstr. 1191/1964; IEEE Trans. Antennas and Propagation (USA), Vol. AP-11, No. 3, 261-6, May 1963.

B.K. Bhattacharyya

Expressions for the total power flow from a vertical oscillating magnetic dipole and a horizontal electric dipole are employed to determine the input resistances of both types of aeriels placed above a homogeneous and isotropic ground. Theoretical curves of the input resistance are drawn for the two cases as a function of the normalized height of the aerial above the ground for fixed values of the permittivity and the ratio of conduction and displacement currents. The input resistance is affected appreciably when the conductivity is altered only by a factor of ten.

The curves show marked changes with change in permittivity when the displacement current is not negligible compared with the conduction current. The ratio of the height of the aerial above the ground to the radiated wavelength should be kept smaller than 0.3 to obtain any appreciable variation of the input resistance with changes in either the conductivity or the permittivity. Factors determining a judicious choice of the height and the wavelength are discussed. A comparison between a horizontal electric dipole and a vertical magnetic dipole is made, so far as their input resistances are concerned.

ELECTROMAGNETIC FIELDS OF A VERTICAL MAGNETIC DIPOLE PLACED ABOVE THE EARTH'S SURFACE

Phys. Abstr. 19439/1963; Geophysics (USA), Vol. 28, No. 3, Pgs 408-25, June 1963.

B.K. Bhattacharyya

Electromagnetic fields due to a small loop aerial placed above the surface of a homogeneous and isotropic earth have been calculated. The effect of both the conduction and displacement currents are taken into account. Because of the complexity of the functions defining the fields, expressions valid separately for high and low frequencies are developed for the electric and magnetic field components. These expressions are then utilised to determine, for a step-function current source, (a) the mutual impedance function $Z_m(t)$ between the primary loop and a small length of wire and (b) the voltage $v(t)$ induced in a secondary loop. Two parameters are used to fix the locations of the primary loop and the receiving aerial with respect to the earth. A number of curves are plotted showing the mutual impedance function and the voltage function against time for different values of the parameters and the conductivity and the permittivity of the earth. With increase in either the conductivity or the permittivity, the amplitude and the rate of decay of the two functions decrease appreciably. However, the amplitudes of both $Z_m(t)$ and $v(t)$ become smaller and the rate of decay higher as the receiving aerial is gradually lifted vertically from the ground. For all values of permittivity, the amplitude of the mutual impedance rises to a maximum with the horizontal separation between the two aeriels before beginning to decrease, but at the same time the rate of decay of the transient becomes faster. With increase in the horizontal separation, the amplitude of the voltage function decreases inversely as the fifth power of the distance between the image of the transmitting dipole and the receiving aerial, but the rate of decay increases markedly.

EXPERIMENTAL VERIFICATION OF DIPOLE RADIATION IN A CONDUCTING HALF-SPACE

IEEE Abstr. 1192/1964; IEEE Trans. Antennas & Propagation (USA), AP-11, No. 3, 269-73, May 1963.

W.E. Blair

A laboratory size model of the flat earth-air (two-layer) problem, constructed to verify certain proposed theories on electromagnetic propagation through the sea, is described. The modelling system is used in

scaling and measuring electromagnetic field components of electric or magnetic aeri-als submerged in sea water. Specifically, the experimental results are compared with the theory of radiation from a horizontal electric dipole aerial submerged in the sea. The results presented here verify that (1) the cylindrical coordinate E_r and E_θ field components measured in the sea vary with radial distance from the aerial as ρ^{-3} in the near-zone and ρ^1 and ρ^2 , and respectively, in the far-zone; (2) all field components vary with depth, z , as $\exp(-z/d)$, where d is skindepth; (3) the E_r and E_θ components vary θ as $\cos \theta$ and $\sin \theta$, respectively; (4) all field components vary linearly with length l and dipole current, I . In addition, the H_θ , H_r , and E_z components were measured in the air as a function of ρ for the static-zone, near-zone, and far-zone. The modelling system representing the sea includes a cylindrical tank 11.5 ft. in diameter, 2 ft. deep, containing a salt solution of 4 mhos/meter conductivity. The transmitting frequency varied from 100 to 400 Mc/s. For submerged aeri-als that can be validly scaled at least 10^{-2} in size and 10^4 in frequency, this model can conveniently be used to verify experimentally the radiation characteristics of these aeri-als.

DIDACTIC NOTE ON SOMMERFELD'S PROBLEM

Phys. Abstr. 24464/1964; Atti. Accad. Sci., Torino I (Italy), Vol. 96, No. 5a-6a, 820-38, 1961-62. In Italian.
M. Boella, F. Einaudi

The problem considered is the analytical determination of the effect of a plane finitely conducting earth upon the radiation of an oscillating dipole. Various classical solutions are considered and ambiguities arising from conventional definitions of a "unit" dipole are discussed.

ELECTRICALLY SMALL ANTENNAS AND THE LOW-FREQUENCY AIRCRAFT ANTENNA PROBLEM

Phys. Abstr. 1764/1954; Inst. Radio Engrs, (USA), Trans., V. AP-1, Pgs 46-54, October 1953.
J.T. Bolljahn

Deals with the properties of aeri-als which are small relative to their operating wavelength. A brief analysis based upon quasi-static principles is presented. and two experimental procedures suggested by the nature of the analytical results are described. The application of these experimental procedures is illustrated with examples of measurements made in connection with the design of l.f. aircraft aeri-als.

ON THE RECEPTION OF ELECTROMAGNETIC WAVES

H. Bondi
See Section I, Page 12.

THE INTERACTION BETWEEN ELECTROMAGNETIC WAVES AND DIPOLES
EE Abstr. 363/1954; Arch. elek. Ubertragung, Germany, V. 7,
Pgs. 463-6, October 1953.
F. Bergnis

Presents a new rigorous derivation of the average real power S_w that can be abstracted from an incident electromagnetic wave by a dipole small compared with the wavelength. The method differs from that of Slater (1942) in carrying out the integration over a small, rather than a very large, spherical surface enclosing the dipole. The method is extended to include the magnetic dipole case, and in both cases the effective cross-section for absorption is shown to be $3\lambda^2/8\pi$.

ELECTROMAGNETIC ENERGY DENSITY IN DISPERSIVE MEDIA
Phys. Abstr. 9151/1960; Z. Phys., Germany, V. 159, No. 1, Pgs. 1-6,
1960.
F. Bergnis

General expressions for electromagnetic energy densities and losses in dispersive media are derived. They depend in general, on the way the fields are established. It is only when fields of harmonic time dependence are established extremely slowly that the energy becomes independent of the transient character of the field and can be represented by a simple expression.

ON THE PROBLEM OF THE PLANE OF PROPAGATION OF THE HORIZONTAL ELECTRIC DIPOLE
G. Boudouris, D. Ilias.
See Section I, Pg.13.

STUDY OF ELECTROMAGNETIC POINT SOURCES
EE Abstr. 1132/1960; Ann. Telecomm, France, V. 14, Pgs 143-50,
Nos. 5, 6, May-June 1959.
M. Bouix

A theorem is proved which shows that any system of electromagnetic sources can be represented by a system of applied electric and magnetic currents flowing on a surface containing all the singularities of the system. Formulae are given for the currents in terms of the electric and magnetic field components at the surface. The current systems giving rise to some fields expressible in terms of spherical polar co-ordinates are derived and consideration of the field arising from a current element shows surprisingly that a magnetic as well as an electric applied current system is required to express the field adequately.

FERROMAGNETISM

Van Nostrand, Illus., 1951. \$22.50.

R.M. Bozorth

THE RADIATION OF A HERTZIAN DIPOLE OVER A COATED CONDUCTOR

EE Abstr. 806/1955; Proc. Instn. Elect. Engr, G.B., Monogr. No. 113 R,
15th December 1954, 18 p.

D.B. Brick

The idealized problems of an infinitesimal Hertzian dipole in and over a perfect dielectric coating a perfect conductor and an Abraham dipole lying on the conductor are treated. Unintegrated forms of the Hertz potential are obtained both for electric and magnetic dipoles. Integrated far-zone forms of the potentials and fields are obtained for electric dipoles by means of asymptotic integrations. Far-zone radiation patterns are given in order to indicate the distortion of the fields and the magnitudes of the residue waves caused by the dielectric coatings. These show that such layers cause very large increase in the relative strength in the direction along the surface. It is proved that the power radiated by the dipole may be divided into two independent quantities - the power fed to radiation-type and that fed to surface or guide-type fields. For certain cases numerical results are given for the total power radiated and the relative powers to feed the two types of fields. Formulae are derived and illustrated with numerical examples of the radiation resistance of the dipoles and the attenuation coefficient of the surface modes due to finite conductivity on the ground plane.

RADIATION FIELDS FROM A HORIZONTAL ELECTRIC DIPOLE IN A SEMI-INFINITE CONDUCTING MEDIUM

IRE Trans Antennas & Propagation (USA), Vol. AP-10, No. 4, 358-62,
July 1962, Phys. Abstr. 20133/1962.

A.W. Briggs

The radiation fields of a horizontal electric dipole in a semi-infinite conducting medium are developed to yield a ground wave near the surface and a space wave above it. Previous work for points of observation slightly above the conducting medium is extended to the entire region by including the height of the observation point in the evaluation of the integral by the saddle point method. The effect of burying a horizontal electric dipole is to modify the field intensity by $\exp(-h/o)$, where h is the depth of burial and o is the skin depth of the medium. As h approaches zero, the expressions for radiation fields are identical with those developed by Norton.

IMPEDANCE BETWEEN PERFECT CONDUCTORS IN A FINITELY CONDUCTING MEDIUM
WITH APPLICATION TO COMPOSITE MEDIA

EE Abstr. 1480/1964; J. Appl. Phys. (USA), Vol. 34, No. 11, 3414,
November 1963.

R.N. Buchal, J.B. Keller

The impedance is calculated between two perfect conductors embedded in a material of finite conductivity. The result is applied to the case of two large parallel perfectly-conducting electrodes, between which is a composite medium consisting of a lattice of perfectly-conducting identical bodies, embedded in a medium of finite conductivity.

ELEKTRISCHE UND MAGNETISCHE POTENTIALFELDER

Springer-Verlag, Berlin, 1957.

H. Buchholz

THE IMPEDANCE OF AN AERIAL IMMersed IN AN ANISOTROPIC MEDIUM

Symposium on Electromagnetic Theory and Antennas, Copenhagen.
25th - 30th June 1962.

K.G. Budden.

No abstract

THE INFLUENCE OF THE EARTH'S MAGNETIC FIELD ON RADIO PROPAGATION BY
WAVE-GUIDE MODES

See Section I, Page 22.

K.G. Budden

ELECTROMAGNETIC ENERGY IN A DISPERSIVE MEDIUM

EE Abstr. 1826/1961; Proc. Inst. Radio Engrs. (USA), V. 48, No. 9,
Pg. 1657, September 1960.

R.E. Burgess

A note pointing out that the dispersive forms of the energy are also those required for the mean thermal fluctuation energy of the electric (or magnetic) fields in a CR (or LR) circuit to comply with the equipartition principle.

DC SIGNALLING IN CONDUCTING MEDIA

Inst. Radio Engrs (USA), Trans. V. AP-10, No. 3, Pgs 328-34, May 1962.
EE. Abstr. 11304/1962.

C.R. Burrows

The electric field produced by the dc current between two spheres is calculated and expressed in terms of input power. The attenuation between these spheres and a pair of receiving spheres considered as a four terminal network is found to be $P_2/P_1 = 1/16 \frac{a_1^2 a_2^2}{r^6}$, where a_1 is

the radius of the transmitting spheres separated by a distance l_1 apart, a_2 is the radius of the receiving spheres separated by a distance l_2 , and r is the distance between transmitter and receiver all in the same units. This equation applies when the line joining the receiving spheres is parallel to the line joining the transmitting spheres and perpendicular to the direction of propagation. For colinear spheres, P_2/P_1 is four times as great but other factors combine to counteract this apparent advantage. The transient responses to a unit step and a unit pulse are calculated and presented as curves. The minimum practical pulse duration for the former configuration is $t_0 = 6\mu r^2 / 8$ where σ is the conductivity and μ the permeability all in mks units. A pulse of the same length is more smeared in the colinear direction and reduced in amplitude by a factor of approximately three, and power by a factor of nine more than counteracting the favourable factor of four for the steady-state condition for colinear spheres.

THE DISTRIBUTION OF THE MAGNETIC FIELD AND RETURN CURRENT ROUND A
SUBMARINE CABLE CARRYING ALTERNATING CURRENT: PART 2.

(See Drysdale, C.V., for Part 1)

Phil. Trans. (GB), V. A 224, Pgs 141-184, 1924.

S. Butterworth

No abstract

MAGNETIC FIELD OF A DIRECT CURRENT IN A SOLID CONDUCTOR OF ANY SHAPE.
APPLICATION TO CYLINDRICAL CONDUCTOR

EE Abstr. 841/1954; Rev. gen. Elect. (France), V. 62, Pgs 536-42,
November 1953.

R. Cazenave

The classical theory of the measurement of magnetic fields based on the idea of magnetic shells is criticised and found to be useless under certain conditions. A new theory based on Laplace's law is explained and the properties of magnetic fields and vector potentials set out. The modified formula and laws of Ampère are obtained for a part of the circuit with, as a special case, the one where the formula approximately reduces to the classical form. The existence of a scalar magnetic potential outside the conductor carrying the currents, and the orthogonality of the magnetic field and vector potential of a cylindrical current, are considered.

ARC LENGTHS ALONG THE LINES OF FORCE OF A MAGNETIC DIPOLE

J. Geophys. Research, Vol. 61, Pgs 485-488, September 1956.

S. Chapman, M. Sugiura

Formulas and tables for the arc length along the lines of force of magnetic dipole are given with reference to the earth treated at a sphere. These tables may prove useful in connection with the study of radio whistlers and of the motion of charged particles along the lines of geomagnetic force.

FIELD OF A LOW-FREQUENCY ELECTRIC DIPOLE SITUATED ON THE SURFACE OF A UNIFORM ANISOTROPIC CONDUCTING HALF-SPACE

Phys. Abstr. 14740/1963; Zh. tekhn. Fiz. (USSR), Vol. 32, No. 11, Pgs 1342-8, November 1962. In Russian. English translation in: Soviet Physics - Tech. Physics (USA), Vol. 7, No. 11, Pgs 991-5, May 1963.

D.N. Chetaev

Fek's problem (1933) of the field of a low-frequency current situated on the surface of a stratified isotropic conducting half-space is here extended to the case of a stratified anisotropic medium in which the horizontal and vertical components of the conductivity tensor are unequal. The solution is expressed in terms of tabulated functions, and its values on the surface of the half-space are expressed in elementary functions.

ETUDE D'UN SYSTEME A 4 BOBINES POUR LA PRODUCTION D'UN CHAMP MAGNETIQUE HOMOGENE

Z. Angew. Math. Phys. (Switzerland), V. 12, Pg. 458, 1961.

P. Cornaz

No abstract

SKIN EFFECT. CALCULATION OF THE EFFECTIVE RESISTANCE OF CONDUCTORS CARRYING ALTERNATING CURRENT

EE Abstr. 1391/1953; Técnica (Portugal), V. 26, Pgs 151-6, December 1952.

A.A. De Carvalho Ferrandes

The propagation of the electromagnetic field in a semi-infinite conductor is considered on the basis of Maxwell's equations and the exponential decrease of current, using the Poynting vector, and the effective resistance of conductors of rectangular and of circular cross-section is calculated. A table gives values of d.c. and of a.c. resistance for various high frequencies.

RADIATION OF PULSES GENERATED BY A VERTICAL ELECTRIC DIPOLE ABOVE A PLANE, NON-CONDUCTING EARTH

EE Abstr. 6806/1961; Appl. Sci. Res. (Netherlands), Vol. 8, No. 4, Pgs 369-77, 1960.

A.T. de Hoop, H.J. Frankena

At a height h above a plane, non-conducting, earth a vertical electric dipole emits an impulsive electromagnetic wave. The resulting electromagnetic field in the air is determined; it consists of a reflective wave which is superimposed upon the given incident wave. The Hertzian vector corresponding to the reflected wave is expressed in terms of a single integral over a finite interval; this interval is written in such a form that its numerical evaluation can easily be performed.

IMPEDANCE OF AN ANTENNA IN A CONDUCTING MEDIUM

EE Abstr. 1000/1963; IRE Trans. Antennas and Propagation (USA), Vol. AP-10, No. 5, Pgs 648-50, September 1962

G.A. Deschamps

Proves that the following familiar proposition still holds when the medium characteristic constants are complex numbers (e.g. lossy medium): the impedance normalized to that of the medium takes the same value at frequency ω in a medium of index n as it does at frequency $n\omega$ in a medium of index 1. The result is applied to an aerial with TEM-waveguide feed.

THE DISTRIBUTION OF A MAGNETIC FIELD AND RETURN CURRENT ROUND A SUB-MARINE CABLE CARRYING ALTERNATING CURRENT. PART I.

(See Butterworth, S, for Part II.

Phil. Trans. (GB), V. A 224, Pgs 95-140, 1924.

C.V. Drysdale.

No abstract

AIR-TO-UNDERSEA COMMUNICATION-ELECTROMAGNETIC FIELDS IN THE TWO MEDIA, CAUSED BY VERTICAL AND HORIZONTAL ELECTRIC DIPOLES IN AIR.

S.H. Durrani

See Section I, Page 32.

AIR -TO-UNDERSEA COMMUNICATION WITH ELECTRIC DIPOLES

S.H. Durrani

See Section I, Page 33.

AIR-TO-UNDERSEA COMMUNICATION

EE Abstr. 7244/1962; Proc. Inst. Radio Engrs (USA), Vol. 50, No. 1, Pgs 96-7, January 1962.

S.H. Durrani

This letter outlines the author's method, developed in the reference paper (Engineering Experimental Station, University of New Mexico, Albuquerque, Tech. Rep. EE-61 (September 1961)) for obtaining solutions to the Sommerfeld integrals over the 'quasi-near' range for the fields produced by a submerged aerial, and gives the approximate \vec{E} and \vec{H} components in this range for both a vertical and a horizontal dipole.

ON THE ELECTROMAGNETIC RADIATION FROM A PULSED DIPOLE IN THE PRESENCE
OF TWO MEDIA

Office of Naval Research, London, ONRL-30-61, 23rd March 1961
L.B. Felsen

In recent years, considerable interest has been shown in problems of electromagnetic radiation from pulsed sources. This report describes a simplified method of analysis employed by de Hoop and Frankena (Electro-technical Dept., Institute of Technology, Delft, Netherlands) for the determination of the fields due to a pulsed dipole situated in a uniform dissipationless, dielectric half-space with a plane boundary.

SUBMERGED ANTENNA CHARACTERISTICS

EE Abstr. 1183/1964; IEEE Trans. Antennas & Prop. (USA), Vol. AP-11, No. 3, Pgs 296-305, May 1963.
R.C. Fenwick, W.L. Weeks

Gives the results of a theoretical and experimental study of the characteristics of aerials in lossy environments, such as aerials buried in the earth or sea. The results of experiments to determine the input impedance of and current distribution on wires of different sizes, insulating thicknesses, depths and environments are summarized and compared to a simple theory. A figure of merit called relative communication efficiency (RCE) for submerged aerials is defined. A table of formulae for RCE of common aerial types is presented and the theoretical results are compared to experimental values obtained by field strength measurements.

ELECTRIC FIELD IN THE OCEAN OF A SUBMERGED HORIZONTAL DIPOLE
Scripps Instn. of Oceanography, La Jolla, Calif., Ref. 53-14,
H.G. Ferris

The structure of the electric fields in the ocean produced by a submerged horizontal antenna is studied theoretically by a method which is essentially an extension of Sommerfeld's work on the problem of the horizontal antenna over an arbitrary plane earth. From the results of Sommerfeld's work together with that of Norton, expressions are found for the electric field components in terms of certain basic integrals. Evaluation of the integrals describing the fields in the water is carried out for the case of low frequency and ranges of less than a wavelength in air but greater than a wavelength in water. The method employed in this evaluation follows an argument suggested to the writer by work of Niessen based upon Green's integral theorem, and consists of extending down into water expressions of Wise and Van der Pol for the integrals along the interface. Thus analytical expressions for the electric field components in the water are obtained which are valid for the ranges and frequencies indicated and which are suitable for computational purposes.

THE FIELD OF A PLANE WAVE NEAR THE SURFACE OF A CONDUCTING BODY

V.A. Fock,

See Section I, Page 38.

THE INTERPRETATION OF CHARACTERISTICS AND FUNDAMENTAL EQUATIONS OF THE ELECTROMAGNETIC FIELD

EE Abstr. 5297/1960; Periodica Polytech. Elect. Engng. (Hungary), V. 3, Pgs 197-215, 1959.

G. Fodor

Electromagnetic fields in vacuum may be defined solely by the electric field intensity vector E and the magnetic flux density vector B . The same quantities describe the field also in continuous media if the material is represented by bound charges and currents. However, this representation is too general to be useful even in the analysis of very simple problems. The introduction of the well-known electric displacement vector D and the magnetic intensity vector H becomes very desirable. The question of the independent existence of these latter vectors is investigated and the conclusion made that the D and H vectors are vector potential-like quantities which are not unequivocally determined by the defining equations.

THE POTENTIAL DUE TO A CURRENT DIPOLE IN AN INFINITE CONDUCTING SLAB.

ESL Technical rept. No. 18, 15th May 1953, Yale University, New Haven, Conn.

D. Foster

A current dipole of arbitrary orientation is embedded in a uniform conductor bounded by infinite parallel insulating planes. The potential is the sum of the potentials due to the parallel and perpendicular components into which the dipole moment is resolved. Using the method of images, the potential due to either component is the sum of the potential arising from two infinite uniformly spaced collinear arrays of dipoles. Mathematically, the problem is to find an approximation to the sum of a slowly converging series of positive terms. This is done in such a way that the arithmetical work is shortened and the relative error is always less than any desired number. Curves are given which show how the errors of certain very simple approximations depend on position in the field. Equipotential surfaces are shown for the parallel component. For this case, at distances greater than twice the thickness, the equipotential surfaces are very close to the circular cylinders characteristic of a linear dipole of uniform density in an unbounded conductor.

ELECTRIC POTENTIAL PRODUCED BY TWO POINT CURRENT SOURCES IN A HOMOGENEOUS CONDUCTING SPHERE

Phys. Abstr. 825/1953; J. appl. Phys. (USA), V. 23, Pgs. 1225-8, November 1952
E. Frank

The electric potential produced by a positive and negative point current sources located in a homogeneous conducting sphere, a problem of interest in the field of electrocardiography, is obtained for arbitrary source locations and separations. Certain special cases of the general solution that are of particular value both experimental and theoretical electrocardiographic research are also presented.

ON THE DISTORTION OF A STATIC, HOMOGENEOUS FIELD IN AN ANISOTROPIC MEDIUM CAUSED BY AN ELLIPSOIDAL CAVITY FILLED WITH ANOTHER ANISOTROPIC MEDIUM

Symposium on Electromagnetic Theory and Antennas, Copenhagen, 25th - 30th June 1962
V. Frank

No abstract

ON THE PENETRATION OF A STATIC HOMOGENEOUS FIELD IN AN ANISOTROPIC MEDIUM INTO AN ELLIPSOIDAL INCLUSION CONSISTING OF ANOTHER ANISOTROPIC MEDIUM

Electromagnetic Theory and Antennas, Proceedings of Symposium held at Copenhagen, Denmark, June 1962, edited by E.C. Jordan, Pg. 615-623.
V. Frank

It is shown that a homogeneous field in an anisotropic medium will penetrate into an ellipsoidal inclusion of another anisotropic medium in such a manner that the field in the inclusion is also homogeneous. The relation between the outer and the inner field is established, and a method for constructing the tensor of depolarizing coefficients for the system is given. The tensor depends both on the shape of the ellipsoid and on the properties of the symmetrical part of the tensor of permittivity of the outer medium. The case of an elliptic cylinder, which presents some special features is also considered.

GENERATION OF UNIFORM MAGNETIC FIELDS BY MEANS OF AIR-CORE COILS
Phys. Abstr. 20097/1962; Rev. sci. Instrum (USA), Vol. 33, No. 9,
Pgs 933-8, September 1962.
W. Franzen

The generation of uniform magnetic fields over extended regions of space by means of circular coils of large cross-sectional area is analysed. It is shown by an extension of Garrett's theory of axially symmetric magnetic fields that the optimum shape of the coil cross-section can be found analytically without numerical integration over the winding area. The theory is illustrated by application to Helmholtz coils and double Helmholtz coils of rectangular cross-section. Choice of the optimum dimensions makes it possible to generate very uniform fields of great intensity.

SUBMERGED VLF RECEPTION. A STUDY OF VARIOUS LOOP COUPLING METHODS.
U.S. Naval. Res. Lab., Washington, D.C. Rept. No. R-2872, 31st December
1946, illus.
S.V. Fratianni

This problem provides for research to yield more effective submerged reception, the present phase relating to the attainment of the best energy transfer from the collecting loop to the receiver. Various coupling units available to the service have been studied. While the study of coupling is the prime consideration, it was found desirable to include the limitations of the various couplers and their usefulness to the Navy. This report contains electric and mechanical information, such as, sensitivity comparisons of various coupling methods, operating characteristics, and mechanical and electrical recommendations.

DISPLACEMENT CURRENTS AND MAGNETIC FIELDS
Phys. Abstr. 12293/1963; Amer. J. Phys. Vol. 31, No. 3, 201-4,
March 1963.
A.P. French, J.R. Tessman

The methods of calculating fields due to quasisteady currents in closed and unclosed circuits are reviewed. It is emphasised that it is sufficient to apply the Biot-Savart law to all the moving charges and to ignore the vacuum displacement current. Attention is drawn to a basic error in the widespread practice of treating a circuit containing a capacitor as though the fringing fields could be ignored and the displacement current replaced by conduction currents confined to the gap between the plates.

ON THE ELECTROMAGNETIC RADIATION FROM A VERTICAL DIPOLE OVER THE SURFACE OF ARBITRARY SURFACE IMPEDANCE
EE Abstr. 5592/1960; J. Radio Res. Lab. (Japan), V. 6, Pgs 269-91, April 1959.
K. Furutsu

A rigorous and explicit solution is obtained for the problem of the electromagnetic radiation from a vertical dipole located over a flat surface of arbitrary surface impedance Z . The solution is valid throughout the whole range of frequency and space. Though there are four asymptotic expansions, the expansion by Hadamard's method seems to have the most explicit physical meaning. According to this expansion, only the ordinary surface wave can be present explicitly on the condition of $\arg \sqrt{1 - \sqrt{1 - Z^2}}/4$. On the other hand, variation of the field over a spherical surface due to the change of surface is investigated by the use of the ordinary Van der Pol and Bremmer formula with slight modification. In this case, when $\arg(Z) > \pi/3$ and Z is larger than some definite value Z_0 , one of the terms of the formula is found to have the asymptotic form similar to the surface-wave term in the flat surface case and, when the surface is highly inductive, it becomes the leading term at a large distance from the dipole. The height-gain factor of this term first decreases rapidly with height up to some point and then gradually increases. On the other hand, when $Z \ll Z_0$, the leading term can scarcely have the correspondence with that in a flat surface case. Finally, the propagation of surface wave over spherical surface across several boundaries of discontinuity of the surface impedance is considered. The leading term is found to take the simple form as in the ordinary transmission line. The results in the case of a flat plane are derived from these results as asymptotic forms in the limit of infinite radius of curvature of spherical surface.

IMPULSE EXCITATION OF A CONDUCTING MEDIUM

EE Abstr. 6706/1960; Inst. Radio Engrs (USA), Trans. V. AP-8, No. 2, Pgs 227-8, March 1960.
J. Galejs

The depth of penetration into a conducting medium, where sinusoidal surface excitation generate peak magnetic fields or derivatives equal to those of an impulse-type surface excitation, is calculated. Finite pulses generate fields similar to those of a surface impulse provided they are sufficiently short. The maximum permissible pulse duration is proportional to the square of the specified penetration depth. In order to exhibit minimum attenuation, the excitation field must be unipolar over a time period comparable with the transient duration. Such fields may be generated within the induction field of the source.

EXCITATION OF VLF AND ELF RADIO WAVES BY A HORIZONTAL MAGNETIC DIPOLE
Phys. Abstr. 7142/1961; J. Res. Nat. Bur. Stand. (USA), V. 45D, No. 3,
Pgs 305-11, May-June 1961.
J. Galejs

The v.l.f. and e.l.f. modes excited by a horizontal magnetic dipole (vertical loop) in the spherical shell between a finitely conducting earth and an isotropic sharply bounded ionosphere are shown to have a nearly transverse magnetic character. The modes are similar to those of a vertical electric dipole. With the exception of the zero-order mode the propagating modes excited by the magnetic dipole are of slightly higher amplitudes, provided that the far fields of the horizontal magnetic and vertical electric dipoles are equal over flat earth in the absence of ionosphere. The transient fields generated by a current step in the magnetic dipole are in the first approximation similar to the fields generated by a current impulse in a vertical electric dipole. Response of the zero-order mode of the magnetic dipole is calculated.

SCATTERING FROM A CONDUCTING SPHERE EMBEDDED IN A SEMI-INFINITE DISSIPATIVE MEDIUM

Applied Research Lab. Sylvania Electronics Systems, Waltham 54, Mass.
Submitted to: J. Res. Nat. Bur. Stand. (USA), Section D, Radio Propagation,
1962. Phys. Abstr. 497/1963.
J. Galejs.

The conducting sphere is embedded in a semi-infinite dissipative medium and is excited by a surface wave or by vertical electric and horizontal magnetic dipoles from the lossless half-space. The sphere acts as a combination of horizontal magnetic and electric dipoles. Its dipole moment depends on the wave incident from the interface of the two media and on the multiple reflections between the sphere and the interface. The transient reflections are calculated after establishing the overall harmonic response of the system.

SMALL ELECTRIC AND MAGNETIC ANTENNAS WITH CORES OF A LOSSY DIELECTRIC
EE Abstr. 13845/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 4,
Pgs. 445-51, July-August 1963.
J. Galejs

A small loop aerial which is wound on a spherical dielectric core is compared with a cylindrical dielectric filled capacitor. Both aeri-als provide comparable radiation resistance and reactance for equal aerial volumes. The electric field near the loop is weaker than in the vicinity of the capacitor. This makes the efficiency of the loop less affected by the presence of a lossy dielectric core. For equal efficiencies and volumes of both aeri-als, the loss tangent of the dielectric in the loop aerial may be higher than that of the comparable capacitor type by a factor of at least $[\lambda / (2\pi a)]^2$ where a is the aerial radius. Practical design problems are discussed and an approximate method for estimating the losses in loop cores of arbitrary shape is presented.

PRODUCTION OF A UNIFORM MAGNETIC FIELD BY MEANS OF AN END-CORRECTED SOLENOID

Rev. Sci. Instrum, (USA), V. 31, No. 9, Pgs 929-934, September 1960.
M.E. Gardner, and others

No abstract

THE FIELD OF A PULSED DIPOLE IN AN INTERFACE

Inst. of Math. Sciences, New York University, New York, N.Y.
C.S. Gardner, J.B. Keller

No abstract

AXIALLY SYMMETRIC SYSTEMS FOR GENERATING AND MEASURING MAGNETIC FIELDS, PART I.

J. Appl. Phys. V. 22, Pg. 1091, 1951.
W. Garrett

No abstract

TABLES OF THE INTERNAL MAGNETIC SOURCE FUNCTIONS U_n FOR THICK SOLENOIDS AND DISK COILS

$n = 3$ to $n = 17$, to Cosine Arguments, 8 to 5 Decimals, with Second differences. With a short Table of the External Source Functions W_n numerical examples of some applications of the functions, with notes, equations, and auxiliary tables.
AD 22130; Research Corp., Ann Arbor, Michigan, 13 p. plus tables. 1953.
M.W. Garrett

No abstract

FLUX DENSITY IN A CYLINDRICAL AND UNIFORM COIL OF FINITE LENGTH

Phys. Abstr. 11749/1962; C.R. Acad. Sci. (France), Vol. 254, No. 7, Pgs 1216-18, 12th February 1962. In French.
J. Gelard

The flux density is derived in terms of elliptic integrals of the first and the third kinds for a finite and a semi-infinite coil. Special formulae are provided for the flux near the edges of coils.

CALCULATION OF INDUCED MAGNETIC MOMENT IN AN OBLATE FERROMAGNETIC ELLIPSOID OF REVOLUTION IN AN ALTERNATING MAGNETIC FIELD.

Soviet Physics-Technical Physics, (USA), translated from Zh. tekhn. Fiz., (USSR), V. 28, No. 3, Pgs 592-598, 1958.
L.A. Gel'bukh

No abstract

THE RADIATION-TO-MEDIUM COUPLING IN AN UNDERGROUND COMMUNICATION SYSTEM

Proc. Nat. Elect. Conf. (USA), V. 16, Pgs 279-289, 1960.
R.N. Ghose

No abstract

A VLF ANTENNA FOR GENERATING A HORIZONTALLY POLARIZED RADIATION FIELD.
Tech. Rept. 2, Contract AF 18(600)-1552, Electrical Engineering Dept.,
California Inst. of Technology, Pasadena, Calif., (July 1957).
AFOSR-TN-57-9. AD-115 041.
R.M. Golden, R.S. Macmillan, W.V.T. Rusch.

The radiation fields of a half-wave, horizontal, linear antenna, located at the surface of an imperfect earth, have been calculated. The results of this calculation are as follows:

- (1) A horizontally polarized field is radiated in the plane normal to the centre of the antenna.
- (2) A vertically polarized field is radiated along the axis of the antenna.
- (3) The vertically polarized field is zero in the plane normal to the centre of the antenna.

The methods used in this technical report to analyze the radiation properties of this antenna can be generalized to certain types of more complicated antenna-systems.

DESIGN AND CONSTRUCTION OF EQUIPMENT USED TO OPERATE A COMMERCIAL POWER LINE AS A VERY LOW FREQUENCY ANTENNA.

Tech. Rept. 3, Contract AF 18(600)-1552. Electrical Engineering Dept., Calif. Inst. of Technology, Pasadena, Calif., (1st October 1958)
AFOSR-TN-58-908. Ad-204 514.
R.M. Golden, and others

A system which employs a single-phase, medium voltage power line as a VLF transmitting antenna has been described, and the design and construction of the necessary components have been presented. Excluding the safety network, the only equipment necessary to convert the line into an antenna was:

- 4 high-voltage parallel-resonant circuits
- 2 low-voltage parallel-resonant circuits
- 4 series resonant circuits

Although most of this equipment is available commercially, it was found necessary to construct several of the above components. A number of possible uses of this antenna system in vertical propagation experiments have been suggested. However, this paper describes only the theory and details of construction of the system as an aid to researchers who may desire to construct a similar system.

IMPEDANCE OF LONG ANTENNAS IN AIR AND IN DISSIPATIVE MEDIA
Phys. Abstr. 1945/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 67D,
No. 3, Pgs 355-60, May-June 1963.
D.W. Goech, C.W. Harrison, Jr., R.W.P. King, T.T. Wu.

Graphs are provided for the normalized impedance of centre-driven cylindrical dipole aeriols when immersed in air or in a dissipative medium. The electric half-length ranges from 1 to 100 for dipoles in air and from 1 to 19.7 for dipoles in a dissipative medium. Three ratios of radius of the aerial to wavelength have been used. The properties of the medium are expressed in terms of the ratio α/β in the range from zero to one where β and α are, respectively, the real and imaginary parts of the complex propagation constant k .

SOME PRELIMINARY EXPERIMENTAL TESTS OF A NOVEL METHOD OF RADIATING AT VERY LOW FREQUENCIES
Phys. Abstr. 19015/1961; Nature (GB), Pgs 332-3, April 22nd 1961, (Vol.10).
R.N. Gould

Describes the use of a long narrow peninsular (in Loch Long-Gareloch area) composed of poorly conducting material, as a radiator at v.l.f. The cable energizing the radiator was placed across the root of the peninsular, its ends were earthed in the sea and power was fed into its mid-point. The transmitter delivered 50 W at 10 kc/s. Genuine radiation effects were observed and an attempt was made to determine impedance characteristics of the radiator.

THE ELECTRIC DIPOLE IN A LOSSY MEDIUM
Proc. of the Nat. Electronics Conf., V. 12, Pgs. 858-869, 1956.
L.A. Gregory

No abstract

THE MAGNETIZATION OF LONG CYLINDERS IN WEAK CONSTANT FIELDS
Latv. PSR Zinat. Akad. Vestis (USSR), No. 2, (151), Pgs 73-7, 1960.
G. Grinberg

It is shown that it is most convenient in calculating the field within a long magnetic rod to use a variable which is the length variable referred to the radius. It is also necessary to take account of the permeability of the material. It is shown that for long cylinders, the field distribution depends much more on the permeability than on the position at which the field is measured. The distributions which are derived are in terms of two special functions which are given.

PENETRATION OF TRANSIENT ELECTROMAGNETIC FIELDS INTO A CONDUCTOR
Phys. Abstr. 7204/1959; J. appl. Phys. (USA), V. 30, No. 5,
Pgs. 682-6, May 1959.
A. Grumet

The case of a uniform electric field, infinite in extent, abruptly applied to the plane face of a semi-infinite conductor is considered. The amplitude of the field as a function of distance into the conductor and of time is then determined for different conductivities. The time element and distance for ignoring the displacement current term in Maxwell's equations is determined. Finally the time and space nature of the applied electric field at distances far removed from the semi-infinite conductor is considered.

METHOD OF DETERMINING MAGNETIC FIELDS OF DISTRIBUTED CURRENTS
EE Abstr. 1486/1964; Zh. Tekh. Fiz. (USSR), Vol. 33, No. 5, Pgs 636-8,
May 1963. In Russian. English trans. in: Soviet Physics-Technical
Physics (USA), Vol. 8, No. 5, Pgs. 473-4, November 1963.
D.B. Gurvich, E.A. Svyadoshch

Considers the problem of calculating the magnetic field produced by distributed currents in a medium (i.e. currents produced by stationary electric currents flowing from electrodes in the medium). Formulae for the spherical polar components of the magnetic field are obtained in terms of the multipole coefficients of the potential of the distributed current potential.

GROUND SYSTEM STUDIES OF HIGH POWER VLF ANTENNAS
W.E. Gustafson, T.E. Devaney, A.N. Smith
See Section I, Page 47.

ANTENNA MODEL STUDIES RELATED TO THE DESIGN OF THE NORTH ATLANTIC VLF
TRANSMITTING STATION
Research & Development Rept. for June 1955 to 1st March 1958. NEL
Report 844, US Navy Electronics Lab. San Diego, Calif., 19th December
1958. AD-217 424.
W.E. Gustafson, T.E. Devaney, N.H. Balli.

Model studies of three antenna types - the Goliath, the Trideco, and the Triatic - were conducted as part of a comprehensive vlf systems study conducted in connection with design of a 2-megawatt transmitting station to be built at Cutler, Maine. The straight-forward ground system design of the Goliath and Trideco antennas makes them preferable to the Triatic. For economy and ease of maintenance, grounded outer towers and guys are superior to insulated structures. For a given radiated power and efficiency, guyed structures are more economical than unguyed structures. The measurement techniques employed are appended.

DESIGN CRITERIA FOR BURIED ANTENNAS

Boeing Aircraft Co., Preliminary Report D2-7760, January 1961.
A.W. Guy, G. Hasserjian

No abstract

EXPERIMENTAL DATA ON BURIED ANTENNAS

Boeing Aircraft Co., Preliminary Report D2-11190
A.W. Guy

No abstract

ELECTRIC AND MAGNETIC IMAGES

Proc. Instn. Elect. Engrs. Mongr. 379, publ. May 1960, 88 p.
to be published in Part C.
P. Hammond

The method of images as applied to electrostatic, magnetostatic and electromagnetic fields is investigated. By considering the uniqueness of the field it is shown within what limits the methods can safely be used, and rules are given for its use. The application of the method is illustrated by a discussion of the electric field near a cylindrical cathode and the magnetic fields near the end-windings of electrical machines.

THE ELECTRIC FIELD AT THE GROUND PLANE NEAR A DISK-LOADED MONOPOLE
Phys. Abstr. 16040/1962; J. Res. Nat. Bur. Stand. (USA), Vol. 66D,
No. 2, 205-10, March-April 1962.
J. Hansen, T. Larsen

In calculating ground losses for aerials with a ground-wire system, it is necessary to know the vertical electric-field strength and the tangential magnetic field strength at the surface of the ground. In this paper the vertical electric field strength at the ground plane near the base of an electrically short vertical aerial with a top loading in the shape of a circular disk is calculated. Numerical computations are carried out to some extent.

RADIATION AND RECEPTION WITH BURIED AND SUBMERGED ANTENNAS

Electromagnetic Theory and Antennas, edited by E.C. Jordan.
Proceedings of a Symposium held at Copenhagen, Denmark, June 1962.
Pgs 1173-1177.
R.C. Hansen

Antennas in lossy media and propagation along loss interfaces have, like optics, been enjoying a postwar renaissance after many

decades of theoretical and experimental efforts. However, much of the literature on the subject is either highly mathematical or fragmentary. The purpose of the paper is to trace in broad fashion the historical development, to discuss the several approximate solutions to the field integral, to derive merit factors, and to present a physical picture of the radiation mechanism.

RADIATION AND RECEPTION WITH BURIED AND SUBMERGED ANTENNAS
EE Abstr. 1180/1964; IEEE Trans Antennas & Propagation (USA), Vol. AP-11, No. 3, Pgs 207-15, May 1963.
R.C. Hansen

Intends to present a link between the abstruse boundary value problem solutions and the systems engineer. A brief bibliographic review of the boundary problem is given, followed by a discussion of the several approximate solutions and their regions of validity. The propagation path, for almost all practical applications, consists of an evanescent wave from the transmitting aerial to the surface where a conventional Norton surface wave is excited. Part of the wave energy leaks into the lossy medium, thus reaching the receiving aerial. Merit factors are given for three types of aerial loops and dipoles in insulating radomes, and an insulated long wire with end electrodes. A particularly useful merit factor, relative gain, which relates vertically polarized power per unit solid angle over the surface to total input power, is defined. The long wire is shown to be appreciably superior to loops or dipoles. Among the latter two, superiority depends on the relative sizes of radome, skin depth and wavelength. A simplified physical model is presented wherein the fields of the long wire are derived from a vertical quadripole of conduction current. Due to the low mutual impedance between aerials in lossy-media, some array gain can be realized without concomitant beam sharpening.

LOW-FREQUENCY SUBSURFACE ANTENNAS
EE Abstr. 1190/1964; IEEE Trans. Antennas & Prop. (USA), Vol. AP-11, No. 3, Pgs 225-31, May 1963.
G. Hasserjian, A.W. Guy

The fields of a dipole in a semi-infinite conducting medium are discussed and experimental verification of theoretical approximations presented. From these results, concepts and criteria are developed to determine optimum, subsurface aerial configurations. Impedance and mutual coupling properties of such aerials are discussed in the companion paper entitled "Impedance Properties of Large Subsurface Antenna Arrays". (See Abstr. 1208 of 1963).

SOME THEORETICAL CONSIDERATIONS ON INDUCED POLARIZATION
Phys. Abstr. 3602/1958; Geophysics (USA), V. 23, No. 2,
Pgs. 299-304, April 1958.
J.H. Henkel.

The phenomenon of induced polarization is treated as an induced electromotive force, leading to a polarization constant which is included in the effective resistivity of polarizable materials, such as earth materials. The transmission of sinusoidal electromagnetic waves through a polarizable earth is treated for frequencies above 30 c/s. The polarization induced in a two-layer earth is treated theoretically and calculations are presented.

FORCES AND FIELD STRENGTHS IN THE ELECTROMAGNETIC FIELD
EE Abstr. 3931/1960; Elektrotech. u. Maschinenbau, (E. u. M)
(Austria), V. 76, No. 24, Pgs 608-13, 15th December 1959.
H. Hefmann

Explains the distinction between "direct" and "ponderomotive" forces in the electromagnetic field and relates them to the field vectors.

EQUIVALENT DIAGRAMS FOR ELECTROMAGNETIC FIELDS
EE Abstr. 12524/1963; Arch. Elektrotech, (Poland), Vol. 12, No. 1,
39-46 (1963). In Polish.
J. Hryńczuk

Presents a method of obtaining equivalent diagrams for electromagnetic fields by expanding operational impedance expressions into continued fractions. To illustrate the method three examples most often met have been considered, viz. a conductor with a circular cross-section, a cable screen and a single-wire overhead line. In a relatively simple way an equivalent diagram may be obtained without exact knowledge of the behaviour of the analysed electromagnetic field. Diagrams thus obtained are valid for processes of arbitrary type, which enables simple modelling of complex configurations and opens new analytical possibilities.

REMOTE CONTROL BY "NEAR" MAGNETIC FIELD
EE Abstr. 237/1960; Electronic Industr. (USA), V. 18, No. 7,
Pgs. 82-5, July 1959.
J.J. Hupert

The induction field is compared with the radiation field and its characteristics studied. The pattern of the near electric field is

similar to that of the far field but its intensity is lower than that of the near magnetic field. The polarization of the near magnetic field is elliptical but at very near distances it becomes linear again. Plots of the magnetic field for the two conditions are given and optimum orientation for the receiving aerials are indicated.

THE MAGNETIC FIELDS OF A FERRITE ELLIPSOID
Canad. J. Phys. V. 36, Pgs. 1072-1083, 1958.
R.A. Hurd

Approximate expressions are found for the internal and the adjacent external magnetic fields of a small ferrite ellipsoid under plane wave excitation. Consideration is given to the variation of apparent susceptibility with the size of the ferrite.

THE INSULATED DIPOLE ANTENNA IMMERSSED IN A CONDUCTING MEDIUM
Electromagnetic Theory & Antennas, edited by E.C. Jordan, Proceedings of a Symposium held at Copenhagen, Denmark, June 1962, Pgs 1179-1182.
K. Iizuka

It is the object of this investigation to measure the driving-point admittance and the amplitude and the phase distribution of the current relative to those at the driving-point for an insulated cylindrical antenna immersed in a conducting medium.

AN EXPERIMENTAL STUDY OF THE HALF-WAVE DIPOLE ANTENNA IMMERSSED IN A STRATIFIED CONDUCTING MEDIUM
EE Abstr. 13440/1962; IRE Trans Antennas & Propagation (USA), Vol. AP-10, No. 4, Pgs 393-9, July 1962.
K. Iizuka, R.W.P. King

Measurements are described of the driving-point admittance and the amplitude and phase distributions of the current for a half-wave dipole aerial immersed in a stratified medium for various gradients S of the ratio $\sigma/\omega\epsilon_r\epsilon_0$ $b+sx$, where the origin of the co-ordinates is at the driving point of the dipole aerial and the x axis is along the aerial. The study includes a description of the apparatus, a discussion of the effect of the nylon films separating the layers, and an interpretation of the data. Reference is made to the possible application of a half-wave dipole aerial to the detection of an inhomogeneity in a medium.

THE DIPOLE ANTENNA IMMERSSED IN A HOMOGENEOUS CONDUCTING MEDIUM
EE Abstr. 13439/1962; IRE Trans Antennas & Propagation (USA), Vol. AP-10, No. 4, Pgs 384-92, July 1962.
K. Iizuka, R.W.P. King

It is the object of this investigation to measure the driving-point admittance, the amplitude distribution of the current, and the phase

distribution of the current, relative to the phase at the driving-point for a dipole aerial immersed in a homogeneous conducting medium. Measurements of the driving-point admittance were made for a range of values of the ratio $\sigma/\omega\epsilon_r\epsilon_0$ of the medium taking the electrical height of the antenna βh as a parameter. The ratio $\sigma/\omega\epsilon_r\epsilon_0$ is varied from $\sigma/\omega\epsilon_r\epsilon_0 = 0.036$ to $\sigma/\omega\epsilon_r\epsilon_0 = 8.8$ and the aerial height βh is varied from $\beta h = 0.1$ to 2π at intervals of 0.1. The amplitude and phase distribution of the current have been measured for $\beta h = \pi/2, 3\pi/4, \pi,$ and $5/4\pi$ in a homogeneous conducting medium whose conductivity is varied from $\sigma/\omega\epsilon_r\epsilon_0 = 0.036$ to $\sigma/\omega\epsilon_r\epsilon_0 = 8.8$.

THE DIPOLE ANTENNA AS A PROBE FOR DETERMINING THE ELECTRICAL PROPERTIES OF A STRATIFIED MEDIUM

EE Abstr. 5337/1963; IRE Trans Antennas and Prop. (USA), Vol. AP-10, No. 6, Pgs 783-4, November 1962.
K. Iizuka, R.W.P. King

A note describing in detail, with numerical results, a simple experiment using a sub-divided (electrolytic) tank in which is immersed a microwave dipole aerial. Admittance measurements demonstrate the limited volume within which a change of medium conductivity is observable, and hence that the dipole can be used to examine localized inhomogeneity.

EFFECT OF A DISSIPATIVE MEDIUM OF FINITE SIZE ON ANTENNA MEASUREMENT

Phys. Abstr. 21977/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 4, Pgs. 397-403, July-August 1963.
K. Iizuka, R.W.P. King

An experimental investigation was made of the driving-point admittance of a dipole aerial immersed in a finite dissipative medium in order to obtain fundamental information about the dependence of the admittance upon the size of the medium. This information is intended to assist in determining the size of a tank filled with a dissipative medium for use in studying the properties of aerials in such a finite medium. The effect of reflections from the side and back walls was investigated quantitatively by means of sixteen tanks of different sizes. It was shown that a shift in the position of an aerial from the centre of the tank is equivalent to enlarging the dimensions of the tank. A resonance phenomenon was observed and studied in terms of (a) the distortion of the admittance curve as a function of the size of the tank, (b) the distribution of the current on the aerial, (c) the frequency characteristics of the field intensity inside the tank, and (d) the sensitivity of the system to perturbation. Certain precautions to be taken in the design of a dissipative-solution-filled tank are discussed briefly.

NUMERICAL RESULTS FOR THE SURFACE IMPEDANCE OF A STRATIFIED CONDUCTOR
Nat. Bur. Stand. (USA), Boulder Labs., Boulder, Colorado, Technical
Note. No. 143, 19th March 1962.
C.M. Jackson, J.R. Wait, L.C. Walters

Extensive numerical results are presented for the surface impedance
of a horizontally stratified conducting medium. Both two- and three-
layer models are considered and the results are given for both normal
and oblique incidence.

SOLENOID PAIR FOR PRODUCTION OF A SEVENTH-ORDER EXTERNAL FIELD
Phys. Abstr. 5374/1960; Rev. sci. Instrum. (USA), V. 31, No. 2,
Pgs 171-2, February 1960.
J.A. Jungermann, C.G. Patten

The magnetic field is calculated for a coaxial pair of solenoids
having an external axial field which decreases as the inverse seventh
power of the distance from the solenoid centres. The effect of
finite coil thickness is discussed.

WIRBELSTROME UND SCHIRMUNG IN DER NACHRICHTENTECHNIK
Springer-Verlag, Berlin, 1959.
H. Kaden.

DEGREE OF COHERENCE OF THE ELECTROMAGNETIC FIELD
Phys. Abstr. 19437/1963; Phys. Letters (Netherlands), Vol. 5, No. 3,
Pgs 191-2, 1st July 1963.
B. Karczewski

A formula is derived for a quantity which serves as a definition
of the degree of coherence of an electromagnetic field. This can be
determined experimentally, since the formula involves observational
quantities.

SYSTEMATIC IMPROVEMENT OF QUASISTATIC CALCULATIONS
Symposium on Electromagnetic Theory and Antennas, Copenhagen, 25th to
30th June 1962.
S.N. Karp

No abstract.

THE HALF-WAVE CYLINDRICAL ANTENNA IN A DISSIPATIVE MEDIUM: CURRENT AND IMPEDANCE

Phys. Abstr. 12701/1960; J. Res. Nat. Bur. Stand., (USA), V. 64D, No. 4, Pgs 365-80, July-August 1960.

R. King, C.W. Harrison

An integral equation for the distribution of current along a cylindrical aerial in a conducting dielectric is derived. It is shown that the boundary conditions for an aerial in such a medium are formally the same as for an aerial in free space. The equation is solved for the current I and the driving-point impedance Z by means of a technique that achieves sufficiently high accuracy in the leading terms of an iteration procedure so that the higher-order terms do not need to be evaluated. Moreover, these leading terms consist only of trigonometric functions with complex coefficients. The electromagnetic field in the infinite dissipative medium may be computed relatively easily since the current in the aerial is expressed in such simple terms. A numerical analysis is made to determine the properties of an aerial with an electrical length of one-half wavelength in the medium with conductivity and relative dielectric constant ϵ . Universal curves are given of $I/\sqrt{E_v}$ with $\sigma/\omega\epsilon_0\epsilon_v$ as the parameter and $Z/\sqrt{E_v}$ with $\sigma/\omega\epsilon_0\epsilon_v$ as the variable in the range $0.5\sigma/\omega\epsilon_0\epsilon_v \leq 0.4$. A table of numerical values of the impedance is given for media such as an isotropic ionosphere, dry salt, dry earth, wet earth, and lake water.

DIPOLLES IN A DISSIPATIVE MEDIA

Phys. Abstr. 7746/1962; AD 253 465; Cruft Lab., Harvard University, Cambridge, Mass., Technical Rept., No. 336, 42 p., illus. 1961. Also published in EM Waves Symposium, Madison, 1961 (see Abstr. 9255/1962), Pgs. 199-241. EE Abstr. 11288/1962.

R.W.P. King

The problem of a highly conducting cylindrical aerial immersed in a homogeneous isotropic, dissipative medium is examined in detail. An integral equation is obtained for the current on the aerial and an approximate solution obtained by iteration. The electromagnetic field of the aerial is also calculated and the particular cases of the half-wave dipole and the electrically short aerial are examined in great detail.

THE TRANSIENT RESPONSE OF LINEAR ANTENNAS AND LOOPS

EE Abstr. 11277/1962; IRE Trans Antennas & Propagation (USA), Vol. AP-10, No. 3, Pgs 222-8, May 1962.
R.W.P. King, H.J. Schmitt

The transient response of straight wires and circular loops when short pulses are applied is studied experimentally and theoretically. It is shown that the initial response is always that of an infinitely long aerial at a frequency near the upper limit of the frequencies contained in the pulse provided this is sufficiently short so that the first reflection from the end of the wire or loop is not superimposed on it.

THE COMPLETE ELECTROMAGNETIC FIELD OF A HALF-WAVE DIPOLE IN A DISSIPATIVE MEDIUM.

EE Abstr. 1193/1964; IEEE Trans. Antennas & Propagation (USA), Vol. AP-11, No. 3, Pgs 275-85, May 1963.
R.W.P. King, C. Iizuka

The electromagnetic field of a dipole aerial immersed in a homogeneous isotropic dissipative medium is studied theoretically and experimentally. Expressions are obtained for the electric and magnetic fields both near and far in terms of currents and admittances that are more accurate than in conventional formulations. The elliptically polarized field near a half-wave dipole is evaluated theoretically and compared with experimental measurements over a wide range of values of attenuation.

SOME VECTOR FORMULAE AND EXAMPLES OF THEIR APPLICATION

Phys. Abstr. 5579/1953; Fysik T. (Denmark), No. 3-4, Pgs 101-112, No. 5-6, Pgs 163-75, 1952
H.L. Knudsen

Series of vector formulae based on (a) Gauss's theorem, (b) Stokes's theorem, and (c) a line integral over a closed loop are derived and illustrated in problems in (a) electric, (b) magnetic polarization and (c) the field due to a current loop.

EARTH CURRENTS NEAR A TOP-LOADED MONOPOLE ANTENNA WITH SPECIAL REGARD TO ELECTRICALLY SMALL L- AND T-ANTENNAS

Phys. Abstr. 11294/1959; J. Res. Nat. Bur. Stand. (USA), V. 62, No. 6, Pgs 283-96, June 1959.
H.L. Knudsen

An investigation has been made of the ground currents near a top-loaded monopole with non-azimuthal symmetry. Formulae have been developed for the surface current density produced by an inclined, straight wire

over a horizontal ground plane for an arbitrary current distribution on the aerial. Working formulae have been developed and numerical calculations of the surface current density on the ground plane have been carried out for the case of a small aerial with a linear current distribution. These results have been used for the calculation of the contribution to the surface current density due to the top loading in the case of an L-aerial and in the case of a T-aerial. In each case both the absolute value of the surface current density arising from the top loading and the relative value of its ϕ -component under certain circumstances may be important in calculating the ground losses in the case of a system of radial ground wires.

THE ELECTRIC FIELD AT THE GROUND PLANE NEAR A TOP-LOADED MONOPOLE ANTENNA WITH SPECIAL REGARD TO ELECTRICALLY SMALL L- AND T-ANTENNAS, J. Research (D. Radio Propagation) Nat. Bur. Stands. 64D, Pgs 139-151, March-April 1960
H.L. Knudsen, T. Larsen

No abstract

THE AMPLITUDE AND PHASE OF A FIELD WHEN THE COMPONENTS ARE DISTRIBUTED ACCORDING TO LOGNORMAL LAW
EE Abstr. 12522/1963; Radiotekhnika i Elektronika (USSR), Vol. 7, No. 12, Pgs 1988-96, December 1962. In Russian.
L.E. Kopilovich, S. Ya Braude

Calculates the amplitude, phase, and phase difference distributions when

$$x \in \Lambda \left(\mu, \frac{1}{2} \sigma^2 \right), y \in \Lambda \left(\mu, \frac{1}{2} \sigma^2 \right)$$

where x, y are the components of the random electric (magnetic) field vector, $\mu = \overline{\ln x} = \overline{\ln y}$, and $\frac{1}{2} \sigma^2 = (\ln x)^2 - (\overline{\ln x})^2 = (\ln y)^2 - (\overline{\ln y})^2$. The more general case is then considered when

$$|x| \in \Lambda \left(\mu, \frac{1}{2} \sigma^2 \right), |y| \in \Lambda \left(\mu, \frac{1}{2} \sigma^2 \right)$$

TRANSFORMATION OF SOUND AND ELECTROMAGNETIC WAVES AT THE BOUNDARY OF A LIQUID CONDUCTOR IN A MAGNETIC FIELD
Phys. Abstr. 72/1962; Zh. eksper. teor. Fiz. (USSR), V. 41, No. 4, (10), Pgs 1195-1204, October 1961.
V.M. Kontorovich, A.M. Glutsyuk

Calculates the electromagnetic field which arises when a sound wave strikes the boundary between a conducting liquid and a non-conducting medium in a weak magnetic field. The amplitude of the sound wave diverging from the interface on which electromagnetic waves are incident is also determined. (English translation in Society Physics JETP (USA)).

THE LATER STAGE OF THE ESTABLISHMENT OF A MAGNETIC FIELD IN A LAYERED MEDIUM

Phys. Abstr. 2081/1963; Izv. Akad. Nauk. SSSR, Ser. geofiz, 1962; No. 4, Pgs 506-13. In Russian. English trans. in: Bull, Acad. Sci. USSR, geophys. Ser. (USA), No. 4, Pgs 332-6, (April 1962; publ. July 1962).
K.P. Koroleva, O.A. Skugarevskaya

Calculations are given for the later stage of the establishment of a magnetic field in two layered and three layered media with a non-conducting base. The field is generated by a grounded dipole or ungrounded loop. Curves are calculated for different distances from the source.

BASIC EXPERIMENTAL STUDIES OF THE MAGNETIC FIELD FROM ELECTROMAGNETIC SOURCES IMMERSSED IN A SEMI-INFINITE MEDIUM

J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 1, January-February 1960.
M.B. Kraichman

Using electromagnetic sources, consisting of various dipoles and loops immersed in a concentrated sodium chloride solution, measurements were made verifying the magnetic field propagation equations in air, derived previously by several authors. The receiver was farther away from the source than a wavelength in the conducting medium, but much closer than a wavelength in air. An expression is derived giving the value of the magnetic field in air due to a rectangular loop with a horizontal axis by assuming the loop to consist of two electric dipoles corresponding to the horizontal members. Experimental data verifying this expression are presented. Also, using submerged electric dipoles, measurements were made of the magnetic field in air which show that the field is determined solely by the current in the horizontal radiating wires of the dipole.

THE SELF IMPEDANCE OF A CIRCULAR LOOP IN A CONDUCTING MEDIUM

U.S. Naval Ordnance Lab., White Oak, Maryland, NAVWEPS Report No. 7290, 8 p, 1960.
M.B. Kraichman

Integral expressions are derived for the radiation resistance and external self inductance of a circular loop immersed in a conducting medium. These expressions are evaluated for the case where the radius of the loop is much smaller than a wavelength. The radiation resistance and external self inductance are expressed in terms of their values in air plus a correction term due to immersion. Values of the correction terms are plotted as a function of a loop-wave parameter.

IMPEDANCE OF A CIRCULAR LOOP IN AN INFINITE CONDUCTING MEDIUM
Phys. Abstr. 15878/1962; J. Res. Nat. Bur. Stand. (USA), Vol. 66D,
No. 4, Pgs 499-507, July-August 1962.
M.B. Kraichman

Expressions are derived for the resistance and reactance of a circular loop of thinly insulated wire which carries a uniform current and is immersed in a conducting medium. The results for the resistance is compared with that known for a circular loop in spherical insulating cavity.

INDUCTION IN A SMALL LOOP MOVING WITH A MAGNETOSTATIC DIPOLE TOWARDS A CONDUCTING HALF-SPACE.
J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 6, Pgs 731-5, November-December 1962. Phys. Abstr. 5810/1963.
M.B. Kraichman

A formal solution is obtained for the magnetic field produced by a vertical magnetostatic dipole which moves in free space at a constant velocity along the normal to a conducting half-space. Where the velocity of the dipole is much less than that of light, the field in free space is governed by Laplace's equation, and that in the conducting half-space by the diffusion equation. An expression in closed form is derived for the voltage induced in a small loop moving with the dipole. For certain values of the parameters, simplified expressions are obtained for induction. Numerical results are presented for certain cases.

MAGNETIC FIELD OF A FINITE SOLENOID
Phys. Abstr. 6129/1953; Latv. PSR Zinat. Akad. Vestis, (USSR),
No. 9, Pgs 1473-82, 1951.
P.E. Kunin, I.M. Taksar.

Magnetic field of a solenoid of finite length is calculated within an infinitely thin layer on the surface of the solenoid and its component along the solenoid's axis is equal to zero. The solution is a function involving full elliptical integrals.

FORCE-FREE COILS FOR MAGNETIC FIELDS OF INFINITE LENGTH
Phys. Abstr. 11752/1962; Zh. tekh. Fiz. (USSR), Vol. 31, No. 6, Pgs 650-6,
June 1961. In Russian.
A.A. Kuznetsev

A method is given for computing the magnetic forces in coils of infinite length which produce axial and azimuthal magnetic fields. The conditions are found which must be satisfied rigorously by force-free coils of this kind. (English trans. in "Soviet Physics - Technical Physics (USA)", Vol. 6, No. 6, Pgs 472-5, December 1961).

NEW METHOD OF COMPUTING ELEMENTS OF THE MAGNETIC FIELD IN THE UPPER HALF-SPACE ACCORDING TO AN ASSIGNED (ON SURFACE) DISTRIBUTION OF VERTICAL COMPONENT ΔZ .

Phys. Abstr. 21675/1962; Izv. Akad. Nauk SSR, Ser. geofiz, 1962, No. 3, Pgs 317-35; In Russian.
M.I. Lapina, V.N. Strakhov

A new method is advanced for computing the potential fields in an upper half-space from the distribution on the plane of the observed vertical field component, of greater accuracy and requiring less work than those previously suggested. (English trans. in: Bull. Acad. Sci. USSR, geophys. Ser. (USA), No. 3, Pgs 215-26, March 1962; publ. June 1962).

NUMERICAL INVESTIGATION OF THE EQUIVALENT IMPEDANCE OF A WIRE GRID PARALLEL TO THE INTERFACE BETWEEN TWO MEDIA

Phys. Abstr. 16057/1962; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 1, Pgs 7-14; January-February 1962.
T. Larsen

Based on a formula derived by Wait, a numerical investigation of the equivalent impedance of a wire grid parallel to the plane interface between two homogeneous media (ground and air) was carried out. The calculations, which are of special interest to ground wire system design, are carried out for the grid placed in the air as well as in the ground.

THE E-FIELD AND H-FIELD LOSSES AROUND ANTENNAS WITH A RADIAL GROUND WIRE SYSTEM

Phys. Abstr. 16039/1962; J. Res. Bur. Stand. (USA), Vol. 66D, No. 2, Pgs 189-204, March-April 1962.
T. Larsen

Describes an investigation of the ratio between the E-field and the H-field losses per unit area, and the absolute value of these losses around a half-wavelength monopole, a quarter-wavelength monopole, and around electrically short monopoles with as well as without top-loading all of them with a radial ground wire system.

A NOTE ON THE ANALYSIS OF THE FIELDS OF LINE CURRENTS AND CHARGES
EE Abstr. 4890/1962; Proc. Instn. Engrs (GB), Monogr. 466 V. 109 C.
Pgs 86-90, August 1961.
P.J. Lawrenson

Republication of the paper already abstracted as Abstr. 4913/1961.

DISCUSSION ON "ELECTRIC FIELD OF AN OSCILLATING DIPOLE ON THE SURFACE OF A TWO LAYER EARTH"

Geophysics, (USA), V. 11, Pgs. 535-537.

W.B. Lewis

No abstract

RADIATION FROM A HORIZONTAL DIPOLE IN A SEMI-INFINITE DISSIPATIVE MEDIUM

J. appl. Phys. (USA), V. 24, No. 1, January 1953

R.H. Lien

Expressions for the electric field due to an oscillating horizontal dipole placed in a semi-infinite dissipative medium have been derived for the case when the frequency is low. The main work involves the evaluation of some complex integrals which have been reduced to forms for numerical computation.

ELECTROMAGNETIC FIELD OF A DIPOLE SOURCE ABOVE A GROUNDED DIELECTRIC SLAB

EE Abstr. 3433/1954; J. appl. Phys. (USA), V. 25, 733-40, June 1954.

Y.T. Lo

A theoretical investigation of the electromagnetic waves due to a dipole source above a grounded dielectric slab has been made by integral transforms. The solutions in integral form are evaluated asymptotically for distant field. It is found that the fields consist of a space wave and a surface wave. The former, spherical in nature, predominates in the free space, while the latter, cylindrical in nature and with a finite number of modes, is guided along the dielectric. As a result of the existence of at least one pole of the integrand, this surface wave always exists. At the dielectric surface, the zero-order spherical wave has a null value except the case of critical thickness; then it should be referred to the next-order solution.

GEOMETRICAL MODEL OF ELECTROMAGNETIC FIELDS

EE Abstr. 13/1964; Amer. J. Phys., Vol. 31, No. 11, Pgs 871-82, November 1963.

E.S. Lowry

The electrostatic field, electromagnetic waves, electromagnetic induction, and the pure magnetic field are illustrated and explained in terms of a single pictorial representation of the general electromagnetic field of a classical charged particle. The field of a charged particle is described by the orientation and density of a family of surfaces radially distributed about the path of the particle in space-time. This description of the Maxwell field requires no reference to any co-ordinate system or field components.

A VERY-LOW FREQUENCY ANTENNA FOR INVESTIGATING THE IONOSPHERE WITH
HORIZONTALLY POLARIZED RADIO WAVES

R.S. Macmillan, W.V.T. Rusch, R.M. Golden
See Section I, Page 68.

A VLF ANTENNA FOR GENERATING A HORIZONTALLY POLARIZED RADIATION FIELD
Prepublication Papers NBS-IRE PGAP Symp. on Propagation of VLF Waves,
Boulder, Colorado, 23rd-25th January 1957, Voll. II, Paper 18.
R.S. Macmillan, R.M. Golden, W.V.T. Rusch

The radiation fields of a half-wave, horizontal, dipole antenna, located at the surface of an imperfect earth, have been calculated. The results of this calculation are as follows:

1. A horizontally polarized field is radiated in the plane normal to the centre of the dipole.
2. A vertically polarized field is radiated along the axis of the dipole.
3. The vertically polarized field is zero in the plane normal to the centre of the dipole.

The nature of these fields have been verified experimentally.

A NEW ANTENNA TO ELIMINATE GROUND WAVE INTERFERENCE IN IONOSPHERIC
SOUNDING EXPERIMENTS

J. Atmos. Terrest. Phys. Vol. 13, Nos. 1-2, Pgs 183-186, December 1958.
R.S. Macmillan, W.V.T. Rusch, R.M. Golden.

Calculations of the radiation fields of a half-wave, horizontal linear antenna show characteristics ideally suited to ionospheric sounding. Three of these antennas have been built; (1) at 97 kc, (2) at 60 kc, and (3) tunable over 14 to 70 kc.

IMPEDANCE OF A MONOPOLE ANTENNA WITH A RADIAL-WIRE GROUND SYSTEM ON AN
IMPERFECTLY CONDUCTING HALF-SPACE. I.

J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 2, Pgs 175-80, March-April, 1962. Phys. Abstr. 16037/1962.
S.W. Maley, R.J. King.

The effectiveness of a radial wire ground system as an approximation to a radial conducting disk ground system for a vertical monopole antenna over an imperfectly conducting ground is investigated experimentally by means of impedance measurements. The results were compared with theoretical work by J.R. Wait (1954). The comparison shows that Wait's formula for the effective surface impedance of a radial wire ground system gives results which agree well with the measurements.

THE ELECTROMAGNETIC FIELD PRODUCED BY AN ELECTRIC DIPOLE IN A WEDGE SHAPED REGION

Dokl. Akad. Nauk SSSR, Vol. 146, No. 5, Pgs 1039-42, 11th Oct. 1962.
In Russian. English trans. in: Soviet-Physics-Doklady (USA).
Phys. Abstr. 5845/1963
G.D. Malyuzhinets, A.A. Tuzhilin

Considers the problem of diffraction of electromagnetic waves by a wedge shaped obstacle. The method used is a generalization of one first used by Carslaw (Proc. Lond. Math. Soc., Vol. 30, 121 (1898)) and developed by one of the present authors (Malyuzhinets, 1950). As an example of the method the problem considered is the vector problem of the determination of the field of an electric dipole in a wedge shaped region with perfectly conductive boundaries.

AXIAL VARIATION OF THE MAGNETIC FIELD IN SOLENOIDS OF FINITE THICKNESS
AD 48 076; University of Illinois, Urbana, Illinois, 14 p, plus tables, 1954.

D.E. Mapother, J.N. Snyder

No abstract

THE FIELD OF A MAGNETIC DIPOLE IN THE PRESENCE OF A CONDUCTING SPHERE
Geophysics, (USA), V. 18, Pgs 671-84, 1953.
H.W. March

Formulas are derived for the components of the distorted field of a magnetic dipole in the presence of a conducting sphere in a homogeneous medium. In the method employed, the field is resolved into partial fields and the first of which the radial component of the magnetic vector vanishes. From the general formulas, approximate formulas are derived for the field components in the special case in which the conductivity of the medium is low, the radius of the sphere is not too large and both the dipole and the observer are in the vicinity of the sphere. These approximate formulas are within limits applicable to the problem of locating a spherical body of ore buried in a mass of rock.

APPARATUS DRAWINGS PROJECT. REPORT No. 2. MAGNETIC FIELD OF A CIRCULAR COIL

Phys. Abstr. 1179/1960; Amer. J. Phys. V. 28, No. 2, Pgs 147-50, Feb. 1960.
R.G. Marcley

The apparatus to be described will permit a quantitative investigation of the magnitude and direction of a 3-dimensional, cylindrically symmetrical B field, produced by a current-carrying coil. A 400 c/s current through the coil produces a time-varying field which is measured with an accuracy of 2% by a moveable research coil, simple preamplifier, and a.c. voltmeter.

THE EQUIVALENCE OF ELECTRIC AND MAGNETIC SOURCES
Inst. Radio Engrs (USA), Trans. V. AP-6, No. 3, July 1958.
P.E. Mayes

The convenience of introducing nonphysical magnetic current sources into electromagnetic analysis has long been recognized. The distributions of electric currents which yield the same fields are well known for some elementary magnetic current sources. The derivation of a general equivalence relation is quite simple and the application to various problems of propagation in waveguides is quite useful.

ON THE GENERATION OF HOMOGENEOUS MAGNETIC FIELDS
SACLANT ASW Res. Cent. Technical Note No. 7, March 1961.
P.E. Mijnares

In this report a brief account is given of a method of designing coil systems meant to give a magnetic field with prescribed properties. This method, first published by M.W. Garrett, greatly reduces the number of calculations. After a short review of the underlying theory some simple coil systems for the generation of homogeneous magnetic fields are designed.

RADIATION RESISTANCE OF A DIPOLE ANTENNA ABOVE A CONDUCTING PLANE WITH A VIEW TO RADIO-GEOPHYSICAL PROSPECTION
Phys. Abstr. 4850/1959; Proc. Math. Phys. Sec. Egypt, No. 21, Pgs 93-8, May 1957.
F. Minaw

A study is made of the properties of a dipole aerial above a conducting plane. It is found that the radiation resistance of the dipole increases with increase of frequency, till a maximum is reached. After this the radiation resistance varies periodically. From the frequency for the first maximum, it is possible to calculate the distance of the dipole from the conducting plane. For geophysical applications, the present investigation is used as a model for the case of a conducting bed or underground water lying under dry sand in an arid region.

FIELD SOLUTION FOR A DIPOLE IN AN ANISOTROPIC MEDIUM
Electromagnetic Theory and Antennas, Proceedings of a Symposium held at Copenhagen, Denmark, June 1962, edited by E.C. Jordan, Pgs 495-512.
R. Mittra, G.A. Deschamps

In this paper, Maxwell's equations are solved for an anisotropic medium in the presence of an infinitesimally small electric current source with an arbitrary orientation. Three-dimensional Fourier transforms technique is used to obtain the solution of the field equations, and the

inversion of the transforms is discussed in detail. The singular terms representing the very near fields are obtained in a closed form and the remainder of the solution is expressed in a finite range integral whose integrand is finite everywhere, making the form of the solution convenient for numerical calculations. Unlike the solutions obtained by the previous workers, the present one is not restricted either to the far field evaluation or to a lossless medium.

DESIGN CHARTS FOR LOW-FREQUENCY ANTENNA EFFICIENCY

EE Abstr. 2158/1962; Electronics (USA), V. 34, No. 14, Pgs 90-2,
7th April 1961
G.J. Monser

In l.f. systems the designer must be able to predict the conversion efficiency from the transmitter output power to useful radiated power compatible with the radiation bandwidth. Two nomograms are given which enable (1) attainable conversion efficiency to be found knowing aerial size, operating frequency and bandwidth; (2) conversion efficiency and aerial size to be found knowing radiated power and bandwidth. The method is an extension of one described by the author previously (Electronics, Vol. 33, No. 12, 18th March 1960). The nomograms are valid for vertical short monopole aerials up to 0.1 wavelength.

ANTENNAS IN CONDUCTING MEDIA

Paper Summary presented URSI-IRE Spring meeting, Washington, D.C.
16th-18th April 1951, Proc. Inst. Radio Engrs. (USA), V. 39, No. 6,
June 1951.
R.K. Moore

A chief difficulty arises from high losses in the immediate vicinity of the antennas. The input impedance to an antenna in a conducting medium is essentially due to current flowing near the antenna and bears little relation to the field at a distance. Methods for analyzing certain kinds of antennas are shown and results of analysis are compared.

DIPOLE RADIATION IN A CONDUCTING HALF-SPACE

Phys. Abstr. 5478/1962; J. Res. Nat. Bur. Stand. (USA), V. 65D,
No. 6, Pgs 547-63, November-December 1961
R.K. Moore, W.E. Blair

The problem of communication between aerials, submerged in a conducting medium such as seawater, is analysed in terms of a dipole radiating in a conducting half-space separated by a plane boundary from a dielectric half-space. The theory is discussed for both horizontal and vertical, electric and magnetic dipoles.

Expressions for the Hertzian potentials of the dipole in the conducting half-space can be reduced to integrals obtained by Sommerfeld (for a dipole at the boundary) multiplied by an exponential depth attenuation factor. The Hertzian potentials are used to determine the electric and magnetic field components. This analysis shows that the main path of communication between submerged aeri-als is composed of three parts as follows: (a) energy flow from the transmitting dipole directly to the surface of the sea, (b) creation of a wave that travels along the surface refracting back into the sea, (c) energy flow normal to the surface to the receiving dipole.

SUBMARINE COMMUNICATIONS BY ELECTROMAGNETIC MEANS

AD 239 901; University of New Mexico, Albuquerque, New Mexico,
27th April 1960.

R.K. Moore, W.L. Anderson & others

The electromagnetic problems arising in radio communication with submarines operating relatively near the surface are examined. The study treats both propagation and antenna problems. Proposed is an airborne antenna (a trailing wire antenna of 1000 feet, suspended below the aircraft) which is well adapted for VLF transmission. Advantages of this antenna are that it is suspended freely below the craft; it is end-driven, requiring no special ground plane on the craft; its input admittance is controllable through side and end leading impedance; its polarization of radiated field is correct for air to underwater communication and vice-versa. In progress is an experiment designed to extend previous investigations of submerged and surface reception conducted elsewhere. Primarily the experiment will investigate the approximations in the theory of submerged antennas and will check its basic assumption that a "coaxial" antenna originates from a hole in an infinite perfectly conducting screen. It will also check impedance problems associated with feed for uninsulated antennas and various assumptions for loop antennas with different configurations of ferromagnetic and insulating cores.

VERTICAL AND HORIZONTAL, ELECTRIC AND MAGNETIC DIPOLE RADIATION IN A CONDUCTING HALF-SPACE

AD 250 811 University of New Mexico, Albuquerque, New Mexico, Technical Report EE-40, January 1961.

R.K. Moore, W.E. Blair

The problem of communication between a transmitting and a receiving antenna, submerged in a conducting medium of sea water, is a dipole radiating in a semi-infinite conducting half-space, separated by a plane interface from a semi-infinite dielectric half-space. The theory is discussed for electric and magnetic dipoles for both horizontal and vertical antennas. After a discussion of electromagnetic waves in a

conducting medium, the Hertzian potential is derived for both electric and magnetic dipoles. By investigation of contours for the Hertzian potential integrals, the case of the dipole in the conducting half-space can be reduced to that of the Sommerfeld case of an antenna at the interface. Finally the Hertzian potentials are used to determine the electric and magnetic field components for the four cases of the electric and magnetic, horizontal and vertical dipoles. This analysis shows that the main path of communication is such that the transmitted wave travels perpendicularly to the interface, attenuating rapidly and exponentially; travels as a vertically polarized wave almost unattenuated along the surface, part of which refracts back into the conducting medium; and travels perpendicularly from the surface to the receiver again attenuating rapidly and exponentially in the conducting medium.

EFFECTS OF A SURROUNDING CONDUCTING MEDIUM ON ANTENNA ANALYSIS

EE Abstr. 1181/1964; IEEE Trans Antennas & Propagation (USA), Vol. AP-11, No. 3, Pgs 216-25, May 1963.

R.K. Moore

Analysis of aerials immersed in conducting media is, in many ways, quite different from the corresponding analysis for aerials in air. The usual simple techniques applied for determining radiation resistance for aerials in the air break down for aerials in conducting media. The normal concepts of aerial gain and aerial pattern break down when the aerial is in a conducting medium. The pattern, for example, becomes highly dependent upon the choice of the origin of the co-ordinate system. These effects are due to the dissipation of most of the energy in the immediate vicinity of the aerial. Such dissipation is caused by the fields which, for aerials in air, are associated with stored, but not dissipated, energy. The primary purpose of this paper is to illustrate failure of standard aerial analysis techniques when the aerials are in conducting media. Surprisingly, the biconical aerial, whose input impedance requires rather extensive calculations in air, turns out to be extremely simple to analyse in a conducting medium. A discussion of this is presented to show how an analysis can be simplified by the presence of the conducting medium. Comparison of a redefined gain for the biconical, loop, and two forms of straight wire aerials, indicates that there is very little difference between the gains of the different configurations provided the sizes are approximately the same. Although the loop aerial is considered only for dimensions small compared with the wavelength, no such limitation is placed on the other aerials.

AN ISLAND AS A NATURAL VERY-LOW FREQUENCY TRANSMITTING ANTENNA

M.G. Morgan

See Section I, Page 74.

THE RADIATION RESISTANCE OF A STRAIGHT WIRE IN FREE SPACE

EE Abstr. 2736/1953; Arch. elek. Ubertragung, (Germany), V. 7,
Pgs 56-9, January 1952.
R. Müller

By integrating the Poynting vector over an enclosing surface an expression for radiation resistance is found and plotted as a function of $1/\lambda$. Attention is drawn to the fact that the curve has an oscillatory component, which it is stated, has not hitherto been pointed out.

GENERALIZED CONCEPTION OF AERIAL AMPLIFICATION IN THE CASE OF CONDUCTING MEDIA

EE Abstr. 1003/1963; Radiotekhnika (USSR), Vol. 17, No. 8, Pgs 22-5, August 1962. In Russian. English trans in: Telecomm. Radio Engng, Pt 2, (USA), Vol. 17, No. 8, Pgs 19-22, August 1962.
Yu. K. Murav'ev

A brief mathematic contribution to the general theory of aerials in conducting media is presented. Previous investigations by quoted American authors are criticised, and a new method is suggested which considers the amplification factor of the aerial in comparison with a hypothetical omni-directional ideal radiator placed in the same medium, characterized by $E=E_0 e^{-r}/r$ where $\gamma = i.m. \sqrt{\epsilon_r'}$ is the propagation constant, ϵ_r' - complex dielectric constant of the medium, m - phase constant in vacuum and E_0 - proportionality coefficient. Based on the Poynting theorem, equations for the directional aerial are written down in above terms and of gain coefficient G , effective area A and resistive component of the aerial impedance. The derived formulae yield $G=4\pi A/\lambda^2$ for free space, $G=4\pi A/\lambda^2$ for weakly conducting media ($60\sqrt{\lambda} \ll \epsilon_r'$) $G \approx 4\pi A/\lambda^2 30\sqrt{\lambda}$ for strongly conducting media. ($60\sqrt{\lambda} \gg \epsilon_r'$). Practical applications of these expressions are indicated, illustrated by curves plotting G versus dipole-length with dipole wire diameter as parameter.

RADIATION RESISTANCE OF A VERTICAL MAGNETIC DIPOLE OVER AN INHOMOGENEOUS EARTH

Phys. Abstr. 20802/1961; Geophysics, (USA), V. 26, No. 5, Pgs 635-42, October 1961.
J.G. Negi

The expressions for the energy radiated per sec. from an oscillating vertical magnetic dipole situated above a two-layer earth are derived. Of the three important cases to which particular attention has been given, the first and the second involve the presence of a conducting and insulating substratum, respectively. The third deals with a dipole placed over a thin conducting sheet of infinite extent. Appropriate approximations are made such that the results may be useful for geoelectrical exploration.

THE MAGNETIZATION AND FIELD OF ROD-SHAPED OBJECTS

Z. Phys. (Germany), V. 160, No. 3, Pgs 268-276, 20th October 1960.
G. Obermair, C. Schwink

No abstract

MAXWELL'S EQUATIONS AND SYSTEMS OF ELECTROMAGNETIC UNITS

EE Abstr. 1130/1960; Ingegneria, (Italy), V. 33, No. 11, Pgs 985-90,
No. 12, Pgs 1103-8, November and December 1959.
F. Odone

A discussion of the problem of devising a uniform system of units for the various quantities involved in electromagnetic field theory. Suggested systems include modified versions of the Giorgi system, due to Perruca and Palacios respectively.

STROMVERDRANGUNG BEIM SEEKABEL

Archiv für Elektrotechnik, (Germany), V. 7, No. 11, November 1920.
O. Oldenberg

No abstract

COMMENT ON THE PROOF BY W.H. WISE CONCERNING THE NON-EXISTENCE OF ZENNECK'S SURFACE WAVE IN THE FIELD OF AN AERIAL

EE Abstr. 2732/1953; Z. Naturforsch. (Germany), V. 8a, Pgs 100-3, 1953.
H. Ott

The author shows that the much quoted proof of Wise does not exclude the existence of a Zenneck surface in the radiation field of a dipole in the vicinity of a good conducting boundary; the surface wave may even be dominant. The result is due to the failure of the asymptotic series for the Sommerfeld solution in the vicinity of a good conducting boundary a circumstance which appears to have been overlooked previously.

THE ELECTROMAGNETIC FIELD AND CURRENT DISTRIBUTION ALONG AN INFINITELY LONG NON-INSULATED CONDUCTOR IN A CONDUCTING MEDIUM

EE Abstr. 4095/1962; Radiotekhnika i Elektronika (USSR), V. 6, No. 7, Pgs 1106-15, July 1961.
P.P. Pavlov

The electromagnetic field, input impedance and current distribution are investigated for the case of an electromotive force producing a lateral field along a finite segment of the conductor. The attenuation and input impedance are calculated for sea water, damp soil and dry soil for a wire of radius 2 mm. over the frequency range from $6 \cdot 10^3$ to $3 \cdot 10^7$ c/s. Expressions are given for the electromagnetic field in space and for directional characteristics of the wire.

ELECTROMAGNETIC FIELD AND INPUT RESISTANCE OF A LOOP WITH FINITELY LONG CYLINDRICAL FERRITE CORE PLACED IN A CONDUCTING MEDIUM

EE Abstr. 12259/1963; Radiotekhnika i Elektronika (USSR), Vol. 7, No. 3, Pgs 437-47, March 1962. In Russian. English trans in: Radio Engng Electronic Phys. (USA), Vol. 7, No. 3, Pgs 411-21, March 1962. P.P. Pavlov

No abstract

THE MAGNETIC FIELDS PRODUCED BY UNIFORMLY MAGNETIZED ELLIPSOIDS OF REVOLUTION

Phys. Abstr. 6935/1953; Brit. J. Appl. Phys (GB), V.4, Pgs 207-9, 1953. H.J. Peake, N. Davy

Expressions are obtained for the fields produced by a uniformly magnetized ellipsoid of revolution with a given intensity of magnetization at external points on its axes of symmetry. The formulae are stated in a form suitable for arithmetical calculation. Tables and graphs are provided.

THE FIELD INDUCED BY EDDY CURRENTS IN A SEMI-INFINITE SOLID

Phys. Abstr. 11751/1962; Proc. Inst. Radio Engrs. (USA), Vol. 50, No.1, Pgs 88-9, January 1962. R.W. Peterson

Considers the problem of a current-carrying wire at a small distance about a semi-infinite solid of known conductivity and permeability. The drive current in the wire is switched. An asymptotic series is derived giving the magnetic field as a function of time.

SOLUTIONS OF SOME PROBLEMS IN CONSTANT-CURRENT ELECTRIC PROSPECTING

Phys. Abstr. 3436/1963; Izv. Akad. Nauk. SSSR, Ser. geofiz. 1962, No. 6, Pgs 750-7. In Russian. English trans in: Bull. Acad. Sci. USSR, Geophys. Ser (USA), No. 6, Pgs 485-8, (June 1962; publ. Sept. 1962). N.A. Plokhikh

The field of a linear source located at the surface of the earth above a two-dimensionally inhomogeneous medium and parallel to the rock strike is investigated. The method of inversion with respect to a circle is used.

CURRENT DIPOLE IMAGES AND REFERENCE POTENTIALS

EE Abstr. 6599/1963; IEEE Trans. bio-med. Electronics (USA), Vol. BME-10, No. 1, Pgs 3-9, January 1963. R. Plonsey

Reviews the application of image theory to the problem of a current dipole in a homogeneous conducting medium where the boundary is a plane or circular cylinder, and shows how the technique applies to the case of a radial dipole in a spherical volume. The use of images for arbitrary shaped volumes is then considered. A rough criterion is developed and the approximation checked for the case of a "horizontal" dipole in a sphere. Finally the question of zero potentials is reviewed in the context of the previous work and in general.

CALCULATION OF MAGNETIC MOMENTS

Phys. Abstr. 2086/1963; Izv. Akad. Nauk SSSR, Ser. geofiz., 1962, No. 6, Pgs 726-30. In Russian. English trans in: Bull. Acad. Sci. USSR, geophys. Ser. (USA), No. 6, Pgs 472-4 (June 1962; publ. Sept. 1962).
A.M. Polonsky

The method of calculating the magnetic moments of bodies from values of the vertical component Z of the magnetic field in which the remaining integrals need not be taken into consideration (A.M. Polonsky, Bull. Acad. Sci. USSR, geophys. Ser., No. 6 (1961)), is further developed. An arbitrary integration net is considered. The method is generalized for the case of one or more vertical cylindrical bodies of arbitrary cross-section with lower edges receding practically to infinity.

EDDY CURRENT LOSSES IN A SEMI-INFINITE SOLID DUE TO A NEARBY ALTERNATING CURRENT

EE Abstr. 3968/1954; Commun. and Electronics (USA), No. 12, Pgs 97-106, May 1954.
H. Poritsky, R.P. Jerrard

The solid is bounded by a plane face, and the current flows parallel to the face, at a distance h from it. The field components are determined by solving Maxwell's equations, and the solutions give the induced electric field and the magnetic field. These solutions involve h and the conductivity λ and the permeability μ (Assumed constant). Curves are provided in dimensionless form which the complete losses due to the eddy currents may be found. A Fourier integral method is used in solving Maxwell's equations.

CONDUCTING SPHERE IN ALTERNATING MAGNETIC FIELDS

EE Abstr. 3932/1960; Trans. Amer. Inst. Elect. Engrs (USA), V. 78, Pgs 937-42, 1960 = Commun. and Electronics (USA), No. 46, January 1960.
H. Poritsky

Gives an analysis of the field disturbance produced when a conducting sphere is placed in a uniform alternating magnetic field. Applications of theory include eddy-current heating and the location of hidden metallic bodies.

NEAR-ZONE FIELD STRENGTH OF A BURIED HORIZONTAL DIPOLE NEAR AN INTER-FACE

Inst. Radio Engrs. (USA), PG MIL 1961 Winter Convention
J.W. Powers, D.E. Ross

No abstract

THE FIELD OF AN ALTERNATING DIPOLE IN A NON-HOMOGENEOUS SEMI-INFINITE MEDIUM

Phys. Abstr. 551/1957 Czechoslovakia J. Phys. V. 5, No. 4, Pgs 515-27, December 1955.

O. Praus

This has been studied theoretically for the case of a low-frequency dipole at the earth's surface, which is taken to be non-homogenous and semi-infinite with a discontinuity in its conductivity at a given depth. A general solution is derived. From the direct component resistance curves are obtained which can be used in the interpretation of field measurements. The alternating component is used to calculate curves of the mutual impedances of two dipoles. These curves may be useful in determining the depth of the boundary between two layers of different conductivities.

EFFECT OF UNDERGROUND INDUCED POLARIZATION ON ELF PROPAGATION

Phys. Abstr. 19039/1961; J. Geophys. Res. (USA), V. 66, No. 6, Pgs 1596-7, May 1961.

H. Raemer

Schumann (Abstr. 7206 of 1958) and Wait's (Abstr. 12715 of 1960) theory is used to show that such polarization has a negligible effect on the frequencies of resonant modes in the earth-air-ionosphere cavity for frequencies below 1 kc.

ATTENUATION OF MAGNETIC DISTURBANCES IN THE SEA

U.S. Naval Ordnance Lab., White Oak, Maryland, NAVWEPS Rept. No. 7330, 15 p. 7th October 1960.

S.J. Raff

Transmission line methods are used to analyze the attenuation of magnetic disturbances in the sea. A set of formulae are developed by means of which, using Fourier techniques, one can calculate for any magnetic field configuration on the surface, the variation of field intensity with depth in different depths of water with different bottom conductivities. Graphs have been prepared for .02 cycles per second fields in a few configurations of interest using this method. These graphs present the magnetic field at the bottom of two different polarizations, two degrees of field localization, water depths 60 to 3000 feet and a wide range of bottom conductivities. Low bottom conductivity greatly reduces the horizontal component of the magnetic field at the bottom, particularly for fields of large extent. It also increases the vertical component slightly. For average bottom conductivities (.4 - .04 mhos per meter) and field dimensions of 10 to 1000 miles, the attenuation of the horizontal magnetic field in 100 meters of water is about a factor of 2, while the vertical magnetic field is reduced only about 5% below its value at the surface. The amount of the field reduction increases with water depth. The large influence of bottom conductivity and other features of the attenuation are discussed in terms of transmission line concepts.

A PRACTICAL UNDERGROUND TRANSMITTING ANTENNA
Proceedings of the 1960 Conference on the Propagation of ELF Radio
Waves, Nat. Bur. Stand. (USA), Boulder Labs., Technical Note No. 61,
1960.

L. Rawls

No abstract.

ELECTROMAGNETIC INDUCTION IN A HEMI-SPHERICAL OCEAN BY SQ.
J. Geomagn. Geoelect. (Japan), V. XI, No. 3, 1960.
T. Rikitake

A theory of electromagnetic induction within a hemispherical conducting sheet is described. The theory is applied to the induction by sq in a large ocean of uniform depth bounded by two meridians. The patterns of the induced currents are obtained and illustrated both for the 24- and 12-hourly components. Unlike the previous theories, the effect of self-induction, which turns out to be rather important, is fully taken into account. The magnetic fields produced by the currents induced in the ocean amount to several gammas. The electric field in the sea associated with the induction would be of the order of mv/km.

STUDY OF THE ELECTROMAGNETIC FIELD CREATED BY A MAGNETIC DOUBLET IN
THE PRESENCE OF TWO MEDIA SEPARATED BY A PLANE
EE Abstr. 6549/1961; Ann. Telecomm. (France), V. 16, No. 3-4, Pgs 96-
104, March-April 1961.
L. Robin

Consists of a simple problem of the propagation of waves (underground prospecting threw attention on the problem), treated mathematically rigorously in a very general way. Three cases are considered: (1) the case of the doublet with the axis perpendicular to the plane of separation of the two media; (2) with the axis parallel to the plane; (3) the general case which results from the superimposing of the two former cases. The case of particular media are also studied.

VECTOR WAVE EQUATIONS FOR E AND H INHOMOGENEOUS ANISOTROPIC MEDIA.
Applied Research Lab., Sylvania Electronic Systems, Waltham, 54,
Mass., Engng Note No. 280.
R. Row

No abstract

NEW INTERPRETATION TECHNIQUES FOR TELLURIC AND SOME DIRECT CURRENT
FIELDS

Phys. Abstr. 16197/1963; Geophysics (USA), Vol. 28, No. 2, Pgs 250-61,
April 1963.

A. Roy

Since the normal derivative of the telluric potential at the ground surface is zero, the odd terms in the Taylor expansion disappear, resulting in a simple technique of computing the downward continued potentials. The top of the non-conducting basement is a flow surface and can, therefore, be determined by sketching in curves orthogonal to the (continued) equipotential lines in suitably chosen sections. A model tank example is given. The applicability of the method of continuation to the interpretation of self potential data is also illustrated. A discussion of the derivatives, two limiting formulas, and a method for calculating telluric anomalies are included.

W.V.T. Rusch - see Page 183

ON THE RADIATION OF LONG WAVES OF A HORIZONTAL DIPOLE IN THE AIR CAVITY
BETWEEN EARTH AND IONOSPHERE. I.

W.O. Schumann

See Section I, Page 91.

ON THE RADIATION OF LONG WAVES OF A HORIZONTAL DIPOLE IN THE AIR CAVITY
BETWEEN EARTH AND IONOSPHERE. II.

W.O. Schumann

See Section I, Page 91.

UBER DIE STRAHLUNGSLOSEN EIGENSCHWINGUNGEN EINER LEITENDEN KUGEL, DIE
VON EINER LUFTSCHICHT UND EINER IONOSPHERENHULLE UMGEBEN IST.

Z. Naturforsch (Germany), V. 7a, Pgs 149-154, 1952.

W.O. Schumann

No abstract

UBER DIE OBERFELDER BEI DER AUSBREITUNG LANGER, ELEKTRISCHER WELLEN
IM SYSTEM ERDE-LUFT-IONOSPHERE UND 2 ANWENDUNGEN (HORIZONTALER UND
SENKRECHTER DIPOL)

Z. angew. Phys. (Germany), V. 6, No. 1, Pgs 35-43, 1954.

W.O. Schumann

No abstract

EXPERIMENTAL DETERMINATION OF THE FIELD OF A PERMEABLE ALLOY
CYLINDER, PLACED IN A UNIFORM MAGNETIC FIELD PARALLEL TO ITS AXIS
OF REVOLUTION

Ann. Geophys. (France), V. 12, Pgs 144-146, 1956.
E. Selzer

No abstract

INFLUENCE OF THE SPECIFIC RESISTANCE OF THE SURROUNDING MEDIUM ON
THE FORM OF ANOMALY CURVE OBTAINED IN AERIAL ELECTRICAL PROSPECTING
Phys. Abstr. 3425/1963; Izv. Akad. Nauk. SSSR, Ser. geofiz, 1962,
No. 5, Pgs 652-8. In Russian. English trans. in: Bull. Acad.
Sci. USSR, geophys. Ser. (USA), No. 5, Pgs 423-6, (May 1962, publ.
Sept. 1962).

Yu. B. Shaub

The influence of the surrounding medium on the anomalous field
produced by a spherical inclusion is considered. Calculations are
carried out using two methods that can be applied in aerial prospecting.

ON THE DEMAGNETIZING FACTOR OF CYLINDRICAL RODS

Phys. Abstr. 18972/1961; Sci. Rep. Res. Insts Tohoku Univ. (Japan).
V. 12A, No. 3, Pgs 219-25, June 1960.

Y. Shirakawa

The ballistic demagnetizing factor of cylindrical rods of ferro-
magnetic substances, whose dimension ratio is smaller than 10, was
experimentally determined by a new method using the demagnetizing
curve of a new K.S. magnet alloy having a high coercive force. The
relationship between the demagnetizing factor, N , and the dimension
ratio, m , was expressed as follows: $N=5.5(m+0.54)^{-1.4}$, $m < 10$.

VARIATIONS OF RESISTANCE AND INDUCTANCE OF COIL RODS WITH FREQUENCY

US Naval Ordnance Lab., Washington D.C., Memorandum of 31st July 1942.
G.H. Shortley.

No abstract

AN EXPERIMENTAL STUDY OF UNDERWATER ELECTRIC ANTENNA IMPEDANCES

U.S. Naval Ordnance Lab., White Oak, Maryland, NAVORD Report 6064,
9 p, illus., 1958.

A. Silverstein, F.G. Salton

The input impedance of a variety of underwater electric antennas
was measured in Chesapeake and in a high conductivity salt pool over
a frequency range of 5 - 70 kc. The results were compared with input

impedances calculated from a theory based upon the transmission line approach. The deviation of the measured input impedance from the theoretical values is considerable, particularly for short antennas. A qualitative explanation is given for the failure of the transmission line theory. Recommendations are made for communication at increased depth.

TRANSMISSION COEFFICIENTS FOR ELECTROMAGNETIC PLANE WAVE RADIATION
INTO A CONDUCTING HALF-SPACE

E.B. Simmons

See Section I, Page 94.

AN ASYMPTOTIC SOLUTION OF DIPOLES IN A CONDUCTING MEDIUM

EE Abstr. 7692/1963; IEEE Trans Antennas and Propagation (USA),
Vol. AP-11, No. 2, Pgs 133-42, March 1963.

K. Sivaprasad

The radiation fields of dipoles immersed in a semi-infinite dissipative medium are investigated. A method suggested by Lighthill for asymptotic evaluation of Fourier integrals is suitably modified to obtain solutions valid for large distances both in air and in the conducting medium. The advantages of this method are in its simplicity and ease of application. The results agree closely with those obtained earlier by Banos and Wesley. (University of California, La Jolla, Scripps Oceanographic Inst. Repts, Nos. 53-4 (1953-4)).

FIELD OF AN ALTERNATING MAGNETIC DIPOLE ON THE SURFACE OF A LAYERED
EARTH

Phys. Abstr. 7147/1959; Geophysics, (USA), V. 24, No. 1, Pgs 77-88,
February 1959.

L.B. Slichter, L. Knopoff.

The magnetic field near a vertical alternating magnetic dipole on the surface of a layered earth is computed for points on the surface. In the layer, the dimensionless conductivity parameter is assumed to take the values 0, 1/4, 1 and 4; in the homogeneous sub-stratum, this parameter is assigned the values 0, 1/4, 1, 4 and infinity. The induced field is computed at distances from the source $\frac{1}{2}$, 1, 4, 8, and 16 times the layer thickness.

THE USE OF INSTANTANEOUS POINT SOURCES OR GREEN'S FUNCTIONS IN
EVALUATING ELECTROMAGNETIC FIELDS

EE Abstr. 3476/1954; Commun. and Electronics, (USA), No. 11, Pgs 82-8,
March 1954.

J.J. Smith

A generalization of the methods of a previous paper (abstract 2765 (1953)) to cover the use of time-variant fields. Among examples treated are the fields due to straight wires of finite and infinite length and also the fields in waveguides and resonant cavities excited by given currents.

A TRAILING WIRE VLF ANTENNA PROPOSED FOR USE ON A LIGHTER-THAN-AIR CRAFT

AD 244 078; University of New Mexico, Albuquerque, New Mexico.
Technical Rept., No. EE-36, October 1960
D. Sparks, R.H. Williams.

This paper contains a derivation of the driving point admittance of a hybrid transmission line antenna. The specific transmission line discussed has a terminating impedance at one end, is driven from the other end, and contains a side loading impedance in the middle. The results of this investigation show that in the VLF range the radiation resistance can be made approximately twice that of a cylindrical antenna. This increase in radiation resistance, together with the feature that this antenna can be driven from one end, suggest the use of this hybrid transmission line as an airborne VLF antenna that could be trailed from a lighter-than-air craft.

ANALYSIS OF A NATURAL VLF SLOT ANTENNA

Electromagnetic Theory & Antennas, edited by E.C. Jordan, Proceedings of a Symposium held at Copenhagen, Denmark, June 1962. Pgs 1183-1200.
H. Staras

It has been suggested recently that an island should behave as a reasonably good slot antenna at frequencies below about 15 kc/s since the conductivity of the island is much lower (by a factor of approx. 10^{-4}) than that of the surrounding sea water. The analysis of this paper shows that although the island can be considered as a slot in a good conductor (sea water), the voltage distribution over the slot is not even approximately sinusoidal. This is due to the fact that the earth is not a good dielectric at these low frequencies but rather is a reasonably good conductor. Therefore, the performance of an island slot is not even approximately that of a conventional slot antenna.

Formulas are derived that describe the illumination across the slot, the effectiveness of such an arrangement as a radiating system, and the impedance that this arrangement presents to the transmitter.

The analysis in this paper should also prove useful in more conventional slot antenna applications where the slot is filled with absorbing material.

THE DETERMINATION OF THE ENERGY OF A PLANE ELECTRIC CURRENT FIELD
EE Abstr. 1105/1961; Arch. Elektrotech. (Germany), V. 45, No. 5,
Pgs 343-46, 1960.
F. Stier

A plane, rotation-free magnetic field is replaced by an equivalent plane, rotation-free current field. The magnetic energy is given either by applying Green's theorem to the boundary or in terms of the electrical energy. If the fields are not rotation-free, the energy is given only in terms of the electrical energy.

ON THE TRANSFER OF ENERGY BETWEEN ELECTROMAGNETIC DIPOLES

Phys. Abstr. 5813/1954; Proc. Ry. Irish Acad. V.A56, No. 1, Pgs 1-11, January 1954.

J.L. Synge

The Hertzian dipole is taken as a source and a second Hertzian dipole, with changed sign, as sink. The electromagnetic field in the presence of this source dipole and sink dipole is investigated. The flow of energy out to infinity is found to be the algebraic sum for the two dipoles, regarded as existing each alone in space.

PROPAGATION OF ELECTROMAGNETIC WAVES IN A SEMI-INFINITE CONDUCTING MEDIUM

P. Szulkin

See Section I, Page 96.

THE EFFECT OF THE EARTH AND THE IMPEDANCE OF AN AERIAL

EE Abstr. 7025/1961; Bull. Acad. Polon. Sci. Ser. Sci. tech. (Poland) V. 8, No. 5, Pgs 233-40, 1960.

P. Szulkin

It is assumed that the variation over the surface of the earth of the tangential components of magnetic field are quite slow; that the propagation constant of the earth is much greater than unity; that the variation of the electrical properties of the earth has no significant effect on the tangential components of the magnetic field at the surface of the earth. Expressions are deduced for the change in aerial impedance due to the presence of the earth and it is pointed out that the method used, which is based on the reciprocity theorem can be applied also to waves of other types.

VECTOR TREATMENT OF ELECTROMAGNETIC FIELDS. I-II.

Fernmelde-Ingenieur (Germany), V. 14, Nos. 8 and 9, Pgs 1-31, 15th August and 15th September 1960.

H. Teichmann

An exposition of the methods of modern vectors and tensor analysis particularly in their application to electromagnetic field fit into a generalized field theory.

A NEW METHOD OF SOLVING THE DIFFRACTION PROBLEM FOR A DIPOLE FIELD
EE Abstr. 3550.1957; Bull. Acad. Polon, Sci. Ser. Sci. tech. (Poland),
Cl. 3, V. 4, No. 7, Pgs 433-8, 1956.
R. Teisseyre

A new method analogous to that of Senior (Abstr. 7801/1953) is presented which is much more direct and simple. Certain mathematical difficulties have been overcome. The electro-magnetic field of an arbitrary dipole is constructed from the fields of the Hertz vector electric and magnetic dipoles. At an appropriate point in the analysis the original Sommerfeld solutions are transformed so that the integration path is changed into a steepest descent. There is an adequate discussion of the discontinuities on the shadow boundary.

RADIO PROPAGATION OVER A SECTIONALLY HOMOGENEOUS CYLINDRICAL SURFACE
Phys. Abstr. 11797/1962; Proc. Roy. Soc. A. (GB), Vol. 267, Pgs 183-96,
(8th May 1962).
J.R. Thompson

The two-dimensional problem is considered of the propagation of H-polarized radio waves over two homogeneous sections, having different electrical characteristics, of a circular cylindrical surface. Though the treatment is in the context of a cylindrical geometry, the results may be cast into a form which is equally applicable to propagation over a sphere. Expressions are developed for the field beyond the discontinuity from the source and compared with those of earlier writers, and also for the field reflected back to the source by the discontinuity and in the neighbourhood of discontinuity.

ON THE DETERMINATION OF THE ELECTROMAGNETIC FIELD IN THE INTERIOR OF
A HOMOGENEOUS ISOTROPIC CONDUCTOR
Phys. Abstr. 547/1957; RC Acad. Naz. Lincei (Italy), V. 20, No. 4,
Pgs 403-8, April 1956.
A. Tonolo

Analytical expressions are obtained for the field intensities with a conducting medium in terms of their initial values throughout the medium and their values at any time on the bounding surface.

A NEW TRANSMITTING ANTENNA SYSTEM FOR VERY LOW RADIO FREQUENCIES
Thesis, Tech. Report 4, Contract AF 18(600)-1552, California Inst. of
Technology, Pasadena, California (26th June 1959). AFCSR-TN-59-582.
AD-217 029
W.V.T. Rusch

A system is presented which employs resonant loading circuits to convert a section of an existing power line into a horizontal very-low-

frequency transmitting antenna. The simplicity, low cost, and useful radiation pattern of this horizontal antenna are well suited for many experimental applications. The theoretical antenna problem was solved using a normal mode expansion of the current distribution. A matrix method was developed to compute the current distribution of a thin, linear antenna loaded with lumped-circuit elements, using a digital computer. The series was found to converge relatively fast. Results were obtained for a full wave linear antenna symmetrically loaded with real impedances Z_0 , one half-wave-length apart. Current distributions, feedpoint impedances, radiation patterns, etc., were presented as functions of Z_0 . Results of the idealized problem were applied to the powerline antenna. The matrix method can also be extended to the general linear antenna with any type of loading or feeding. System components, performance, and the 8.4 kc propagation experiments of the Dinkey Creek power-line antenna are described. The problem of interference with nearby audiofrequency communication systems is examined. The series of whistler-mode propagations to probe the exosphere was not completed. However, ionospheric soundings yielded considerable information about the properties of the ionosphere at very low frequency.

INTERACTION BETWEEN A MEDIUM AND THE (ELECTRIC) CURRENT ENTERING IT.
Phys. Abstr. 8147/1958; Zh. éksper. teor. Fiz. (USSR), V. 34, No. 6,
Pgs 1646-8, 1958.
V.N. Tsytovich

Electrostatic and electromagnetic forces will in general be induced in any current-carrying medium with finite resistivity, and these forces will react back on the current producing them. Expressions are derived for these forces and used to formulate current-stability criteria.

THE SOLUTION OF SOME ELECTROMAGNETIC INDUCTION PROBLEMS
EE Abstr. 14180/1963; Electrotehnica (Rumania), Vol. 11, No. 5,
Pgs 163-72, May 1963. In Rumanian.
A. Tugulea, S. Mastero

It appears that doubts still exist concerning the possibility of explaining induction phenomena on the basis of electromagnetic field theory. An attempt is made to tackle such problems, and it is shown that they can be solved correctly within the framework of Maxwell's macroscopic theory. The inconsistency is pointed out for attempts to create new electrodynamics based on distant action, while at the same time ignoring the electromagnetic field as a physical system. 14 references.

SUBMARINE COMMUNICATION ANTENNA SYSTEMS

EE Abstr. 4881/1959; Proc. Inst. Radio Engrs (USA), V. 47,
No. 5 (I), Pgs 735-9, May 1959.
R.W. Turner

Submarine aeriels are divided into three systems, v.l.f., h.f. and u.h.f. The evolution of each system from World War II to the present is described, and some of the problems associated with aeriels in each frequency band are reviewed. H.F. transmission line systems and their losses are discussed, and various environmental problems are considered. Specific examples of stacked and combined aeriels are given.

ON THE UNIQUENESS THEOREM FOR ELECTROMAGNETIC FIELDS

Phys. Abstr. 8374/1961; Proc. Inst. Radio Engrs (USA), V. 48,
No. 9, Pgs 1663-4, September 1960
H. Unz

A proof is given of a theorem which states that a harmonic time-varying electromagnetic field is uniquely determined in a lossy, bounded region by prescribing the values of any one of three parameters over the surrounding surface. The field is not uniquely defined in a lossless region because of the possibility of resonant modes.

DIFFRACTION OF ELECTROMAGNETIC WAVES, PRODUCED BY AN ARBITRARY ORIENTATED ELECTRIC OR MAGNETIC DIPOLE, AT A PERFECTLY CONDUCTING HALF-PLANE

Phys. Abstr. 8450/1954; Zh. éksper. teor. Fiz. (USSR), V. 26,
No. 1, Pgs 3-18, 1954.
V. Yu. Vandakurov

A mathematical generalization of the problem first treated by Sommerfeld and an expression is obtained for the incident and diffracted field in terms of integrals of known functions.

COMPARISON BETWEEN MODE THEORY AND RAY THEORY OF VLF PROPAGATION

H. Volland
See Section I, Page 100.

LOW-FREQUENCY ELECTROMAGNETIC DIPOLE FIELDS IN A SEMI-INFINITE CONDUCTOR

U.S. Navy, Bureau of Ships, Minesweeping Branch, Technical Rept., No. 104,
April 1952.
W. Von Aulock

This report gives a detailed analysis of dipole fields in a semi-infinite conducting medium such as sea water. It is assumed that the

source of the field, which may be an electric dipole or a circular coil, is located within the conducting medium and is orientated either horizontally or vertically. Due to the linearity of the fields equations, fields of dipoles with arbitrary orientation may be obtained by appropriate superposition of the fields computed in this respect. The analysis is restricted to low-frequency fields (0 to 10,000 cps) in a region where the distance from the source is small compared to the wave length in air. The restriction permits neglecting of displacement currents everywhere because in comparison to conduction currents, their contribution to magnetic fields in both media is negligible. With this simplifying assumption the field in the conducting medium is in effect an eddy current field which satisfies the diffusion equation, while the field in air is a potential field and subject to Laplace's equation. Solutions to the diffusion equation under consideration of the pertinent boundary conditions are given in closed form for vector potential, magnetic field intensity and electric current density. Simplified expressions for the components of the field are given for a number of special cases including the primary or incident field, the d-c field, the field on the vertical symmetry axis and the field at a large distance from the source with source and point of observation relatively close to the water surface. In general, electromagnetic fields in a conducting medium are attenuated exponentially with the distance from the source. However, it is shown that in some cases the field may propagate from the source to the surface of the conducting medium, propagate in air along the surface with little attenuation and penetrate the surface again above the point of observation in a vertically downward direction, exponential attenuation occurring only on the vertical paths.

AUSBREITUNG ELEKTROMAGNETISCHER FELDER IN SEEWASSER. (PROPAGATION OF ELECTROMAGNETIC FIELDS IN SEA WATER).

K.W. Wagner

See Section I, Page 100.

THE MAGNETIC DIPOLE OVER THE HORIZONTALLY STRATIFIED EARTH

Canad. J. Phys. V. 29, Pgs 577-592, November 1951.

J.R. Wait

The behaviour of a small current-carrying wire loop over a horizontally stratified earth is investigated. The layers are considered to have a contrast in conductivity and dielectric constant only. Both harmonic steady-state and step-function current sources are considered.

THE CYLINDRICAL ORE BODY IN THE PRESENCE OF A CABLE CARRYING AN
OSCILLATING CURRENT

Geophysios (USA), V. 17, Pgs. 378-386, April 1952.

J.R. Wait

The problem of an infinite cable carrying an oscillating current parallel to a conducting cylinder is solved. The homogeneous electrical properties of the media inside and outside the cylinder can be arbitrary. The special case is considered in detail where the exterior medium is a relatively poor conducting medium. The application to geophysical prospecting for massive sulphide ore zones is discussed.

CURRENT-CARRYING WIRE LOOPS IN A SIMPLE INHOMOGENEOUS REGION

J. appl. Phys. (USA), V. 23, Pgs 497-498, April 1952.

J.R. Wait

No abstract

MUTUAL INDUCTANCE OF CIRCUITS ON A TWO LAYER EARTH

Canad. J. Phys., V. 30, Pgs 450-452, September 1952.

J.R. Wait

A general formula is derived for the mutual inductance of ungrounded insulated wires lying on the surface of a two layer earth with a small conductivity contrast between the layers.

ELECTROMAGNETIC FIELDS OF CURRENT-CARRYING WIRES IN A CONDUCTING
MEDIUM

Canad. J. Phys., V. 30, Pgs. 512-523, September 1952.

J.R. Wait

The fields of a finite wire carrying a harmonically time varying current are calculated for the case of the wire contained in an infinite medium. The insulation of current-carrying wires in a conducting medium is discussed. It is concluded that the insulation characteristics need not usually be considered. The fields of a finite current-carrying vertical wire within a horizontal slab are calculated. The mutual impedance between the finite circuits, one being vertical and within the slab and one horizontal and on the surface of the slab, is calculated for limiting values of the lower medium conductivity. The results are thought to be applicable to electrical methods of well logging in geophysical exploration.

THE MAGNETIC DIPOLE ANTENNA IMMERSSED IN A CONDUCTING MEDIUM
Proc. Inst. Radio Engrs (USA), V. 40, Pgs 1244-45, October 1952.
J.R. Wait

The magnetic dipole antenna or small current-carrying loop immersed in a conducting medium is investigated. Explicit expressions for the fields are derived for the case when there is a spherical insulating cavity enclosing the dipole. The power radiated from the insulated dipole is discussed and an explicit expression for the total power is given for the case when all displacement currents in the media are negligible.

A NOTE ON DIPOLE RADIATION IN A CONDUCTING MEDIUM
Geophysics (USA), V. 17, Pgs 978-979, October 1952.
J.R. Wait

The steady-state fields of both electric and magnetic dipole elements in a conducting medium are discussed numerically. The dependence of the fields on the dielectric constant is noted. Considerable interest has been shown recently in the propagation of electromagnetic waves in a conducting medium. The experimental investigations are often carried out at frequencies such that the fields are observed at distances within a few effective wavelengths from the transmitting antenna. The nature of the radiated fields of a short antenna in this range is not as complicated as is commonly supposed. Also the effect of displacement currents which are usually neglected can be included. This latter point is important since the dielectric constants of large value are not uncommon.

THE ELECTRIC FIELDS OF A LONG CURRENT-CARRYING WIRE ON A STRATIFIED EARTH
J. geophys. Res. (USA), V. 57, Pgs 481-485, December 1952.
J.R. Wait

A numerical solution is given for the problem of a long insulated wire carrying a uniform oscillating current over a stratified earth with a highly conducting lower layer. The resultant electrical field parallel to this wire is shown to be influenced to an appreciable extent by the presence of a conducting zone at a depth of 500 metres for a frequency of 500 cycles per second.

THE FIELDS OF AN ELECTRIC DIPOLE IN A SEMI-INFINITE CONDUCTING MEDIUM
J. geophys. Res. (USA), V. 58, Pgs 21-28, March 1953.
J.R. Wait, L.L. Campbell

The fields of an oscillating magnetic dipole immersed in a semi-infinite conducting medium are investigated. The axis of the dipole is taken to be parallel to the interface between the conducting medium and the semi-infinite insulating space above it. Various special cases are discussed in detail and are illustrated by graphs.

THE POTENTIAL OF TWO CURRENT POINT SOURCES IN A HOMOGENEOUS CONDUCTING PROLATE SPHEROID
J. appl. Phys. (USA), V. 24, Pgs 496-497, April 1953.
J.R. Wait.

The potential distribution in a homogeneous spheroid due to an internal "source" and "sink" is calculated and its relevance to electrocardiography mentioned.

INDUCTION BY A HORIZONTAL OSCILLATING MAGNETIC DIPOLE OVER A CONDUCTING HOMOGENEOUS EARTH
Trans. Amer. geophys. Union (USA), V. 34, Pgs 185-188, April 1953.
J.R. Wait

The magnetic field of an oscillating horizontal magnetic dipole on the surface of a homogeneous earth is calculated. For lower frequencies, where displacement currents can be neglected, the magnetic field on the surface of the earth can be represented in terms of transcendental and cylindrical functions. Particular attention is paid to the vertical component, which vanishes as the conductivity of the earth approaches zero. An explicit formula is given for the value of this component in parametric form involving the conductivity, frequency, and distance to the observer. The magnetic field components tangential to the earth's surface are also considered.

INDUCTION IN A CONDUCTING SHEET BY A SMALL CURRENT-CARRYING LOOP
Appl. sci. Res. (Netherlands), Sec. B, V.3, Pgs 230-235, May 1953.
J.R. Wait

Induction by an oscillating magnetic dipole situated over a conducting sheet is investigated. The exterior medium is considered to be an effective insulator and the sheet thickness is assumed to be small. The result has particular application to electrical methods of geophysical exploration.

RADIATION RESISTANCE OF A SMALL CIRCULAR LOOP IN THE PRESENCE OF A
CONDUCTING GROUND

J. Appl. Phys. (USA), V. 24, No. 5, Pgs 646-649, May 1953.

J.R. Wait

The solution is given for the total power flow from an oscillating magnetic dipole, situated above a flat homogeneous conducting ground and oriented in the vertical direction. The result is employed to derive an expression for the radiation resistance of a small wire loop whose axis is perpendicular to the ground. It is pointed out that for a finitely conducting ground that the radiation resistance is very large when the height of the small loop or dipole is a small fraction of a wavelength.

RADIATION FROM A VERTICAL ELECTRIC DIPOLE OVER A STRATIFIED GROUND

Inst. Radio Engrs (USA) Trans., V. AP-1, Part I, Pgs 9-12, July 1953.

J.R. Wait

Expressions for the radiation fields at low frequencies of a vertical electric dipole situated on a horizontally stratified ground are derived. It is indicated that the well-known numerical results for the homogeneous ground can also be employed for ground wave propagation over a plane conductor composed of any number of parallel layers by suitably defining an "effective numerical distance".

THE RADIATION FIELDS OF A HORIZONTAL DIPOLE IN A SEMI-INFINITE DISSIPATIVE MEDIUM

J. appl. Phys. (USA), V. 24, Pgs 958-959, July 1953.

J.R. Wait

No abstract

ELECTROMAGNETIC COUPLING BETWEEN A CIRCULAR LOOP AND A CONDUCTING SPHERE

Geophysics (USA), V. 18, October 1953.

J.R. Wait

No abstract

RADIATION FROM A LINE SOURCE ADJACENT TO A CONDUCTING HALF-PLANE
J. appl. Phys. (USA), V. 24, No. 12, Pgs 1528-1529, December 1953.
J.R. Wait

The line source is parallel to the axis of the half plane, and carries either an electric or a magnetic current. The solution is completely specified in terms of circular cylindrical harmonics, the Bessel functions being of half-integral order.

THE FIELDS OF A LINE SOURCE OF CURRENT OVER A STRATIFIED CONDUCTOR
Appl. sci. Res. (Netherlands), Sec. B, V. 3, 1953.
J.R. Wait

The problem of a line source of alternating current situated over a stratified dissipative medium is theoretically investigated. Special cases of the general solution are studied in detail and several illustrative curves are given. The results have application to stratigraphic investigations of the earth's crust.

RADIATION FROM A GROUND ANTENNA
Canad. J. Phys., V. 32, Pgs 1-9, January 1954.
J.R. Wait

It is shown that a horizontal electric dipole can radiate vertically polarized waves along the surface of a finitely conducting ground. This result is then employed to calculate the fields of a horizontal antenna of finite length. Particular attention is paid to the shape of the ground wave field pattern for antennas of the travelling wave type.

MUTUAL COUPLING OF LOOPS LYING ON THE GROUND
Geophysics (USA), V. 19, No. 2, Pgs 290-296, April 1954.
J.R. Wait

The theory of a method to measure electrical ground constants by mutual coupling of loops is outlined. Curves are given in parametric form showing the dependence of the mutual impedance on conductivity, dielectric constant, frequency, and separation. An expression is derived in the appendix for the field of a circular wire loop laid on a homogeneous conducting ground.

IMPEDANCE OF A TOP-LOADED ANTENNA OF ARBITRARY LENGTH OVER A CIRCULAR GROUND SCREEN

J. Appl. Phys. (USA), V. 25, No. 5, Pgs 553-555, May 1954.

J.R. Wait, W.J. Surtees

The problem of a vertical monopole situated over a circular perfectly conducting screen lying on a finitely conducting ground is considered. An approximate method employed originally by Abbott to calculate the self-impedance is discussed. Using this formula explicit expressions are derived for the self-impedance of a thin, top loaded monopole. Sinusoidal current distribution is assumed.

THE CHARACTERISTICS OF A VERTICAL ANTENNA WITH A RADIAL CONDUCTOR GROUND SYSTEM

Inst. Radio Engrs., 1954, also, Apply. Sci. Res. (Netherlands), B, V. 4, Pgs 177-195, 1954.

J.R. Wait

Employing an approximate method the input impedance of a ground based vertical radiator is calculated. The ground system consists of a number of radial conductors buried just below the surface of the soil. The integrals involved in the solution are evaluated, in part, by graphical methods. The final results are plotted in a convenient form to illustrate the dependence of the impedance on number and length of radial conductors for a specified frequency, antenna height, and ground conductivity. It is finally shown that under usual conditions the radiated fields are modified by only a few percent due to the presence of the ground system.

RADIATION FROM A VERTICAL DIPOLE OVER A STRATIFIED GROUND (PART II).

Inst. Radio Engrs. (USA), Trans., V. AP-3, No. 4, October 1954.

J.R. Wait, W.C.G. Fraser

Further results are given for the problem of a vertical electric dipole situated over a horizontally stratified conductor. It is pointed out that under certain conditions the surface-wave field intensity for a stratified conducting ground is greater than the corresponding case for a perfectly conducting ground. Numerical values for the attenuation factors are also given.

INPUT RESISTANCE OF L.F. UNIPOLE AERIALS
Wireless Eng., V. 32, Pgs 131-138, May 1955.
J.R. Wait, W.A. Pole

The input resistance of a low-frequency unipole aerial is calculated. The earth system consists of a number of radial conductors buried just below the surface of the soil. The integrals involved in the solution are evaluated, in part, by graphical methods. The final results are plotted in a convenient form to illustrate the dependence of the input resistance on number and length of radial conductors for a specified frequency and earth conductivity. The curves should be useful in the design of earth systems for low-frequency transmitting aerials. It is pointed out that increasing the radius of the earth system beyond a certain limit gives only a slight improvement in radiation efficiency.

MUTUAL ELECTROMAGNETIC COUPLING OF LOOPS OVER A HOMOGENEOUS GROUND
Geophysics, V. 20, No. 3, Pgs 630-637, July 1955.
J.R. Wait

Computations are presented for the mutual impedance between small wire loops situated on or over a semi-infinite conductor. The results have application to electromagnetic methods of geophysical exploration.

RADIATION RESISTANCE OF DIPOLES IN AN INTERFACE BETWEEN TWO
DIELECTRICS
Canad. J. Phys., V. 34, Pgs 24-26, 1956.
J.R. Wait

No abstract

MUTUAL ELECTROMAGNETIC COUPLING OF LOOPS OVER A HOMOGENEOUS GROUND --
AN ADDITIONAL NOTE
Geophysics, V. 21, No. 2, Pgs 479-484, April 1956.
J.R. Wait

Further computations are presented for the mutual impedance between small wire loops over a semi-infinite conductor. The cases considered are where the axes of the loops are parallel to the interface.

RADIATION FROM A VERTICAL ANTENNA OVER A CURVED STRATIFIED GROUND
J. Res. Nat. Bur. Stand. (USA), V. 56, No. 4, Pgs 237-244, April 1956.
J.R. Wait

The problem of radial electric dipole outside a concentrically stratified spherical conductor, such as the earth, is formulated. The solution is facilitated by considering the analogous non-uniform transmission line for the radial modes. The general result is then transformed to a Watson-type residue or azimuthal mode series, which reduces to the well-known result for the homogeneous earth as a special case. Following a method introduced recently by Bremmer, the residue series is converted to an alternative expansion, which is more suitable at short distances. The leading term of this new expansion corresponds to the case of the transmitter and receiver over a plane stratified conducting earth.

EFFECT OF THE GROUND SCREEN ON THE FIELD RADIATED FROM A MONOPOLE
Inst. Radio Engrs. (USA), Trans. V. AP-4, No. 2, Pgs 179-181,
April 1956.
J.R. Wait

No abstract

ON THE CONDUCTANCE OF SLOTS
IRE Trans. on Ant. Prop. AP-4, Pgs 124-127, April 1956.
J.R. Wait

No abstract

LOW FREQUENCY RADIATION FROM A HORIZONTAL ANTENNA OVER A SPHERICAL
EARTH
Canad. J. Phys. V. 34, Pgs 586-595, June 1956.
J.R. Wait

The problem of the radiation from a horizontal antenna at low radio frequencies over a spherical earth is discussed. The solution is facilitated by considering that the surface of the earth can be characterized by a boundary impedance. It is shown that, in general, both vertically and horizontally polarized waves are radiated along the surface of the earth. At short distances for a homogeneous earth, the expressions are in agreement with Norton's formulas for the radiation field of a horizontal dipole over a flat earth.

THE RADIATION PATTERN OF AN ANTENNA MOUNTED ON A SURFACE OF LARGE
RADIUS OF CURVATURE

Proc. IRE, 44, 926, July 1956.
J. R. Wait

No abstract

THE RADIATION PATTERN AND CONDUCTANCE OF SLOTS CUT ON RECTANGULAR
METAL PLATES

Proc. IRE 44, 1469, October 1956.
J.R. Wait, D.G. Frood.

No abstract

SLOTTED-CYLINDER ANTENNA WITH A DIELECTRIC COATING

J. Research Nat. Bur. Standards, 58, 287-296, June 1957.
J.R. Wait, W. Mientka

No abstract

INSULATED LOOP ANTENNA IMMERSSED IN A CONDUCTING MEDIUM

J. Res. Nat. Bur. Stand (USA), V. 59, No. 2, Pgs 133-137, August 1957.
J.R. Wait

A solution is given for the fields of a circular loop in a conducting medium. The loop is assumed to have a uniform current, and it is enclosed by a spherical insulating cavity. The impedance of the loop is also considered. It is shown that the power radiated from the loop varies approximately as the reciprocal of the radius of the cavity for a specified loop current. Furthermore, if the cavity is electrically small, relative to the external medium, the radiation field is not significantly affected by the presence of the cavity.

A STUDY OF EARTH CURRENTS NEAR A V.L.F. MONOPOLE ANTENNA WITH A
RADIAL WIRE GROUND SYSTEM

EE Abstr. 523/1959; Proc. Inst. Radio Engrs. (USA), V. 46, No. 8,
Pgs 1539-41, August 1958.
J.R. Wait

Theoretical considerations suggest that the approximation used for the impedance of the radial wire ground system in previously published theories (see Abstr. 1336/1955 and 3453/1955) is valid when the mean-wire-spacing is less than the skin depth in the soil and also when the length of the wires is greater than this skin depth. Measurements on a 100 ft monopole at 15.5 kc/s confirm the general validity of the theories.

INDUCTION BY AN OSCILLATING MAGNETIC DIPOLE OVER A TWO-LAYER GROUND
Appl. sci. Res. (Netherlands), Section B, V.7, Pgs 73-80, 1958.
J.R. Wait

An expression for the mutual electromagnetic coupling between two small loops over a two-layer ground is derived. The result is expressed in a form which is suitable for calculation by a digital computer. When the heights of separation of the loops are large compared to the skin depth in the ground, simple asymptotic formulas for the fields can be developed. The results are employed to obtain a convenient formula for the self-impedance of a loop over a two-layer ground.

ON THE CALCULATIONS OF TRANSVERSE CURRENT LOSS IN BURIED WIRE GROUND SYSTEMS
Appl. sci. Res. (Netherlands), Section B. V. 7, Pgs 81-86, 1958.
J.R. Wait

A formula is developed for the impedance between a wire buried in a homogeneous ground and an overhead conducting plane. The result can be employed to calculate the power lost due to transverse currents in buried wire ground systems for antennae.

PATTERN OF AN ANTENNA ON A CURVED LOSSY SURFACE
Inst. Radio Engrs (USA), Trans. V. AP-6, No. 4, Pgs 348-359, October 1958.
J.R. Wait, A.M. Conda

Extensive numerical results are presented for the radiation fields of electric and magnetic type antennas mounted on smooth curved surfaces of finite conductivity. The model chosen is a circular cylinder whose surface impedance is specified. A residue series representation is employed for the portion of space deep in the shadow while a geometrical-optical representation is used in the "lit" region. In the penumbra, the fields are expressed in terms of the "Fock functions". The results are also applicable to other smoothly varying curved surfaces such as spheres, parabolic cylinders, and paraboloids. As an application, the E-plane patterns are computed for a small loop antenna on a spherical earth for both sea and land illustrating the so-called cut-back effect.

ON THE THEORY OF REFLECTION FROM A WIRE GRID PARALLEL TO AN INTERFACE BETWEEN HOMOGENEOUS MEDIA (II).
Appl. Sci. Research B 7, Pgs 355-360, 1959.
J.R. Wait

No abstract.

ON THE ELECTROMAGNETIC RESPONSE OF AN IMPERFECTLY CONDUCTING THIN
DYKE

Geophysics, (USA), V. 24, No. 1, Pgs 167-171, February 1959.

J.R. Wait

No abstract

RADIATION FROM A SMALL LOOP IMMERSSED IN A SEMI-INFINITE CONDUCTING
MEDIUM

Canad. J. Phys. V. 37, No. 5, Pgs 672-4, May 1959.

J.R. Wait

Considers the effect of burying a transmitting and/or a receiving loop in the ground for the case where orientation is such as to radiate a vertically polarized ground wave. It is shown that the theoretical solution of the problem can be readily obtained by generalizing Sommerfeld's results for dipoles at the surface and asymptotic expressions are given for the appropriate Hertz vector components, for the case of high conductivity. An expression for the additional attenuation due to immersion of the loops is given.

THE CALCULATION OF THE FIELD IN A HOMOGENEOUS CONDUCTOR WITH A WAVY
INTERFACE

Proc. Inst. Radio Eng (USA), V. 47, No. 6, Pg 1155, June 1959.

J.R. Wait

No abstract

EARTH CURRENTS NEAR A MONOPOLE ANTENNA WITH SYMMETRICAL TOP LOADING

J. Res. Nat. Bur. Stand. (USA), V. 62, No. 6, Pgs 247-255, June 1959.

J.R. Wait

Expressions for the fields are developed for a vertical ground-based monopole with a cone or disk located at the top of the antenna to simulate umbrella top loading. The current distribution on the structure is assumed. Using spherical-wave functions, the magnetic-field distribution on the ground plane near the base of the antenna is computed and illustrated by graphs. For the case where the antenna is electrically small, the currents flowing on the cone or disk are shown to contribute only slightly to the total field.

SOME SOLUTIONS FOR ELECTROMAGNETIC PROBLEMS INVOLVING SPHEROIDAL,
SPHERICAL, AND CYLINDRICAL BODIES
J. Res. Nat. Bur. Stand. (USA), V. 64B, Pgs 15-32, January-March 1960.
J.R. Wait

Solutions are presented for the low-frequency electromagnetic response to an oscillating magnetic dipole by conducting bodies of simple shape. The quasi-stationary approximation is employed throughout, which is valid when the relevant dimensions of the problem are small compared with the free-space wave-length. This amounts to matching solutions of the wave equation within the bodies to solutions of Laplace's equation outside. The results have application to geophysical prospecting.

ON THE ELECTROMAGNETIC RESPONSE OF A CONDUCTING SPHERE TO A DIPOLE
FIELD
Geophysics, (USA), V. 25, July 1960.
J.R. Wait

The electromagnetic coupling between an electric and a magnetic dipole in the presence of a spherical ore body is discussed in the present paper. It is shown that both electric and magnetic modes must be considered even though all dimensions are small compared with the wave-length. The results have application to a geophysical prospecting scheme where the exciting fields are set up by a straight insulating wire grounded at its end points and the secondary fields are detected by an undergrounded closed wire loop.

A NOTE CONCERNING THE EXCITATION OF ELF ELECTROMAGNETIC WAVES
J.R. Wait
See Section I, Page 114.

THE ELECTROMAGNETIC FIELDS OF A HORIZONTAL DIPOLE IN THE PRESENCE OF
A CONDUCTING HALF-SPACE
Canad. J. Phys. V. 39, Pgs 1017-1028, 1961.
J.R. Wait

The problem considered is a horizontal electric dipole which is located above or below the plane surface of a conducting half-space. Expressions for the fields are obtained using three different approaches. The formulas developed are quite simple and, taken together, the whole range of distances from the far-zone is adequately covered.

ON THE IMPEDANCE OF LONG WIRE SUSPENDED OVER THE GROUND
Proc. Inst. Radio Engrs. (USA), V. 49, No. 10, Pg 1576, October 1961.
J.R. Wait

Much has been written over the years on the subject of the impedance of wires lying on the ground or suspended above it. The possibility that a long horizontal wire will be a feasible radiator of VLF radio waves had reopened interest in the problem. It is the purpose of this note to outline a rather simple solution of an infinitely long wire located at a height h over a homogeneous flat ground.

ON THE THEORY OF AN ANTENNA OVER AN INHOMOGENEOUS GROUND PLANE
Symposium on Electromagnetic Theory and Antennas, Copenhagen, 25th to 30th June 1962.
J.R. Wait

No abstract

EFFECTIVE IMPEDANCE OF A WIRE GRID PARALLEL TO THE EARTH'S SURFACE
EE Abstr. 994/1963; IRE Trans Antennas & Propagation (USA),
Vol. AP-10, No. 5, Pgs 538-42, September 1962.
J.R. Wait

The reflection of electromagnetic waves from a parallel wire grid, located near the plane interface of two homogeneous media, is considered. The incident wave is polarized such that the magnetic vector is perpendicular to the grid wires. It is shown that, for this particular case, the grid may be represented by a pure shunt element in the equivalent transmission line circuit. The application of the results to the design of radial wire ground systems for vertical monopole systems is mentioned.

POSSIBLE INFLUENCE OF THE IONOSPHERE ON THE IMPEDANCE OF A GROUND-BASED ANTENNA
EE Abstr. 1002/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 5,
Pgs 563-9, September-October 1962.
J.R. Wait

The analysis for the impedance of a vertical electric dipole in the presence of an isotropic and homogeneous conducting half-space is presented. Various approaches to the problem are then briefly compared and some numerical results are presented in graphical form. The extensions to an anisotropic half-space are also considered. Finally,

the dipole is located in the space between a homogeneous ground and a sharply bounded ionosphere. It is concluded that the presence of the ionosphere has a negligible effect on the impedance of a ground-based aerial unless the frequency is less than 1,000 c/s or so.

THEORY OF MAGNETO-TELLURIC FIELDS

J. Research (D. Radio Propagation). Nat. Bur. Stands, 66D, Pgs 509-541, September-October 1962.

J.R. Wait

No abstract

A NOTE ON E-FIELD AND H-FIELD LOSSES FOR GROUND-BASED ANTENNAS

EE Abstr. 7693/1963; Proc. Inst. Elect. Electronics Engrs (USA), Vol. 51, No. 2, Pg 366, February 1963.

J.R. Wait

When calculating the ohmic ground loss for vertical aerials with radial ground systems it is usually assumed that both E- and H- field losses may be computed separately and then simply added. It is shown that at low frequencies there is some theoretical justification for this procedure.

CALCULATIONS OF THE FIELD NEAR THE APEX OF A WEDGE SURFACE

Nat. Bur. Stands, Boulder, Colorado. Tech. Note 204, 21st November 1963.

J.R. Wait, C.M. Jackson.

No abstract

THE THEORY OF AN ANTENNA OVER AN INHOMOGENEOUS GROUND PLANE

Preprinted from Electromagnetic Theory and Antennas, edited by E.C. Jordan, Pergamon Press, Oxford, 1963.

J.R. Wait

No abstract

THE ELECTROMAGNETIC FIELD WITHIN A DISCONTINUOUS CONDUCTOR WITH REFERENCE TO GEOMAGNETIC MICROPULSATIONS NEAR A COASTLINE

Phys. Abstr. 9928/1963; Canad. J. Phys., Vol. 41, No. 3, Pgs 484-95, March 1963.

J.T. Weaver

The two-dimensional problem of a low frequency plane-polarized electromagnetic wave incident on a semi-infinite conducting medium with a plane surface is treated for the case when the medium has a discontinuity,

the regions on either side of a plane normal to its surface being of different conductivities. Arguments are given to show that it is reasonable to assume, as a low-frequency approximation, that the tangential magnetic field is constant on the surface of the conductor. With the aid of this approximation, solutions are obtained for the two cases when (i) the magnetic vector (H polarization) and (ii) the electric vector (E polarization) is always parallel to the trace of the discontinuity. The model is discussed with reference to the behaviour of geomagnetic micropulsations near a coastline, particular attention being paid to the E-polarization solution which contains a magnetic component normal to the surface of the conductor. The amplitude of this component at the surface is shown to increase sharply as the region of the discontinuity is approached thus providing an explanation of the enhanced Z magnetic component in the micropulsation field observed at coastal stations.

SUBMERGED ANTENNA PERFORMANCE

EE Abstr. 4332/1963; IRE internat. Convention Record (USA), Vol. 10, Pt 1, Pgs 108-35, 1962.
W.L. Weeks, R.C. Fenwick.

Gives the results of a theoretical and experimental study of the characteristics of aerials in lossy environments, such as wires buried in the earth or sea. A criterion for the evaluation of such aerials (for surface waves or any other single mode of propagation), called relative communication efficiency, is defined and a mathematical formula for its calculation is derived. A number of specific evaluations are presented, with emphasis on horizontal wire aerials. The results of experiments to determine the input impedance and current distribution on wires of different sizes and different insulation thicknesses are summarized and compared to a simple theory. The results of measurements of the field strength of horizontal wires and arrays are presented and compared to the theoretical results. The s/n ratios observed with submerged receiving aerial structures are discussed.

THE MAGNETIC FIELD OF A CYLINDRICAL COIL CARRYING DIRECT CURRENT

EE Abstr. 2333/1953; Dtsch. Elektrotech., V. 6, Pgs 605-12, December 1952.
A. Weigand

The treatment is by the fundamental equations of a stationary magnetic field and leads to a partial differential equation of the second order for the current function with given boundary conditions. This can be solved by integrals of the Fourier-Bessel type. For the case of a very thin coil, these integrals reduce to tabulated elliptic integrals. For coils of finite thickness, integration over the coil-thickness is necessary, however. The components of field strength are expressed similarly.

RECIPROCITY THEOREMS FOR ELECTROMAGNETIC FIELDS WHOSE TIME DEPENDENCE IS ARBITRARY
EE Abstr. 6136/1960; Inst. Radio Engrs. (USA), Trans. V. AP-8, No. 1, Pgs 68-73, January 1960
W.J. Welch

Two reciprocity theorems are derived which are valid for fields whose sources may have arbitrary time dependence. The first theorem involves the electromagnetic potentials, and the second is in terms of the electric and magnetic fields directly. In both cases, it is necessary to make use of the retarded solutions to Maxwell's equations. Some properties of the theorems are discussed, and, as an application, the second theorem is used to derive a variational expression scattering of electromagnetic waves from a perfect conductor.

COMMENT ON "RECIPROCITY THEOREMS FOR ELECTROMAGNETIC FIELDS WHOSE TIME DEPENDENCE IS ARBITRARY"
EE Abstr. 3844/1961; Inst. Radio Engrs. (USA), V. AP-9, No. 1, Pgs 114-15, January 1961.
W.J. Welch

An extension to the author's paper abstracted as Abstr. 6136 of 1960.

ON THE EXTERIOR BOUNDARY VALUE PROBLEM OF PERFECT REFLECTION FOR STATIONARY ELECTROMAGNETIC WAVE FIELDS
Symposium on Electromagnetic Theory and Antennas, Copenhagen, 25th to 30th June 1962.
P. Werner

No abstract

FUNDAMENTAL LIMITATIONS OF SMALL ANTENNAS
Proc. Inst. Radio Engrs. (USA), V. 35, Pgs 1479-1484, December 1947.
H.A. Wheeler

No abstract

FUNDAMENTAL LIMITATIONS OF A SMALL VLF ANTENNA FOR SUBMARINES
Inst. Radio Engrs (USA), V. AP-6, No. 1, Pgs 123-5, January 1958.
H.A. Wheeler

Since the propagation in sea-water is nearly vertical (downward from the surface), the only operative types for submarines are horizontal dipoles electric and magnetic. The electric dipole is coupled by

conduction and the magnetic dipole by induction in a loop. The former has no resonance and nearly unlimited bandwidth, but fails when not submerged. The latter, by resonance, is able to present much greater interception area and available power. The magnetic interception area is determined by the size of the radome and by the radian length or skin depth in sea water (2 m at 15 kc/s). The radiation power factor, which is essential to bandwidth and efficiency is influenced also by the size of the inductor and by the magnetic permeability of an iron core. Simple formulae illustrate these relations for the idealized spherical shape of the radome, coil and core. Omnidirectivity in azimuth requires crossed coils in a two-phase circuit.

FUNDAMENTAL RELATIONS IN THE DESIGN OF A VLF TRANSMITTING ANTENNA
EE Abstr. 2700/1958; Inst. Radio Engrs. (USA), Trans. V. AP-6,
No. 1, Pgs 120-2, January 1958.
H.A. Wheeler

For a vlf flat top aerial much smaller than the radian sphere (a sphere whose radius is one radian length), the effective height, effective area and effective volume are defined. The required power factor of the radiation proportionately determines the effective volume. For a specified power to be radiated, the effective height inversely determines the current and the effective area inversely determines the voltage. For a limited electric gradient on the overhead wires, the current requires a proportionate area of conductor surface. A corresponding total length of wire in the flat top is adequate if disposed for uniform distribution of charge and if spread-out to realise the required effective area. These objectives are obtained more readily by some configurations, such as long parallel-wires or concentric circles of wire. This study has been made for a high-power transmitter to be located in Maine, the first to radiate 1 MW continuously at 15 kc/s.

THE SPHERICAL COIL AS AN INDUCTOR, SHIELD OR ANTENNA
Proc. Inst. Radio Engrs (USA), V. 46, Pgs 1595-1602, September 1958
H.A. Wheeler

No abstract

THE RADIANSHERE AROUND A SMALL ANTENNA
Proc. Inst. Radio Engrs. (USA), V. 47, Pgs 1325-1331, August 1959.
H.A. Wheeler

No abstract.

USEFUL RADIATION FROM AN UNDERGROUND ANTENNA

EE Abstr. 1636/1961; J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 1,
Pgs 89-91, January-February 1961.

H.A. Wheeler

An underground aerial delivers power to the surrounding conductive medium, and a fraction of the power goes out as radiation above the surface. This fraction is denoted the radiation efficiency. It is expressed in simple terms for two types of underground aeri-als. The first and simplest is a vertical loop in a submerged spherical radome. The second is a submerged horizontal insulated wire with each end connected to a ground electrode. In each case, the efficiency is the product of three simple factors: the first depending on the index of refraction between air and ground; the second proportional to the size (radius of the radome or length of the wire); the third giving the attenuation with depth. An example for 1 Mc/s gives an efficiency of 0.0014 for an underground wire of specified dimensions. The radiation efficiency is applicable to sender or receiver.

THE TRANSMITTED AND REFLECTED FIELDS DUE TO A PLANE WAVE INCIDENT ON
A DIELECTRIC HALF-SPACE FROM A CONDUCTING HALF-SPACE

R.H. Williams

See Section I, Page 128.

THE TRANSMISSION OF A PARTICULAR NON-UNIFORM PLANE WAVE ACROSS A FLAT
BOUNDARY

R.H. Williams

See Section I, Page 128.

PROPAGATION BETWEEN CONDUCTING AND NON-CONDUCTING MEDIA

R.H. Williams

See Section I, Page 129.

THE FLUX, THROUGH A GIVEN SPACE, OF THE MAGNETIC FIELD DUE TO A
STRAIGHT CONDUCTOR

Arch. Elektrotech. (Germany), V. 44, No. 6, Pgs 373-85, 1959.

H.H. Wolf

General formulae are obtained for the flux through polyhedral surfaces parallel to the axis of the conductor. The current is assumed to be d.c. or at frequencies low enough for the phase-shifts in the medium to be ignored. Graphs of various parameters are given to assist in numerical computation.

DRIVING POINT AND INPUT ADMITTANCE OF LINEAR ANTENNAS
J. appl. Phys. (USA), V. 30, No. 1, January 1959.
T.T. Wu

An infinity in the input admittance of linear antennas owing to the use of an idealized delta-function generator is investigated. It is shown that the infinity may be interpreted in terms of an infinite capacitance between the two halves of the antenna. This conclusion is reached that conventionally used iterative procedures are not invalidated by difficulties with respect to the driving point.

THEORY OF THE DIPOLE ANTENNA AND THE TWO-WIRE TRANSMISSION LINE
J. Math. Phys. (USA), V. 2, Pgs 550-574, 1961.
T.T. Wu.

No abstract

THEORY OF THE THIN CIRCULAR LOOP ANTENNA
EE Abstr. 4338/1963; J. math. Phys. (USA), Vol. 3, No. 6, Pgs 1301-4,
November-December 1962.
T.T. Wu

The current distribution on a thin circular loop transmitting aerial driven by a delta-function generator is determined approximately by Fourier series expansion. A difficulty encountered in previous analysis (Abstr. 4759 of 1961) is shown to be due to an inadequate approximation.

RADIATION FROM A MAGNETIC LINE DIPOLE SOURCE OF FINITE WIDTH
Phys. Abstr. 2120/1963; Proc. Inst. Radio Engrs (USA), Vol. 50,
No. 8, Pgs 1848-9, August 1962.
L.W. Zelby

The problem of radiation from a magnetic line dipole source lying in a lossy plane is of interest since, in addition to the radiating components, a surface wave is also launched. If the line dipole source is of finite width, the surface-wave component can either be maximized or reduced to zero. Mathematical analysis is presented from which the conditions that must be satisfied for true and for "leaky" surface waves, and for maximum and for zero surface waves, are derived. Discussion of these results indicates that for maximum efficiency in launching a surface wave, a source of infinitesimal thickness is required and also a purely inductive surface impedance, in agreement with conditions for the support of surface waves derived by Barlow and Cullen (1953). When the surface impedance is complex, or pure real, a "leaky" surface wave is obtained. The surface wave term can be eliminated only if the surface impedance is not complex.

THE ELECTROMAGNETIC FIELD OF A MAGNETIC DIPOLE SITUATED IN AN INFINITE DIELECTRIC LAYER WITH REFLECTING PLANE

EE Abstr. 4763/1961; Radiotekhnika i Elektronika (USSR), V. 5, No. 12, Pgs 1937-43, December 1960.

N.V. Zernov

The dipole axis is parallel to the ideally conducting plane which forms one boundary of the dielectric layer. A general expression is obtained for the projection of the Hertz vector in the space above the layer. Hence it is shown that the dipole produces spherical and cylindrical surface waves in the external space. The field at a distance is calculated, and the results applied to finding the electromagnetic field of an elementary slit.

THE INFLUENCE OF THE CONDUCTIVITY OF THE SURROUNDING MEDIUM UPON THE INPUT IMPEDANCE OF A CURRENT LOOP

Zh. tekhn. Fiz., V. 29, No. 8, Pgs 1009-13, August 1959.

English trans. in Soviet Physics Tech. Physics, (USA), V. 4, No. 8, Pgs 918-22, February 1960.

V.G. Zernyatko, D.N. Chetaev

Using Fork's solution (1926 and 1933) for the field of a l.f. current element lying on the surface of a conducting medium, the input impedance of a current loop (the latter being dependent upon the conductivity of the underlying medium) is computed by the method of induced e.m.f.'s.

A STUDY OF NON-POTENTIAL ELECTRIC FIELDS

Rev. Gen. Elect. (France), V. 68, No. 9, Pgs 555-9, September 1959.

M.P. Zlatev

The object is to develop a simple relationship between the E and H vectors which is valid for any quasi-stationary variation of B with time. This relationship is derived in terms of a parametric vector whose definition is analogous to the Biot-Savart-Laplace law.

A MAGNETIC DIPOLE IN A MEDIUM WITH CYLINDRICAL INTERFACE

Phys. Abstr. 19417/1963; Izv. Akad. Nauk SSSR, Ser. geofiz, 1963, No. 1, Pgs 128-34. In Russian. English trans in: Bull Acad. Sci. USSR, geophys. Ser (USA), No. 1, 75-8, (January 1963, publ. May 1963).

G.N. Zverev, V.A. Kusov

An oscillating dipole parallel to the axis of an infinite cylinder is placed at the origin of a system of co-ordinates. The electromagnetic field at any point on the axis of the cylinder is calculated by solving Helmholtz's equation by Sommerfield's method, for the case that the surrounding medium

differs in conductivity from the cylinder. The dielectric constant and the magnetic permeability are assumed to be one (in Gaussian units) for both media. It is shown that the expression for the field can be adapted for calculation according to Simpson's formula for numerical integration. A flow diagram of the calculation is given. This was used for programming on an electronic computer. Numerical results for the real and imaginary components of the field are given as a number of graphs. These are intended to be of use in geophysical induction logging methods.

PART III

PART III

ANALYSIS, MEASURING METHODS, MAGNETOMETERS, CORRELATION

EXPERIMENTAL INVESTIGATION OF LOW FREQUENCY NOISE OF THERMIONIC TUBES AND SEMI-CONDUCTOR TRIODES

EE Abstr. 6110/1957; Radiotekhnika (USSR), V. 12, No. 6, Pgs 45-51, 1957.

B.V. Abramov, V.I. Tikhonov

The method and apparatus for measuring noise of thermionic tubes and transistors in the range 66 cps - 15 kc are described in detail. The results of measurements on two Russian valves and two transistors are presented in tables.

ROTATING COIL MAGNETOMETER FOR THE MEASUREMENT OF THE EARTH'S MAGNETIC FIELD

Phys. Abstr. 5525/1961; Amer. J. Phys. (USA), V. 29, No. 5, Pgs 333-4, May 1961.

D.S. Ainslie

No abstract

A GRADIENT MAGNETOMETER USING PROTON FREE-PRECISION

Phys. Abstr. 7671/1963; J. Sci. Instrum (GB), Vol. 39, No. 12, Pgs 625-9, December 1962.

M.J. Aitken, M.S. Tite

Proton free-precision was used to measure weak magnetic gradients in the earth's magnetic field by a direct comparison of the precision frequencies from two detectors spaced several metres apart. The comparison is made by timing the first half-cycle of the beat frequency. In the first instrument described the time is measured electronically, and field differences of 4×10^{-5} oersted were measured to $\pm 10\%$ in this way. The second instrument is semi-quantitative and is essentially an amplifier feeding an earphone. Nevertheless, field differences of 5×10^{-5} oersted can be detected easily, and the instrument is adequate for the magnetic location of archaeological remains.

A NEW NAVAL FACILITY FOR MEASURING LOW-LEVEL MAGNETIC FIELDS
EE Abstr. 1305/1961; Elect. Engng (USA), V. 79, No. 8, Pgs 655-60,
August 1960.
W.W. Anderson

Describes an installation which is used to study the vertical component of magnetic fields produced by equipment designed for naval ships. The test building is constructed of non-magnetic materials ($\mu_r < 1.02$) and a "non-magnetic" radius of 288 feet around the building is obtained by the same permeability restriction. Eleven highly sensitive fluxgate magnetometers each having a resolution of 10^{-5} Oersted and having automatic compensation for random earth's field variation are used. There are 171 fixed probes arranged in 3 horizontal planes below the test equipment, and 11 moveable probes used with the magnetometers to obtain the distribution of magnetic field. Scanning of the probes is automatic and the digital data handling and analysis techniques employed are described.

PHASE-MEASURING EQUIPMENT FOR VLF PROPAGATION INVESTIGATIONS
G.E. Ashwell, C.S. Fowler
See Section I, Page 5.

PORTABLE APPARATUS FOR MEASUREMENT OF VERY SLOW TERRESTRIAL VARIATIONS
Phys. Abstr. 1478/1963; C.R. Acad. Sci. (France), Vol. 255, No. 7,
Pgs 1223-4, (13th August 1962). In French.
M. Aubert, G. Clerc, D. Gilbert

A description is given of the apparatus for use in the field with temporary stations to determine the diurnal and semi-diurnal periods of earth magnetic variations. The slow variations for considerable depths can only be studied by the elimination of the stronger rapid variations. This is accomplished by the use of a filter to suppress the rapid variations. The apparatus is described and an example given of a registration at Garchy on an N-S line of 1300 m. The diurnal variation is very close to one day. A duration of 40 days is sufficient to determine the components of the wave by means of a graphical harmonic analyser. An accuracy of 15% is obtained for the diurnal and semi-diurnal waves. For the two waves the phase of the magnetic field is retarded about 70° on that of the earth field.

THE USE OF AN ELECTRON BEAM FOR THE ACCURATE MEASUREMENT OF ALTERNATING MAGNETIC FIELD STRENGTHS
Phys. Abstr. 11191/1954; Proc. Instn. Elect. Engrs (GB), V. II, No. 101,
Pgs 441-9, August 1954
S.E. Barden, K. Phillips

A special electron-optical system for producing a low-energy beam, as far as possible only in the absence of a magnetic field, is described.

Its use for measuring both the strength of d.c. magnetic fields relative to a static reference field, and the relative strengths of time-dependent magnetic fields, with the aid of the voltage pulse which it produces at field zero, is described. The various factors affecting the amplitude and width of such pulses are discussed, and quasi-static measurements are given in support of the conclusions derived from a simple theoretical analysis of such factors. The operation of such an instrument in time-dependent magnetic fields, such as in the betatron and electron-synchrotron, is briefly discussed.

THE ENGINEERING OF COMMUNICATION SYSTEMS FOR LOW RADIO FREQUENCIES

Proc. IRE, Vol. 47, No. 5, Pgs 661-680, May 1959.

J.S. Belrose, W.L. Hatton, C.A. McKerrow, R.S. Thain

The low radio frequencies are of considerable importance in specific radio communication applications. However, little improvement has been made in recent years in methods of engineering frequency systems. In this paper the factors that influence the design of a communication system at low radio frequencies are discussed, and a description is given of some experimental work designed to obtain information concerning optimum values of some of the design parameters.

MEASUREMENT OF WEAK MAGNETIC FIELDS BY OPTICAL PUMPING METHODS

Phys. Abstr. 13148/1961; Arch. Sci. (Switzerland), V. 13, No. Fasc. Spec., Pgs 21-8, 1960.

P.L. Bender

9th Colloque Ampère Paper (See abstr. 4734 of 1961). A review and comparison of the d.c. alkali vapour magnetometer (Abstr. 6470 of 1957), the self-oscillating alkali vapour magnetometer (Abstr. 7317 of 1957; 6349 of 1958), and the helium magnetometer (Abstr. 722 of 1959; 13415 of 1960). Effects of orientation of the field are considered, and recent modifications made for specific applications are mentioned. For absolute measurements of slowly changing fields, the d.c. alkali vapour magnetometer is preferred. When orientation is not maintained, and fast response is desired, modifications of the self-oscillator are superior.

INVESTIGATION OF STATIC MAGNETIC FIELDS BY MEANS OF NUCLEAR RESONANCE

Phys. Abstr. 5563/1953; J. Phys. Radium (France), V. 13, Pgs 71S-2S, December 1952.

G.J. Béné, P.M. Denis, R.C. Extermann

Describes measurements of the magnetic field strength H of an electromagnet and of a Helmholtz coil system using the relation $\omega = \gamma H$, where ω is the resonance frequency and γ the gyromagnetic ratio.

ON THE MEASUREMENT OF THE SPECTRAL DENSITY OF A NOISE IN GEOPHYSICS.
APPLICATION TO THE EARTH-IONOSPHERE CAVITY
Phys. Abstr. 6947/1963; C.R. Acad. Sci. (France), Vol. 255, No. 19,
Pgs 2496-8, (5th November 1962). In French.
R. Benoit, A. Hourii

The naturally occurring vlf resonances of the earth-ionosphere cavity were analysed by a statistical method, the spectral density being obtained by filters and integration. The conclusions are that the theoretical results of Galejs (Abstr. 508 of 1963), which give an exponential profile for the electron density in the lower ionosphere, agree remarkably well with the experimental results, and this fact shows that the method of spectral analysis used is satisfactory.

ON THE FEASIBILITY OF AN ACOUSTIC ANALOGUE OF VLF ELECTROMAGNETIC PROPAGATION
AD 30851; U.S. Navy Electronics Laboratory, San Diego, California,
Rept. No. 434.
R.T. Beyer, G.E. Hudson

It is feasible, in principle, to form an acoustic analogue of vlf electromagnetic wave propagation in two dimensions. Such an analogue would enable the laboratory experimenter to study (1) the effects of the curvature of the earth and of scattering from suitable surfaces, and (2) the effects of "absorption" by the ionosphere either for a flat earth or a curved earth.

RADIOSPECTROSCOPY (THE FIFTY-THIRD KELVIN LECTURE)
EE Abstr. 1766/1964; Proc. Instn. Elec. Engrs. Paper 4019, publ. Nov. 1962 (Vol. 109B, 457-63).
B. Bleaney

Gives a survey of the theoretical and practical development of radio-frequency spectroscopy from the early work of Debye on solutions of polar molecules to the more recent work in maser technology. The author begins with a discussion of the concept of relaxation time followed by a summary of the important features of the techniques of radiospectroscopy. The gyroscope analogy is introduced in relation to a nuclear magnetic measurements using molecular beam techniques. The increasing activity in post-war years resulting from the development of radar is emphasised leading in particular to the increased importance of absorption spectroscopy at microwave frequencies. The application of the various principles to practical devices is described. These include microwave amplifiers and oscillators, high stability frequency standards, accurate magneticfield measurements and the use of the proton magnetometer for archaeological surveys. The last of these has been used to detect field variations as small as 5×10^{-5} e.m.v.

PRINCIPLES OF OPERATION OF THE RUBIDIUM VAPOUR MAGNETOMETER

Phys. Abstr. 5430/1962; Appl. Optics (USA), V. 1, No. 1, Pgs 61-8, January 1962.

A.L. Bloom

Discusses some of the basic problems involved in designing and using a magnetometer employing optical pumping. Particular attention is given to magnetometers of the self-oscillating type, i.e. those that are analogous to masers in that the resonant properties of the spin system itself are used to sustain continuous oscillation at the resonant frequency. Among the topics treated are amplitude variations with orientation, sensitivity, behaviour in extremely weak magnetic fields, and response to rapid field changes.

THE RELATION OF MAGNETIC MICROPULSATIONS TO ELECTRIC-CURRENT AND SPACE CHARGE SYSTEMS IN THE LOWER IONOSPHERE

Phys. Abstr. 6964/1962; J. geophys. Res. (USA), V. 67, No. 1, Pgs 177-81, January 1962.

H.A. Bomke

During August and September 1960, a very large wire loop (area about 100 km^2) was used to record different types of earth-magnetic micropulsations at Baxter State Park, Maine. The average values of the magnetic amplitudes were compared with the average values of the electric amplitudes of the same type of micropulsations. There is strong indication that for micropulsations in the 1 cps range the ratio E/H is about 100,000 ohms, whereas for micropulsations in the range between 0.1 and 0.01 cps, E/H is of the order of 10 ohms. The distinction is made between electric-dipole radiation, produced by free electric space-charge oscillations, and magnetic-dipole radiation, generated by closed electric currents. The former are assumed to be connected with the absorption of auroral particles in the ionosphere, whereas the latter are the result of the absorption and reflection of hydro-magnetic waves in the lower ionosphere. Simultaneous recordings of the same micropulsation events with two different loops showed an amplitude ratio that corresponded to the loop sensitivity ratio only for the longer micropulsation periods (10 to 100 sec.). The micropulsations around 1 cps often showed a much stronger signal on the small than on the large loop. This seems to indicate that the sources for the 0.1 to 0.01 cps micropulsations are large (at least of 10 km diameter), while the 1 cps sources are very often small (of 400 to 500 m. diameter).

NEW POSSIBILITIES OF PROTON MAGNETOMETERS

Phys. Abstr. 15982/1962; Ann. Geophys. (France), Vol. 18, No. 1, Pgs 62-91. In French.
I.G. Bonnet

The advantages offered by the method of nuclear polarization as far as magnetometers are concerned are studied. New methods are suggested which are likely to improve the accuracy and the linearity characteristics of the field-into-frequency transformations. The problem of the reading of the information is also studied simultaneously and a continuous process is proposed which optimizes the **resolution** power of the system and the compensation of noise effects.

A METHOD OF MEASURING WEAK FIELDS BY FREE PRECESSION IN CONJUNCTION WITH ELECTRONIC PUMPING

Phys. Abstr. 13149/1961; Arch. Sci. (Switzerland), V. 13, No. Fasc. Spec., Pgs 629-33, 1960.
M. Bonnet, M. Servoz-Gaven

9th Colloque Ampère (see Abstr. 4734 of 1961). A new method is proposed in which the increase in magnetization necessary for observation of free precession is obtained continuously by means of nuclear polarization. This overcomes restrictions on rate of repetition of measurement set by relaxation times in the technique of Packard and Varian (Phys. Rev. (USA), V. 93, 941, 1954). The sample is about 100 cm³ of a solution of the substance K₂NO(SO₃)₂ subjected to sufficient power at 56 Mc to saturate the free electron spins. Brief details of the apparatus and results are given.

EXPERIMENTS ON THE DISTORTION OF THE FIELD OF A MAGNETIC PROBE (DEVELOPED BY F. FORSTER) IN THE PRESENCE OF A FERROMAGNETIC BODY

Phys. Abstr. 3641/1954; Elektrotech. u. Maschinenbau (EuM) (Austria), V. 70, Pgs 452-5, October 15, 1953.
F. Brandstaetter

Describes investigations of the Förster probe previously described (Abstr. 2824/1952). The magnetic field in the neighbourhood of the two Permalloy cored coils forming the double transformer of the instrument was measured with a small search coil with and without the presence of a thin iron strip. The effect of the strip **was** to increase the concentration of the field into two sharp maxima on either side of the coil.

MEASUREMENT OF MAGNETIC FIELDS IN VERY SMALL AIR GAPS WITH THE AID OF THE FORSTER PROBE

Phys. Abstr. 13647/1962; Acta phys. Austriaca, Vol. 15, No. 1+2, Pgs 80-9 (1962). In German.
F. Brandstaetter

It is possible to determine the field strength in a small gap of 15 μ of a recording head by means of remanence measurements on a

calibrated magnetic tape. The field strength cannot be inferred simply from the measurements, since the latter have a longitudinal and a transverse component. The Förster probe is particularly suited for separation of these components. For small excitations the transverse magnetization of the tape is negligibly small. If the recording head is made so sensitive that the tape is saturated, the magnitude of longitudinal and transverse field strengths can be determined separately. The marked difference between the saturation values of transverse magnetization in the homogenous field and the gap field demonstrate the strong inhomogeneous magnetization of the tape in the latter field.

DESIGN BASIS OF DIFFERENTIATING AMPLIFIER FOR VARIABLE LOW-FREQUENCY PHENOMENA.

EE Abstr. 3854/1961; Elektronik (Germany), V. 9, No. 12, Pgs 371-2, December 1960.

R. Buck

A mathematical study of the problem of achieving the most accurate differentiation with a simple RC network in the sub-audio range. It is shown that accuracy is greatest when the values of both R and C are a minimum and that an error not exceeding 1.5% is practicable at a frequency of 20 cps. A method of calibration for the amplifier is outlined.

HIGH ALTITUDE MEASUREMENTS OF THE EARTH'S MAGNETIC FIELD WITH A PROTON PRECESSION MAGNETOMETER

J. Geophys. Res. (USA), V. 61, Pgs 547-558, 1956.

L.J. Cahill, Jr., J.A. Van Allen.

No abstract

INVESTIGATION OF THE EQUATORIAL ELECTROJET BY ROCKET MAGNETOMETER

J. Geophys. Res. (USA), V. 64, Pgs 489-503, 1959.

L.J. Cahill, Jr.

No abstract

A STUDY OF THE OUTER GEOMAGNETIC FIELD

Phys. Abstr. 25937/1963; IEEE Trans. nuclear Sci. (USA), Vol. NS-10, No. 3, Pgs 10-19, July 1963.

L.J. Cahill, Jr.

An account is given of the knowledge of the outer geomagnetic field before 1958. The types of magnetometers available for use in satellites are described and their relative merits considered. A survey is made of the magnetometer measurements made in U.S. and Russian satellites and space probes. Measured data indicating a boundary between the magnetosphere and the solar wind between 10 and 15 R_e are reproduced. An extensive bibliography is included.

MAGNETIC FIELD MICROPULSATIONS AND ELECTRON BREMSSTRAHLUNG

Phys. Abstr. 4703/1962; J. geophys. Res. (USA), V. 66, No. 10, Pgs 3599-3600, October 1961.

W.H. Campbell

A report of observations made near College, Alaska, in June-July 1960, using a geomagnetic transient-flux meter with a flat response in the frequency band, 0.4-0.04 cps, and a balloon-borne geiger counter to measure bremsstrahlung electrons of energies > 50 keV. On 28th June the records showed an SC of micropulsation activity coincident with a burst of auroral bremsstrahlung at 1050 UT.

SYSTEM FOR LOW-FREQUENCY NOISE MEASUREMENTS

EE Abstr. 10711/1962; Rev. Sci. Instrum (USA), Vol. 33, No. 6, Pgs 654-5, June 1962.

P.C. Caringella, W.L. Eisenman

A system for measuring low-frequency noise spectra of thermal detectors is described. Its features also make it useful for other noise measuring applications. Low equivalent input noise is realized by incorporating an RCA 6CW4 Nuvistor in the system preamplifier. A constant bandpass of 0.3 o/s is maintained over the entire tuning range of 1 to 50 c/s by utilizing a heterodyne-type spectrum analyser modified for this application. A typical thermistor bolometer noise spectrum is given.

VLF PROPAGATION MEASUREMENTS FOR THE RADUX-OMEGA NAVIGATION SYSTEM

C.J. Casselman, D.P. Heritage, M.L. Tibbals

See Section I, Page 25.

RECORDING ATMOSPHERIC RADIO NOISE

EE Abstr. 6961/1960; Electronic Technol. (GB), V. 37, No. 9, Pgs 346-9, September 1960.

C. Clarke

An investigation was made of the technique required for tape-recording noise at field stations, using simple equipment, with a view to the recordings then being sent to a central research centre for analysis. The method involves recording the i.f. noise envelope obtained from a receiver with a bandwidth of 300 cps centred about 10 kc. By limiting the replay bandwidth by means of a high-pass filter and adjusting the record bias for optimum response, an amplitude range of 60 dB may be recorded without distortion. The main limitation comes from unwanted amplitude modulation caused by misalignment of the tape and contact variations between the head and the tape. This modulation may be reduced to a standard deviation of between 5 and 10% for half-track recording on professional-type or the highest priced domestic-type equipment. A comparison of noise structure on 24 kc obtained from direct measurement and via the medium of tape recording shows that the results are statistically indistinguishable.

TESTS OF UNDERWATER REMOTE CONTROL SYSTEM
AD 240 411L; 1960.
U.S. Coast Guard, Washington, D.C.,

Laboratory and field tests are described of an underwater remote control system. The equipment tested included a transmitter and two different receivers. One receiver was designed only for remote operation of a relay. The other can be used either to receive voice communications or to actuate a relay. It was concluded that the field tests proved the system operated according to required specifications in so far as reliable relay operation was obtained at a range of one-half mile along the perpendicular bisector of the line connecting the transmitting electrodes. Factors which might greatly increase the reliable range of operation are noted.

THE MEASUREMENT OF THE VERTICAL ELECTRIC CURRENT IN THE ATMOSPHERE
EE Abstr. 3677/1963; J. atmos. terrest. Phys. (GB), Vol. 24, Pgs 997-8, November 1962
R.H. Collingbourne

Describes an apparatus for measuring the vertical electric current in the atmosphere, similar to that recommended by Chalmers (Abstr. 11030A of 1962; J. atmos. terrest. Phys. (GB), 297-302 (April 1962)), which has been in regular use at Kew Observatory since 1931. The results obtained with this instrument are summarised.

AN ELECTRONIC MAGNETOMETER
EE Abstr. 5138/1955; J. Sci. Instrum (GB), V. 32, No. 10, Pgs 385-6, October 1955.
B.G. Cragg

A probe unit containing a miniature c.r.t. is brought into the field to be measured, and the resulting deflection of the electron beam is automatically compensated by a voltage applied to the electrostatic deflecting plates. This voltage is proportional to the magnetic field for steady fields and for fields changing at not more than 1 kc. Using standard components an output of 12.5 V/oersted is obtainable with a drift of about 1 mV/min. The smallest field measurable is thus 10^{-4} oersted.

MAGNETOMETERS. I. DEFINITIONS AND THEORY. II. APPARATUS FOR MEASUREMENT OF THE EARTH'S FIELD.

EE Abstr. 4636/1954; Arch. tech. Messen (Germany), Issue No. 217, (Ref. J62-1), Pgs 37-8, February 1954; Issue 220 (Ref. J62-2), Pgs 115-18, May 1954.

O. Dahl, A. Kussmann

Pt I discusses the theory of magnetometric measurements. Pt II describes compass-magnetometers, double compasses, theodolite-magnetometers, electrical magnetometers, torsion-magnetometers, deflector-magnetometers (McNish) and recording magnetometers (variographs).

THE OBSERVATION OF VERY LOW FREQUENCY ELECTROMAGNETIC SIGNALS OF NATURAL ORIGIN

A Thesis for the degree of Ph. D., University of California at Los Angeles, Microfilm, Photographic Service, Univ. of California, Los Angeles 24, California.

O.E. Deal

This investigation is an attempt to determine the nature and source of natural electromagnetic signals in the little known frequency band from 25 to 135 cps. A correlation was found between the seasonal mean diurnal variations of signal level in this band and of atmospheric potential gradient at sea. The following corollary results have been established: (1) that at least a large fraction of the signal in the 25 to 135 cps band is due to radiation from lightning strokes. (2) that this radiation is propagated over great distances with little attenuation.

MAGNETOMETER SYSTEM FOR ORIENTATION IN SPACE

Electronics (USA), V. 33, No. 15, Pgs 55-8, April 1960.

H.E. De Bolt

Describes a method of space vehicle orientation by lining up an axis of the vehicle with the direction of the earth's magnetic field. The system uses optical pumping of the 2^3S metastable energy level of helium to achieve alignment and is capable of detecting magnetic fields smaller than 0.01γ , which permits direction measurement at distances greater than 50,000 miles, from the earth.

STUDIES OF THE DIFFRACTION OF ELECTROMAGNETIC WAVES BY CIRCULAR APERTURES AND COMPLEMENTARY OBSTACLES: THE NEAR-ZONE FIELD

EE Abstr. 2589/1955; J. appl. Phys. (USA), V. 26, No. 3, Pgs 336-45, March 1955.

M.J. Ehrlich, S. Silver, G. Held

Techniques for measuring both the electric and magnetic field distributions are presented and the general experimental problems are

discussed. Data are given for the tangential components of the electric and magnetic vectors in the principal planes in the immediate neighbourhood of the diffracting structures and axial distributions for the corresponding components. The results extend the range of the data available previously. The predicted uniformity of the tangential magnetic field in the aperture plane, for the case of a wave incident normally is verified. An experimental test was made also of the electromagnetic Cabinet principle.

MEASUREMENT OF TWO-DIMENSIONAL FIELDS

Rev. sci. Instrum (GB), V. 25, Pgs 480-5, 1954

W.C. Elmore, M.W. Garret

No abstract

EQUIPMENT FOR OBSERVATION OF THE NATURAL ELECTROMAGNETIC BACKGROUND IN THE FREQUENCY RANGE 0.01-30 CYCLES PER SECOND

Paper No. 42, in Marine Science Instrumentation, V.1, R.D. Gaul and others Editors, Plenum Press, 1962.

W.N. English, and Others

The instruments designed and constructed for measuring the geomagnetic background between 0.01 and 30 cps, which has a great dynamic range in frequency and time, are described. Large effective area detector loops combined with high gain, very low noise amplifiers form an effective receiving system. Methods of absolute calibration are discussed.

MAGNETIC-FIELD PICKUP FOR LOW-FREQUENCY RADIO-INTERFERENCE MEASURING SETS

EE Abstr. 180/1960; Inst. Radio Engrs. (USA), Nat. Convention Record, V. 7, Pt 8, Pgs 64 76, 1959.

M. Epstein, R.B. Schulz

The Hall effect in indium antimonide is used to measure magnetic fields in the range 10^{-5} G from 30 kc, and ferrite rods are used to concentrate the magnetic flux. Use of the semi-conductor leads to a uniform frequency response down to d.c., direct single point calibration, detection of flux density at a point, negligible loading effects on the H field and the use of a very small detector. Details are given of a special element configuration which effectively places in series a number of Hall effect voltages for providing a high output signal, together with design theory for ferrite flux-concentrators.

A NUCLEAR MAGNETOMETER

Phys. Abstr. 7114/1961; Energia Nucleare (Italy), V. 7, No. 10,
Pgs 705-16, October 1960.
G. Faini, A. Fuortes, O. Svelto.

Describes the design and the testing of an apparatus for the measurement of the earth's magnetic field, based on the principle of nuclear induction. The method uses the pre-polarization technique of Packard and Varian that has proved to be best suited for measurements of weak magnetic fields, but differs slightly by using relatively strong pre-polarization of the nuclear sample, followed by a small and sharp "rotation" field. Particular care was given to the maximization of the signal-to-noise ratio, and to the extraction of the maximum information from the nuclear signal. In this way, it was possible to obtain an accuracy of 10^{-5} for absolute measurements and 10^{-6} for relative ones. In conclusion, the results of some measurements are discussed.

MEASUREMENTS OF MAGNETIC FIELDS BY MEANS OF NUCLEAR MAGNETISM

EE Abstr. 190/1962; Alta Frequenza, (Italy), V. 30, No. 5, Pgs 339-47,
May 1961.
G. Faini, O. Svelto

Two methods are described, based respectively on nuclear induction and nuclear resonance. The former is more suitable for weak fields (tens of Gauss) and the latter for strong fields (thousands of Gauss). The absolute accuracy obtained is of the order of 1 part in 10^{-5} .

SIGNAL-TO-NOISE CONSIDERATIONS IN A NUCLEAR MAGNETOMETER

Nuovo Cimento Supply (Italy), Vol. 23, No. 1, Pgs 55-66 (1962).
Phys. Abstr. 11747/1962.
G. Faini, O. Svelto

The accuracy in relative measurements of magnetic fields with nuclear magnetometer depends basically on the signal-to-noise ratio in the sensing coil. This ratio is evaluated in this paper as a function of the coil's geometrical parameters, and graphs are shown which allow the optimum geometrical dimensions to be chosen. In this way it has been possible to build a coil showing an effective signal-to-noise ratio of 540 at amplifier output, with a sensing volume of water of 160 cm^3 (amplifier bandwidth $\cong 10 \text{ c/s}$).

DESCRIPTION OF THE EQUIPMENT OF A STATION FOR RECORDING VERY FAST
CHANGES IN THE EARTH'S MAGNETIC FIELD

Phys. Abstr. 1581/1961; CR Acad. Sci. (France), V. 251, No. 5,
Pgs 671-3, August 1960.

H. Fournier

The station at Nivernais, a branch of the Centre d'Etudes Géophysiques, is equipped with mu-metal bar type induction magnetometers. The electronic amplification system has a very low back-ground noise level with an exceptional sensitivity attaining 1/2000 gamma/mm of writing speed for periodic variations of 4.5 sec duration. Three pass bands cover the total interval from 0.025 to 30 sec. Calibration is by means of an auxiliary ultra-linear magnetic field of known amplitude and of variable period.

ANALYZERS FOR ATMOSPHERICS

EE Abstr. 3674/1954; RC 53 Riun. Assoc. Elettrotec. Ital. (Italy),
V. 40, Fasc. 2, Paper 222, 3 p., 1953.

G. Francini

Two possible designs are described for an equipment which will present directly a spectrum analysis of received atmospheric. The first uses a delay line to convert a simple transient into a repetitive signal by recirculation. This new data is examined by a panoramic receiver. In the second scheme a number of separate filter channels are provided to cover the useful band. The outputs from these channels are selected by an electronic switch and presented on a c.r.o. A variant of this latter idea using a switching tube is at the moment under construction.

A MAGNETOMETER FOR MEASURING THE EARTH'S FIELD USING NUCLEAR PARAMAGNETIC RESONANCE WITH DYNAMIC NUCLEAR POLARIZATION. I. THEORETICAL BACKGROUND

Phys. Abstr. 4689/1962; Onde elec. (France), V. 40, Pgs 590-5,
September 1960.

J. Freycenon, I. Solomon.

The theoretical problems associated with the design of a n.m.r. magnetometer for measuring the earth's magnetic field are discussed. It is shown that for such weak magnetic fields the simple absorption techniques are not sufficiently sensitive. Weak magnetic fields can, however, be measured to high accuracy using the technique of dynamic nuclear polarization. This artificially increases the polarization of the samples by increasing the population of the level of high energy at the expense of the lower. This is done, for the case of protons

in water, by utilizing the coupling which exists between the protons and the electron spins of a paramagnetic radical dissolved in the water. It has been shown that when this coupling exists if a suitable electronic transition is saturated by applying an r.f. field perpendicular to the field to be measured, at a frequency f_0 , the polarization of the nuclear spins is increased in the ratio f_e/f_0 where f_0 is the frequency of the nuclear transition. The material used in this case is a solution of potassium nitrosodisulphonate $K_2 NO(SO_3)_2$ in water. The experimental arrangement and results are described in the following abstract.

A MAGNETOMETER FOR MEASURING THE EARTH'S FIELD USING NUCLEAR PARAMAGNETIC RESONANCE WITH DYNAMIC NUCLEAR POLARIZATION. II. CONSTRUCTION AND USE.

Phys. Abstr. 4690/1962, Onde elect. (France), V. 40, Pgs 596-601, September 1960.

J. Freycenon

See above abstract. This article describes the construction and performance of such devices. Possible applications and modifications to improve the performance are suggested.

GRUNDZUGE DER ANGEWANDTEN GEOELEKTRIC

Manz. Wien, 1949.

V. Fritsch.

ELEKTRISCHE MESSUNGEN AN RAUMLICH AUSGEDEHNTEN LEITERN

Verlag G. Braun, 1960.

V. Fritsch

A MAGNETOMETER WITH MAGNETIC PROBE

EE Abstr. 2006/1954; Elektrotech. Obzor. (Czechoslovakia), V. 42, No. 6, Pgs 342-8, 1953.

B. Fröhlich

Theoretical basis, and description of a portable magnetometer with a magnetic probe which can be used for the measurement of magnetic fields as well as of magnetic characteristics of magnetized or unmagnetized materials. The instrument is essentially based on the occurrence of a second harmonic in certain circuits saturated by an a.c. component when an additional d.c. component is present. The instrument can be used for measuring the magnetic fields of the earth and its variations, the distribution of magnetic fields, for instance of coils, in geophysical research, and as a compass for remote indication.

EFFECT OF RECEIVER BANDWIDTH ON THE AMPLITUDE DISTRIBUTION OF VLF
ATMOSPHERIC NOISE

EE Abstr. 3490/1961; J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 3,
Pgs 299-304, May-June 1961.
F.F. Fulton, jr.

The distribution function of envelope voltage for short samples of atmospheric radio noise as received by a communications receiver in the v.l.f. range always shows a marked departure from that obtained for Gaussian noise. It is considered that this departure is caused by strong noise pulses which do not overlap in time, and the effect of changes in the receiver bandwidth on the observed distribution function is deduced by consideration of the changes in the receiver impulse response. A transformation is obtained which gives an excellent approximation to the change in a mathematical representation of the distribution function in the range of probabilities below 1%. Empirical relationships are suggested which give useful estimates of the change in the distribution function over the total range of probabilities.

ON THE THEORY OF AMPLITUDE DISTRIBUTION OF IMPULSIVE RANDOM NOISE

EE Abstr. 4795/1961; J. appl. Phys. (USA), V. 32, No. 7, Pgs 1206-21,
July 1961.
K. Furutsu, T. Ishida

Two phenomenological models are considered by which impulsive random noises can be described: (a) Poisson noise, consisting of the superposition of independent, randomly occurring elementary impulses. Much electronic noise belongs to this type and the familiar physical examples are precipitation noise, ignition noise, and solar "static"; (b) Poisson-Poisson noise, consisting of the superposition of independent, randomly occurring Poisson noise, each type of Poisson noise forming a wave packet of some duration. Atmospheric noise is a representative example of the latter type. The attempt at first is made to deduce the general amplitude distribution for each model; then because the noise sources in nature are spatially distributed and noise strength decreases with distance so that the amplitude of the received noise sometimes depends seriously on this spatial distribution of noise sources, the amplitude probability distributions are considered according to the two typical cases of the discrete and continuous spatial distributions, and are compared with those of actual atmospherics. Moments of even order and correlation functions are also calculated for each model. Finally, the dependence of the assumptions used on amplitude probability distribution are discussed. The distributions obtained are, in some cases, found to be independent of the adopted models and some of the used assumptions in a wide range of noise amplitude.

RECENT METHODS FOR MEASURING THE ELEMENTS OF THE EARTH'S MAGNETIC FIELD
EE Abstr. 367/1964; Stud. Cercetari Stiint, Fiz. Stiint, Vol. 13, No. 1,
Pgs 51-64 (1962). In Rumanian.
N. Galiniceno, I. Visorian

Describes the following methods with their performance characteristics and limitations - saturated core magnetometers; utilization of the Hall effect; magnetostructive methods; two methods utilizing the deviation of free electrons in a magnetic field and, finally, nuclear resonance methods. 14 references.

NOTE ON A PROPOSED THREE-COMPONENT AERO-MAGNETOMETER

Phys. Abstr. 5787/1954; New Zealand J. Sci. Technol. B, V. 35,
Pgs 1-3, July 1953.
V.B. Gerard

For observation by this instrument, flying is restricted to clear nights, and star photographs are taken by a non-magnetic camera mounted on the fluxgate gimbal mechanism of a total-force aero-magnetometer. The camera's optical axis is parallel to the total-force fluxgate, and, by identifying the stars photographed, the orientation of the total-force fluxgate is determined and the magnetic declination and dip calculated. Tests made on the ground, with an experimental camera, indicated that this proposed method is feasible, and that the expected error would be about $\pm 0.2^\circ$ in both declination and dip.

A SIMPLE, SENSITIVE, SATURATED-CORE RECORDING MAGNETOMETER

EE Abstr. 2760/1955; J. sci. Instrum. (GB), V. 32, No. 5, Pgs 164-6,
May 1955.
V.B. Gerard

A versatile saturated-core magnetometer, designed to meet a number of geophysical uses, is described. Comparisons with a standard magnetic observatory variometer show that the large amount of negative feedback used to keep the instrument very stable. It has good h.f. response, and is simple to manufacture and service.

THE PROBLEM OF THE SPECTRAL ANALYSIS OF THE SPACE HARMONICS OF A QUASI-STATIC ELECTRIC FIELD

EE Abstr. 6116/1961; Radiotekhnika i Elektronika (USSR), V. 4, No. 12,
Pgs 2040-6, December 1959.
G.M. Gershtein, A.V. Khokhlov

A method of analysing the space-harmonic spectra of high-frequency fields in periodic structures is proposed. The method is based on the Shockley-Ramo induced current theorem and consists in simulating the

field by transforming the space harmonics to time harmonics of induced current and subsequent spectral analysis of the latter. The relationship between the spectra of the space and time harmonics is examined and experimental measurements on the space harmonic spectrum of the azimuthal field component of a four-segment inverted magnetron structure rotating with respect to a fixed probe are described. The results obtained by this method agree with theoretical spectra and with those obtained using an electrolytic tank.

SELF-BALANCING FLUX-GATE MAGNETOMETERS

EE Abstr. 4058/1958; Trans. Amer. Inst. Elect. Engrs I (USA), V. 77, Pgs 213-16, 1958; Commun. and Electronics (USA), No. 36, May 1958.
W.A. Geyger

The application of the self-balancing magnetic-amplifier technique in the realm of flux-gate magnetometers is considered. A second-harmonic type of self-balancing flux-gate magnetometer is described which is operated in conjunction with a push-pull magnetic amplifier in such a way that the d.c. flux in the high-permeability cores of the magnetometer is completely balanced by opposing d.c. flux. Thus, the magnetic field to be investigated, e.g. the earth's field in the vicinity of the magnetometer, remains substantially undisturbed. The compensating d.c. flux is linearly proportional to the average value of the polarity-reversible unidirectional output current of the magnetic amplifier. With infinite internal gain ("critical regeneration") this current is varied by an infinitesimal d.c. flux increment in the cores of the magnetometer and may be indicated and/or recorded by means of high-precision moving-coil instruments or d.c. potentiometer recorders. In a modified arrangement, the self-balancing flux-gate magnetometer is used as a "gradiometer" for measurement of inhomogeneity of magnetic fields.

THE RING-CORE MAGNETOMETER - A NEW TYPE OF SECOND-HARMONIC FLUX-GATE MAGNETOMETER

Trans. Amer. Inst. Elect. Engrs I, Vol. 81, 65-72 (1962) - Commun. and Electronics, No. 59, March 1962. EE Abstr. 9017/1962.
W.A. Geyger

A new type of flux-gate element employing an ordinary toroidal core without air-gap has been developed. By using tape-wound or laminated nickel-iron-alloy ring cores (inside diameter-outside diameter ratio in the range from 0.85 to 0.98; mean diameter 0.5 to 1.5 in or less) with semicircularly wound and differentially connected second-harmonic detector windings, a sensitivity of 1000 μ A/Oe or 1 V/Oe can be achieved. The possibility of utilizing such cores as field-sensitive elements in second-harmonic flux-gate magnetometers and gradiometers is

revealed. Although the a.c. excitation windings may be supplied either from a rotating machine or from a vacuum-tube oscillator, a preferred method is to combine the flux-gate element with a switching-transistor magnetic-coupled multivibrator in such a way that the oscillation frequency is solely determined by the parameters of the ring core and its excitation windings. Various circuit configurations and different techniques are described for extracting the second-harmonic or total-even-harmonic output information from ring-core flux-gate elements - including the use of such elements in self-balancing flux-gate magnetometers and gradiometers.

NEW TYPE OF FLUX-GATE MAGNETOMETER

J. appl. Phys. (USA), Suppl. to Vol. 33, No. 3, 1280-1, March 1962.

Phys. Abstr. 13643/1962.

W.A. Geyger

The use of an ordinary toroidal core without air-gap as a flux-gate magnetometer has been overlooked. A magnetometer using such a core as the field-sensitive element with semi-circularly wound and differentially connected second-harmonic detector-windings was developed. The semi-circular portions of a nickel-iron alloy ring core act here like two separate cores (corresponding to the two parallel nickel - iron - alloy strips or scrolls of conventional forms of flux-gate elements), as far as second-harmonic flux components are concerned. By using tape-wound or laminated (washer-type) Superalloy cores having i.d. - o.d. ratios in the range from 0.85 to 0.98 a sensitivity of $1000 \mu \text{ amp/Oe}$ or 1 V/Oe can be achieved. Such "ring-core" flux-gate elements" make it possible to: (1) use ultrathin, 1/8th mil tape and correspondingly high excitation frequencies, 10-40 kc/s; (2) make "point measurements" by reducing the core diameter to 0.5 in. or less; (3) minimize the magnetizing-current requirements; (4) obtain linear characteristics; (5) eliminate memory effects; (6) facilitate matching of the magnetic characteristics of the two active parts of the flux-gate element which belong here to the same core; (7) detect very small changes in the earth's magnetic field; and (8) apply multiple detector windings on a common core. The power requirements of a portable magnetometer, operated from a 6V battery, were reduced to 50 mW by combining the ring-core flux-gate element with a switching-transistor magnetic-coupled multi-vibrator in such a way that the oscillation frequency is solely determined by the parameters of the ring core and its excitation windings.

FLUX-GATE MAGNETOMETER

EE Abstr. 383/1963; Electronics (USA), Vol. 35, No. 22, 48-52, 1st June 1962.

W.A. Geyger

Describes the development of a ring-core flux-gate magnetometer suitable for use in earth-satellite equipment with solar-battery power

supplies. The magnetometer has a toroidal core with semicircularly wound second-harmonic detector windings. Its a.c. excitation is achieved by a transistorized magnetically-coupled multivibrator with an oscillation frequency determined by the parameters of the ring core and its excitation windings. The core swings between saturation levels eliminating memory effects. The unit is small and light and has a power consumption not greater than 20 to 50 mW. The evolution of the ring core from the conventional parallel bar core is discussed together with different types of torodial core magnetometer circuits. These circuits can be sub-divided into two main groups: (1) transformer type circuits with several winding units isolated from each other and used separately as a.c. excitation windings and second-harmonic detector windings; and (2) bridge and differential circuits with auto-connected winding units acting simultaneously as a.c. excitation windings and second-harmonic detector windings.

RING-CORE FLUX-GATE MAGNETOMETERS WITH SELF-SATURATING CIRCUITS
EE Abstr. 374/1964; IEEE Trans. Commun. Electronics (USA), No. 68,
508-14, September 1963.
W.A. Geyger

In the fundamental-frequency types of flux-gate magnetometer described in this paper, ordinary toroidal cores without air gap operate as field-sensitive elements in self-saturating push-pull circuits, as used in the magnetic amplifier art. The simplest form of such a magnetometer consists essentially of a half-wave bridge circuit, in which the two toroidal magnetic amplifier cores are replaced by the semi-circular portions of a single ring core having two or four equally rated gate windings and acting as a flux detector. In a modified arrangement, two half-wave push-pull circuits with ring-core fluxgate elements are combined in a full wave system, which may be utilized either as a very sensitive magnetometer or as a gradiometer for the measurement of the inhomogeneity of the magnetic fields.

MEASUREMENT OF ATMOSPHERIC NOISE
EE Abstr. 6116/1959; J. instn. Telecomm. Engrs (India), V. 5, No. 1,
Pgs 2-16, December 1958.
B.B. Ghosh, S.N. Mitra

Two methods of measuring atmospheric noise levels subjective and objective, are described. Technical aspects of the instrumentation for carrying out the measurements are critically examined and the results of experiments, used as a basis for subjective measurements, are described. A statistical correlation between the two methods is established. Values of minimum signal strength required for satisfactory

reception of broadcast programmes obtained by the subjective method followed at Delhi are presented for the period from November 1955 to March 1958. Diurnal seasonal and frequency variations of these values are given in the form of graphs. Absolute values of noise for different months, frequencies and times of the day are given separately in an appendix.

ELECTROMAGNETIC MAGNETOMETER FOR DIRECT OR BACKED-OFF MEASUREMENT
EE Abstr. 845/1962; Alta Frequenza (Italy), V. 30, No. 6, Pgs 433-43, June 1961.
G. Giachino

The instrument was designed to measure directly from 0.025 At/m to 25 At/m. with provision for backing-off currents for measurement up to 600 At/m. A probe coil is supplied with a constant sinusoidal current sufficient to drive it into saturation. The presence of a continuous magnetic field produces second harmonics in the voltage across the coil. The harmonic is detected by comparison in phase and amplitude with a reference voltage at twice the frequency of the coil feed. The output is proportional to the net d.c. field in the coil. Full circuit details are given, with component values.

ELECTRONIC MAGNETOMETER WITH HIGH SENSITIVITY
EE Abstr. 12071/1962; Publ. 1st Electrotec. Naz. Ferraris (Italy), Vol. 26, 127-41 (1961). In Italian.
G. Giachino

An experimental magnetometer is described which utilizes detection of a second harmonic. Details of the following circuits are given; the generator of the excitation current, the measuring probe, the signal amplifier, the frequency doubler, the detector, and the stabilized supply for the compensating current. The range of the instrument is between 0.1 to 600 Ampere-turns/m.

UNDERWATER ELECTROMAGNETIC DETECTOR
Columbia University Division of War Research, Memorandum, 1943. Available from Office of the Publication Board, Department of Commerce, Washington, 25, D.C. - PB 67708 (CUN DWRM G10/R129), \$ 1.00.
G.D. Gillet

No abstract.

SFERICS MONITORING SYSTEM

EE Abstr. 4256/1961; Inst. Radio Engrs (USA), Trans., V. I-9,
No. 3, Pgs 315-26, December 1960.
E.G. Goddard

This monitoring system was developed for use at three arctic sites to study sferic population; the diurnal, seasonal and auroral effects on v.l.f. propagation; and the locations of sferic sources. The system is an integrated assembly of electronic, photographic, and electromechanical equipment capable of being operated in several different modes to gather the following data: (1) number of sferics occurring in four 20-dB-intensity levels in four 6-hr-time blocks; (2) bearing of individual sferics; (3) waveform of individual sferics; (4) time-integrated bearing patterns; (5) noise level and signals in the 12-to 30-kc range. A secondary frequency standard at each site is checked against WWV or WWVH daily, and provides a common time reference for the records from all sites. A modified Watson-Watt d.f. system with a crossed-loop aerial provides instantaneous bearing. Instantaneous sense is achieved by combining the crossed-loop signals with the signal from an omnidirectional aerial. In addition to the sense function, the latter aerial also provides signal energy to a scanning receiver, a multi-threshold-time-block events counter, and a signal waveform channel.

THE OBSERVATION OF SHORT PERIOD FLUCTUATIONS IN THE GEOMAGNETIC FIELD
A thesis submitted for the degree of Ph.D. (Physics), University of California at Los Angeles, Microfilm, Photographic Service, University of California, Los Angeles, California.
P.A. Goldberg

The investigation reported here was undertaken to determine the character of geomagnetic fluctuations in the frequency range between one and 100 cps. Such fluctuations cannot be studied by instruments normally used in geomagnetic observations because of limitations of their magnet systems. Three recent attempts to observe such short period fluctuations by using detector coils have led to discordant results. A systematic study of the problem of using detector coils for this purpose was made. The principle limitations to the observation were found to be tube noise from the system amplifier, and interference from power lines. It was found possible to make the effect of all system noise negligible through the use of a properly designed detector coil of large area. A 60 cycle rejection filter, although incapable of eliminating noise due to power line fluctuations, was valuable in indicating the presence of disturbances due to power lines. Fourteen observing sites were tested, but only two were free from detectable power line interference. A new high performance system was developed, employing a detector coil of equivalent area

20 times that used by previous investigators. With this system observations were made in 2.2 to 78 cps band at selected sites where power frequency interference was 20,000 times less than previously reported. Under these favourable conditions magnetic fluctuations were observed occurring in bursts of short duration usually less than one second, in contrast to the continuous fluctuation noise previously reported. The burst activity varied from day to day. On an active day bursts occurred as frequently as five times per minute, while on a quiet day bursts were often separated by five minute intervals. The burst activity was found to have no significant correlation with ordinary geomagnetic variables. However, in a comparison of burst activity with the free electron density of the F2 layer, for 270 half-hour intervals, it was found that during periods of high burst activity the electron density was significantly greater than its monthly median value. Possible origins of these short period fluctuations in the geomagnetic field are discussed and further extensions of the investigation are suggested.

NEW MOVING-IRON MAGNETOMETER

EE Abstr. 3216/1953; J. Rech. Cent. Nat. Rech. Sci. (France), V. 21, Pgs 286-91, December 1952.
E. Gondet

It consists essentially of three magnetic cores arranged along a common axis with the outer ones fixed and the inner one free to rotate about an axis perpendicular to the magnetic axis. A coil is mounted on each of the fixed cores and the rotation of the central element induces a voltage in them which can be measured, and depends on the magnitude of the external magnetic field and the speed of rotation of the moving core. The coils can be used to balance out the steady part of the field so that the variations are easily observed. Design considerations are discussed and details of a unit which has been tested are given. At a speed of 6000 r.p.m. it is possible to measure to about 1%. The instrument is well adapted for recording the components of the earth's magnetic field.

THE NEW METHOD OF CALCULATING MAGNETIC NOISE

EE Abstr. 12059/1962; Dokl. Akad. Nauk SSSR, Vol. 144, No. 1, Pgs 97-100, 1st May 1962. In Russian.
S.N. Gorodenskii

The calculation relates to the estimate of magnetic noise level in airborne and space vehicles which will be used for the detection of small magnetic fields. The instruments are particularly sensitive to the effects of small rotations in the field to be measured. The effect of induced currents in conducting parts of the vehicles is taken into account. (English trans. in: Soviet Physics - Doklady (USA)).

SOME PRELIMINARY EXPERIMENTAL TESTS OF A NOVEL METHOD OF RADIATING AT
VERY LOW FREQUENCIES

R.N. Gould

See Section II, Page 151.

THE APPLICATION OF A FLUXGATE MAGNETOMETER TO AN AUTOMATIC ELECTRONIC
DEGAUSSING SYSTEM

Phys. Abstr. 18979/1961; Canad. J. Phys. V. 39, No. 9, Pgs 1357-68,
September 1961.

R.L. Graham, J.S. Geiger

The three-component fluxgate magnetometer developed by Serson was adapted to provide correction signals to the degaussing system of the Chalk River iron-free β -ray spectrometer. Improved electronic circuitry was developed for the magnetometer which minimizes the zero error and reduces to $< 10^{-4}$ gauss long-term drift caused by component aging. The degaussing coil arrangement used to generate uniform magnetic field components opposite to those of the earth is indicated and the current regulation system is described briefly. The method in which the magnetometer correction signal is introduced into the current regulators is shown and an example is given of the performance of this degaussing system during a magnetic storm.

USING DIGITAL TECHNIQUES IN L.F. SPECTRUM ANALYSIS

EE Abstr. 802/1962; Electronics (USA), V. 33, No. 46, Pgs 78-81,
11th November 1960.

B. Grand, L. Packer, J.L. West.

A detailed description is given of a system by means of which signals in the frequency range 0-0025 to 1000 cps are converted to signals in the range 250 to 100,000 cps, thus permitting the use of a standard heterodyne spectrum analyzer. The method used is to sample the input signal, convert the samples to binary coded form and store the resulting numbers; these are then read out of the store repetitively at a higher speed and re-converted to analogue form before feeding to the spectrum analyzer. The effect of repetitive analysis upon the apparent spectrum is discussed and it is shown that a resolution of 0.25% of the maximum frequency in any range may be achieved. Seven input ranges are available, determined by the cut-off frequency of the input filter, the sampling rate in each case being 5 times the cut-off frequency. Typical spectra obtained from low-frequency signals are illustrated.

DIELECTRIC PROPERTIES OF ICE AT VERY LOW FREQUENCY AND THE INFLUENCE OF A POLARIZING FIELD

Helv. Phys. Acta. V. 28, Pgs 300-303, 31st August 1955. In German.
H. Granicher, C. Jaccard, P. Scherrer, A. Steinemann.

Measurements at frequencies down to 0.7 cps are reported. The loss factor passes through a low frequency maximum which is distinguishable from that associated with the dipole dispersion by its different temperature dependence. The effect of impurities is to shift the maximum towards higher frequencies. Application of a unidirectional field does not affect the permittivity of the pure crystals but eliminates the low-frequency dispersion when impurities are present.

THE USE OF A TOTAL-FIELD MAGNETOMETER IN THE MAGNETOTELLURIC METHOD OF VERTICAL RESISTIVITY PROFILING

Phys. Abstr. 13821/1963; J. geophys. Res. (USA), Vol. 68, No. 3, Pgs 869-75, 1st February 1963.
A.W. Green, Jr., B.H. List.

Recent work has indicated that orthogonal E and H components of the magnetotelluric-micropulsation field may be used in the investigation of the vertical resistivity structure of the earth. Most of the techniques used are based on the assumption that the micropulsation field results from vertically incident electromagnetic waves. In their simpler form, the techniques are also based on the assumption that the earth model to be studied is layered in a horizontally homogeneous manner. Under these conditions, the vertical H component is zero and a total-field magnetometer will measure the north-south H component of the geomagnetic micropulsation multiplied by a constant. This measurement may be used in the usual way with an east-west current measurement for the determination of resistivity. Thus, it is possible, in regions of known horizontal homogeneity, to exploit the high sensitivity, portability, and freedom from vibration effects of an optical pumping magnetometer. An experiment is described in which the ratios of $|\vec{H}_y|/|\vec{E}_x|$ for steady-state magnetotelluric waves of the locally predominant periods were computed from E-W earth current and total-field magnetometer records at a test site near Dallas, Texas. The test site was located in a sedimentary basin in which 14,000 ft of horizontally lying Cretaceous and Paleozoic sediments of low resistivity rest on a highly resistive, Precambrian basement. The experimentally determined $|\vec{H}_y|/|\vec{E}_x|$ ratios were in good agreement with theoretical values obtained by the method of Berdichevsky and Brunelli (1959) who used resistivity and structural data obtained from a nearby well.

FIELD MEASUREMENTS BY THE HARMONIC METHOD: THEORETICAL CONSIDERATIONS
EE Abstr. 4641/1959; Nachrichtentechnik (Germany), Vo. 9, No. 4,
Pgs 173-80, April 1959.
J. Greiner.

This is a method of measuring a relatively weak steady field by superimposing it on an alternating field whose amplitude is sufficiently great to saturate an iron core. The strength of the steady field is determined by measuring the amount of second harmonic of the polarizing a.c. field.

SUR L'INFLUENCE DE LA SELF-INDUCTION DES BOBINAGES A NOYAU MAGNETIQUE
UTILIZES POUR L'ENREGISTREMENT DES VARIATIONS RAPIDES DU CHAMP MAGNETIQUE
TERRESTRE
Ann. Geophys. (France), Tome 13, No. 3, 1957.
G. Grenet

Dans un appareil utilisant une bobine de self-induction non négligeable et un galvanomètre plus ou moins couplés on peut réduire à quatre le nombre de constantes caractérisant l'appareil. L'une des constantes ($F \times l$) caractérise l'amplification, une autre (v) la pulsation moyenne de l'appareil, enfin deux constantes seulement (D et E) déterminent la forme des caractéristiques. On montre comment la considération des appareils sans réaction équivalents ou des circuits électriques équivalents facilite la compréhension des phénomènes observés.

A TECHNIQUE FOR THE RAPID ANALYSIS OF WHISTLERS
EE Abstr. 5212/1957; Proc. Inst. Radio Engrs (USA), V. 45, No. 6,
Pgs 806-11, June 1957.
J.K. Grierson

Discusses the design of a new type of sound spectrograph. This instrument is of the single-channel scanning type, but its basic action is to scan the frequency-time plane in frequency at a fixed time rather than, as in existing instruments, in time at a fixed frequency. First, a very short section of the signal to be analysed (roughly equal in duration to the reciprocal of the bandwidth of the analysing filter) is stored in the instrument electronically. The stored signal is then read out repeatedly many times faster than its original speed, and this repeated waveform is analysed by a variable-tuned filter which sweeps once very rapidly through the expanded frequency band which the signal now occupies. The varying output from the filter, representing the variations of the amplitude of the signal with frequency at one particular time, is recorded as one line of a scan across a continuous strip display. Finally, the stored sample of signal is erased, replaced with the next sample, and the whole process repeated. An a.f. spectrograph of this type appears to combine speed of operation with fine resolution in frequency.

MEASUREMENT OF WEAK MAGNETIC FIELDS OF TERRESTRIAL TYPE
Phys. Abstr. 16474/1961; Arch. Sci. (Switzerland), Vol. 13,
No. Fasc. Spec. 567-620, 1960.
P. Grivet

9th Colloque Ampère (Abstr. 4734 of 1961). Following a brief description of the earth's magnetic field and its variations, a full review is given of the various modern techniques developed both for the relative and absolute measurement of the field. Devices based on nuclear magnetic resonance in liquids are discussed in detail.

THE DESCRIPTION OF A RANDOM PROPAGATION CIRCUIT BY THE COHERENCE BETWEEN ADJACENT FREQUENCIES

Electromagnetic Theory and Antennas, Proceedings of a Symp. held at Copenhagen, Denmark, June 1962, edited by E.C. Jordan, Pgs 747-755.
Tor Hagfors

The properties of the response of propagation circuits with statically varying parameters is studied by means of a spaced frequency correlation function. This correlation function is shown to be related to the power pulse response of the circuit. Certain analogies are made with the theory of random noise and it is shown in terms of examples how the theory may be applied to the investigation of random propagation circuits.

THE MODULATION OF A PROTON MAGNETOMETER SIGNAL DUE TO ROTATION

Phys. Abstr. 465/1963; Geophys. J. (GB), Vol. 7, No. 1, Pgs 131-41, September 1962.
S.H. Hall

Expressions for the amplitude and frequency modulation of the signal from a rotating proton precession magnetometer are derived by treating the net magnetization of the proton-rich fluid as a simple dipole. The instantaneous frequency modulation is depicted in two sets of curves, either of which can be used dependent upon the choice of angular quantities used to specify the instrument's attitude during rotation. In practice the frequency is measured by counting methods and this results in a mean frequency for the counting interval. An expression for the mean frequency is derived and the method of correction discussed.

A LOW FREQUENCY PHASEMETER

EE Abstr. 1477/1959; Electronic Engng (GB), V. 31, Pgs 13-15, January 1959.
N. Hambley.

This unit provides quick and accurate measurement of the phase difference between two waveforms. The waveforms operate gates which allow electronic digital counters to display the phase difference in degrees. The phase measuring equipment requires an input level between 1 V and 10 V r.m.s. The frequency range is 1 cps to 100 cps but the upper limit can be extended, by a simple modification, to 3 kc.

RAPID GEOMAGNETIC FLUCTUATIONS

Phys. Abstr. 2516/1962, Tellus (Sweden), V. 13, No. 3, Pgs 432-7,
August 1961.
S. Haraldson

Presents an investigation of VLF oscillations (0.2-200 cps) in the earth's magnetic field. The measurements were made in the archipelago of Stockholm (59° N) during the period July 1957 - June 1959. The oscillations were recorded by two different instruments: a high-speed Heiland oscillograph and a low-speed Esterline-Angus recorder. In the Esterline-Angus diagrams a morning minimum at about 8 o'clock local time was found. In the Heiland oscillograms three different features were found: (1) Frequent occurrence of sinusoidal fluctuations presenting a few very narrow bands; (2) oscillations in the H- and Z-component are sometimes simultaneous, sometimes not; (3) the amplitudes in the Z-component are smaller than in the H-component. It was not possible to find a correlation between the fluctuations and other geophysical phenomena. A possible mechanism for generation of the sinusoidal oscillations is discussed.

RANDOM FLUCTUATIONS IN VERY LOW FREQUENCY SIGNALS REFLECTED OBLIQUELY FROM THE IONOSPHERE

J.K. Hargreaves
See Section I, Page 48.

THE MEASUREMENT OF ATMOSPHERIC RADIO NOISE BY AN AURAL COMPARISON METHOD IN THE RANGE 15-500 KC.

EE Abstr. 443/1960; Proc. Instn. Eleot. Engrs. (GB), Paper 3115E,
V. 107B, Pgs 39-52, January 1950.
J. Harwood, B.N. Harden.

Atmospheric noise received on a vertical aerial is compared with a locally-generated keyed signal to estimate the level at which the signal is 95% intelligible. This method was used in earlier high-frequency equipment and has been adapted for the range 15-500 kc. The apparatus and its method of operation are described. Results obtained at a number of sites are discussed in relation to more objective measurements. In particular, deduced noise powers are compared with existing world-wide predictions, revealing some differences.

ATMOSPHERIC RADIO NOISE

EE Abstr. 4100/1958; Electronic Radio Engr., V. 35, No. 5, Pgs 183-90, May 1958.

J. Harwood, C. Nicolson

A description is given of equipment used to measure the characteristics of atmospheric noise. The measurements relate to the envelope of the noise after passage through a narrow-bandwidth receiver, and the following parameters were recorded: (i) the average voltage; (ii) the average of the parts exceeding a series of voltages; (iii) the number of excursions per second above these voltages; (iv) the proportion of time for which these voltages were exceeded. A method of automatically recording the parameters of the noise envelope is described.

ATMOSPHERIC RADIO NOISE AT FREQUENCIES BETWEEN 10 KC AND 30 KC

EE Abstr. 3256/1958; Proc. Instn. Elect. Engrs. (GB), Paper 2619R, V. 105B, Pgs 293-300, May 1958.

J. Harwood

Measurements of the characteristics of very-low-frequency atmospheric noise in Southern England have been made with automatic equipment during the last few years. The results are described in terms of statistical parameters of the envelope at the output of a narrow-bandwidth receiver (300 cps between 3 db points). The average voltage of the envelope, recorded via an integrating circuit with equal charge and discharge time-constants of 8 sec, showed short-term fluctuations of about 5% and clear diurnal and seasonal variations. The r.m.s. voltage, deduced by integration of measured amplitude probability distributions, varied between 4 and 8 times the average voltage; the values were very dependent of the incidence of large infrequent pulses. The noise was always much more impulsive than fluctuation noise. The character of the noise was always approximately the same in spite of substantial changes of average voltage from time to time. Variations of the intensity and structure with frequency and bandwidth were examined.

REMARKS ON THE MEASURABILITY OF ELECTROMAGNETIC FIELDS

G. Heber

See Addendum, Page 545.

UBER DIE MESSUNG KLEINSTER MAGNETISCHER FELDER MIT HALLGENERATOREN

H.V. Hieronymus, H. Weiss

See Addendum, Page 546.

HIGH RESOLUTION AND THE MEASUREMENT OF WEAK FIELDS BY NMR

G. Hochstrasser, G. Béne, R. Extermann

See Addendum, Page 546.

A COMPARISON OF MEASUREMENTS MADE WITH TWO N.M.R. MAGNETOMETERS OF DIFFERENT TYPES: THE SOLAR ECLIPSE OF 15TH FEBRUARY 1961.

G. Hochstrasser, A. Erbeia

See Addendum, Page 547.

INSTRUMENTATION FOR RECORDING AND ANALYSIS OF AUDIO AND SUB-AUDIO
NOISE

D.D. Howard

See Addendum, Page 547.

A DEVELOPMENT OF THE USE OF THE ELECTROLYTIC TANK FOR FIELD STUDIES

J. Hudson

See Addendum, Page 547.

REMARKS ON THE MEASURABILITY OF ELECTROMAGNETIC FIELDS

Phys. Abstr. 2416/1958; Nuovo Cimento (Italy), V. 7, No. 5,
Pgs 677-84, 1st March 1958.

G. Heber

Indeterminacy relations are derived, which express the facts, that only 4-dimensional averages of electromagnetic fields are measurable and that also an average cannot be measured with unlimited accuracy simultaneously with the position of the averaging region in space-time continuum.

THE EPHI SYSTEM FOR VLF DIRECTION FINDING

J. Research (C. Engineering & Instrumentation), Nat. Bur. Stands.
65C, Pgs 43-49, January-March 1961.

G. Hefley, R.F. Linfield, T.L. Davis.

No abstract

SOME OBSERVATIONS OF THE GEOMAGNETIC FLUCTUATION SPECTRUM AT AUDIO
FREQUENCIES

Phys. Abstr. 1593/1961; J. Geophys. Res. (USA), V. 65, No. 8,
Pgs 2545-7, August 1960.

J.R. Heirtzler, D.L. Nichols, R.A. Santirocco

Graphs of geomagnetic fluctuation spectra in the range 10 to 10,000 cps at two sites in the north eastern United States are given and compared with earlier results (Abstr. 3540 of 1948; U.S. Naval Ordnance Lab., Navord rept. No. 4009 of 1957; Abstr. 5217B of 1957, Proc. Inst. Radio Engrs, V. 45, No. 6, Pgs 787-94, June 1957). Computations of cross-correlation coefficients between the envelopes of noise observed simultaneously at two frequencies show that there is a loss of time coherence between the fluctuations near 2 kc and those at other frequencies.

ATMOSPHERIC WAVEFORMS WITH VERY LOW-FREQUENCY COMPONENTS BELOW 1 KC
KNOWN AS SLOW TAILS

J. Atmos. terrest. Phys.(GB), V. 10, Pgs 266-287, 1957.

F. Hepburn

Extensive observations are described of the forms, magnitude, quasi-period, and delay relative to the high-frequency component of the slow tails of atmospheric waveforms and the variations with time of day and propagation distance. Theoretical considerations of possible source conditions and propagation characteristics fit the observations.

AUTOMATIC SYNCHRONOUS EXCITATION OF SUSPENDED SYSTEMS

Phys. Abstr. 2925/1964; Rev. Sci. Instrum (USA), Vol. 34, No. 11,
Pgs 1254-7, November 1963.

F.V. Hunt

The sensitivity and the signal-to-noise ratio of electrically deflected measuring instruments, such as magnetometers or galvanometers, can be increased significantly by reversing the exciting current periodically at the fundamental resonance frequency of the suspended system and observing the peak amplitude of the oscillatory dynamic deflection. If these current reversals are made to occur exactly at the midpoints between successive zeros of deflection, the oscillations of the suspended system will be stably maintained at the resonance frequency with a ratio of dynamic to static deflection of approximately $4/\delta$ where δ is the logarithmic decrement for free oscillation. This note describes electronic apparatus devised for controlling automatically the required quadrature timing of the current reversals. The circuits comprise a photocell-actuated Schmitt trigger, a bistable flip-flop, a timing capacitor, and a voltage comparator. Small timing errors due to finite slit width and hysteresis in the voltage comparator are of opposite sense and can be made to cancel.

NOL VECTOR AIRBORNE MAGNETOMETER TYPES 2A AND 2B

U.S. Naval Ordnance Lab., White Oak, Maryland, Rept. No. 1187, 180 p.,
illus., 1954.

H.R. Irons, E.O. Schonstedt

No abstract

ON SOME PROBLEMS CONCERNING THE ACCURACY OF WAVE FORM ANALYSIS OF ATMOSPHERICS

Bull, Research Inst. Atmospherics, Nagoya Univ., Vol. 4, Pg 90 (1953).

In Japanese.

H. Ishikawa, H. Ito.

Authors attempt to determine the accuracy of the measurements of waveform fine structures which were recorded on photographic films during the observation period. It has been discussed first the accuracy of width measurement of pulse which usually presents itself frequently on the waveform during thunderstorm and it has been pointed out the possibilities of over-estimation of pulse width owing to a fast sweeping speed of the bright spot on C.R.T. screen and those of under-estimation of that owing to a slow sweeping speed. The sweep length of the bright spot on CRT screen generally fluctuates within 6% of its mean length, which is attributed to the instabilities of one shot sweeping device and supplying voltage in power line. It has been also made clear that the width of sweeping line broadens from wave-top to wave-tail and that this effect can be explained rather reasonably from the possible distortion of one shot sweeping waveform. Finally it has been made clear from our estimation that the width of a sweeping line represents almost the diameter of bright spot on CRT screen when the time of sweeping of bright spot is larger than 6 milli-seconds.

ANALYSIS OF THE OUTPUT OF ROCKET-BORNE MAGNETOMETERS

EE Abstr. 11414/1963; Canad. J. Phys., Vol. 41, No. 8, Pgs 1252-62, August 1963.

M. Ito

The output is analysed for assumed simple angular motions of the magnetometer frame of reference. Calculated output records are given and a qualitative analysis is made by referring to a simple pictorial model for the magnetometer output pattern.

A PROPOSED EXPERIMENT TO DETERMINE ELF PROPAGATION CHARACTERISTICS

Abstract in Proceedings of the 1960 Conference on the Propagation of ELF Radio Waves, Nat. Bur. Stand. (USA), Boulder Labs., Technical Note No. 61, 1960.

A.G. Jean, W.L. Taylor

A plan for establishing an experiment at the Boulder Laboratories to study the propagation of radio waves at extremely low frequencies (ELF) is described. The technique consists of receiving the same atmospheric at two or more stations situated approximately along a great-circle which passes through the source. The attenuation suffered by the atmospheric in propagating between two stations can be calculated from the spectra of the waveforms using methods developed at the Boulder Laboratories. Recently, the analytical techniques were extended to include calculations of relative phase velocities. Recently, ELF recording stations were installed at Fairbanks, Boulder and Maui. Preliminary results obtained with this network confirm the feasibility of locating lightning discharges in certain areas of the Pacific Ocean and of obtaining two station waveform observations of sufficient quality to warrant performing detailed transient analyses.

CALIBRATION OF LOOP ANTENNAS AT VLF

J. Res. Nat. Bur. Stand. (USA), V. 65C, No. 3, Pgs 189-193, July-September 1961.

A.G. Jean, H.E. Taggart, J.R. Wait

A technique and the equipment used for the precise determination of field strength of signals received from VLF transmitters is described. The equipment, which is battery-operated, contains provisions for the reception of VLF signals and the generation of standard fields to an accuracy of 5%. Both the receiving and transmitting antennas are loops. The field strength is determined in terms of a quasi-static magnetic field with the two loop antennas positioned coaxially at a spacing of approximately two meters. Although the technique was developed for use at VLF, it can be used at higher frequencies for calibrating loop antennas, generators, and voltmeters, and for determining effective heights of antennas, or similar applications.

OBSERVED MAGNETIC EFFECTS FROM METEORS

Phys. Abstr. 16407/1960; J. geophys. Res. (USA), V. 65, No. 5,
Pgs 1617-19, May 1960.

A.W. Jenkins, C.A. Phillips, E. Maple, Jr.

See Abstr. 5432/1950, 1942/1959. A preliminary analysis of data from the I.G.Y. programme on geomagnetic fluctuations in the range 1-50 cps, indicates a correlation between meteoric activity and the average (rectified and integrated) level of fluctuation. The frequency range was subdivided into six approximately octave bands. For every major meteor shower, with one possible exception, in the three months considered, there is a peak in geomagnetic activity in the 1-5 cps bands only. Other peaks occur, not coincident with meteor showers, but these appear in all the six bands and are attributed to thunderstorms.

GROUND-CONDUCTIVITY DETERMINATIONS AT LOW RADIO FREQUENCIES BY AN ANALYSIS OF THE SPHERIC SIGNATURES OF THUNDERSTORMS

J. Geophys. Research. Vol. 66, No. 10, Pgs 3233-3244, October 1961.

J.R. Johler, C.M. Lilley

A technique is described for determining the conductivity of the ground at low frequencies with the aid of spheric pulses from thunderstorms. The paper is illustrated with an actual conductivity determination, and the detailed comparison of waveforms predicted theoretically with those observed experimentally indicates that an effective value of conductivity can be measured to a precision of one or two significant figures. The results of the analysis indicate application of both experimental and analytic techniques to other propagation studies, such as the evaluation of the reflection and transmission properties of the lower ionosphere.

DATA REDUCTION INSTRUMENTATION FOR RADIO PROPAGATION RESEARCH

July 1961; (NBS Tech. Note. No. 111). (PB 161612). \$1.00.

W.E. Johnson

No abstract

THE PIONEER I, EXPLORER VI AND PIONEER V HIGH-SENSITIVITY TRANSISTORIZED SEARCH COIL MAGNETOMETER

EE Abstr. 1790/1961; Inst. Radio Engrs (USA) Trans., V. SET-6, No. 3-4,
Pgs 114-21, September-December 1960.

D.L. Judge, M.G. McLeod, A.R. Sims.

The magnetometer described was designed for the purpose of measuring the distant geomagnetic and interplanetary magnetic fields. The sensing element is a coil fixed in the frame of a spinning vehicle. The associated nonlinear amplifier has a dynamic range of approximately three decades and

an equivalent noise threshold of 6.0 microgauss. This system was flown in the Pioneer I, Explorer VI and Pioneer V payloads to detect both absolute magnitude and directional changes in the magnetic field intensity at great distances. The complete unit enclosed in an r.f.-shielded container weighs one pound.

APPLICATION OF ELECTRON SPIN RESONANCE TO THE MEASUREMENT OF THE EARTH'S MAGNETIC FIELD

Phys. Abstr. 2315/1964; Arch. Sci. (Switzerland), Vol. 14, Special No. 132-7 (September 1961). In French. (Ampere Colloquium, Leipzig, 1961). (See abstr. 23198 of 1963).

P. Jung, J. van Cakenberghe

An apparatus is described using the absorption of DPPH with an alternating 10 G field superimposed on the earth's field. The latter is measured from the asymmetry it produces. By using a rotating field and servo a compass is realized. The sensitivity is independent of the field strength measured, in contrast to n.m.r. and optical pumping magnetometers. It is also able to measure faster field variations.

THREE METHODS OF MEASURING MAGNETIC FIELDS. I. MEASUREMENT BASED ON THE GENERATOR PRINCIPLE. II. MEASUREMENT OF THE FIELD ON THE AXIS OF MAGNETIC ELECTRON LENSES. III. MEASUREMENT BY THE PROTON RESONANCE METHOD.

Phys. Abstr. 6722/1954; Philips tech. Rev. V, 15, Pgs 49-62, August 1953.

B.F. Jürgens (Pt. I), A.C. van Dorsten A.J.J. Franken (Pt II), H.G. Beljers (Pt. III).

Three instruments for the measurement of magnetic fields, based on three entirely different principles, are described. The first of these makes use of an extremely small coil (outside dia. 1 mm., length 1.5 mm.), mounted on the shaft of a small synchronous motor and rotated with constant angular velocity in the field to be measured. The measuring range is very wide, viz. 10^{-4} to 3 Wb/m^2 (1-30,000 gauss.) and the accuracy is 3%. The second instrument was developed especially for the measurement of fields along the axis of magnetic electron lenses. A long thin solenoid, the winding direction of which is reversed at the centre, is suspended vertically by two flat springs and is mounted so as to coincide with the axis of the electron lens. When a constant 50 cps alternating current is passed through the solenoid, an alternating force acts upon the coil, this being proportional to the magnetic induction at the point where the winding changes direction. By this method the field at any point on the axis of a magnetic electron lens can be measured simply and quickly with an error of $< 1\%$. In the third method, a small container of water is placed in the field to be measured. A weak alternating field set up at right angles to this field, brings the hydrogen

nuclei of the water molecules into resonance. The frequency at which this proton resonance occurs is proportional to the strength of the field to be measured. The method is very suitable for the accurate, absolute measurement of strong homogeneous magnetic fields (error < 0.01%).

A FLUXMETER DEVICE FOR THE OBSERVATION OF RAPID SMALL CHANGES IN THE EARTH'S MAGNETIC FIELD

Annals of the IGY, V. 4, Pergamon, Pgs 304-305, illus., 1957.
A.G. Kalasnikov

Equipment used in the USSR for recording magnetic variations of small amplitudes.

A STUDY OF THE KUBECKI "MAGNETIC" TUBE AS A MAGNETIC FIELD INDICATOR AD 50272; English translation from Dok. Akad. Nauk. SSSR, V. 56, No. 7, Pgs 703-705, 1947, by E.R. Hope, DRB, Canada.

A.G. Kalashnikov, N.V. Krasnogorskaya.

No abstract

THE HALL COMPASS

E.A. Keller

See Part VIII. Page 531.

EINIGE BEMERKUNGEN ZUM PROTONENMAGNETOMETER

Z. angew. Phys. (Germany), V. 11, Pgs 495-497, 1958.

G. Klose

Discussion of sources of error.

THE CONSTRUCTION OF INDUCTION PICK-UPS FOR MAGNETOTELLURIC INVESTIGATIONS Phys. Abstr. 9122/1963; Izv. Akad. Nauk. SSSR, Ser. geofiz. 1962, No. 10, Pgs 1381-96. In Russian. English trans: Bull Acad. Sci. USSR, geophys. Ser. (USA), No. 10, Pgs 860-9, October 1962; publ. Jan. 1963.
M.V. Kolmakov, I.A. Zelensov

The elements of the theory are described. Results are given of the experimental determination of various parameters of the devices. Methods of increasing the sensitivity and of lowering the range of the recorded frequency are discussed. Principles for the construction of improved devices are given.

A STUDY OF THE APPLICABILITY OF THE KUBECKI "MOSAIC" MULTIPLIER AS A
MAGNETIC FIELD INDICATOR

AD 50272; English Translation from Izv. Akad. Nauk. SSSR, Geographical
and Geophysical Series, V. 15, No. 1, Pgs. 43-50, 1951, by E.R. Hope,
DRB, Canada.

N.V. Krasnogorskaya

No abstract

DER HALLGENERATOR UND SEINE ANWENDUNG IN DER MEBTECHNIK

Elektron. Rundschau (Germany), No. 1, February 1960.

F. Kuhrt

Die intermetallischen Verbindungshalbleiter Indiumantimonid und Indiumarsenid ermöglichen die Herstellung leistungsfähiger Hallgeneratoren. Ihre elektrischen Eigenschaften werden diskutiert. Unter den anwendungsbeispielen aus der meBtechnik werden die messung magnetischer felder, die leistungsmessung und leistungsszillografie, die kontaktlose signalgabe, die umsetzung kleinster bewegungen in eine elektrische spannung sowie die statische abfragung von magnetogrammen behandelt.

FUNDAMENTAL PROPERTIES OF FLUX GATE MAGNETOMETERS WITH (EVEN HARMONIC)
PULSE OUTPUT

EE Abstr. 846/1962; Rozprawy elektrotech. (Poland), V. 16, No. 4,
Pgs 475-92, 1960.

J. Kulikowski, M. Nalecz

A straight line approximation to the B-H curve is used in presenting the theory of the magnetometer. The approximation consists of assuming different values of μ for the saturated and unsaturated regions. It is shown that the mean value of the total even harmonic output is proportional to the field intensity and fairly independent of small changes of amplitude or waveform of the excitation voltage. Formulae of Rozenblat (Abstr. 187/1958 and other papers) are quoted to account for the core shape. Measurements were carried out at 50 cps using permalloy cores and a synchronised mechanical rectifier. Sensitivity of 10^{-3} A/m is claimed.

LABORATORY SIMULATION OF VLF PROPAGATION AND UNDERGROUND ANTENNA
PERFORMANCE

T.C. Larter, M.E. Louapre, A.P. Stogryn

See Section I, Page 65.

IDENTIFICATION AND EVALUATION OF MAGNETIC-FIELD SOURCES OF MAGNETIC AIRBORNE DETECTOR EQUIPPED AIRCRAFT
EE Abstr. 2512/1962; Inst. Radio Engrs. (USA), Trans., V. ANE-8, No. 3, Pgs 95-105, September 1961.
P. Leliak

A general method for identifying and evaluating magnetic sources associated with the magnetic airborne detector-equipped aircraft is described. It is derived for the compensation of magnetic noise related to the manoeuvres of the aircraft. Mathematical formulae are included with a uniform engineering method, independent of the type of magnetic source encountered, for analysing magnetic airborne detector records. A method for calibrating magnetic sources while in flight is also offered.

SENSITIVE RECORDING MAGNETIC FLUXMETER
Phys. Abstr. 3825/1960; J. sci. Instrum. (GB), V. 36, No. 9, Pgs 388-9, September 1959.
P. Lerond, A. Thulin.

The fluxmeter described uses a taut-suspension galvanometer, the torque of which is compensated by positive feedback. This latter is furnished by a servo-operated potentiometer, the wiper of which follows the motion of the galvanometer light spot. The device is an adaption of a commercially available recorder and permits recording of flux-variations as low as 100 Maxwell-turns per second.

VLF UTILIZATION AT NASA SATELLITE TRACKING STATIONS
Radio Science Journ. of Research NBS/USNC-URSI, Vol. 68D, No. 1, Jan. 1964, Pgs 43-45.
C.H. Looney, Jr.

The time and frequency requirements of the network of NASA satellite tracking stations are described, and it is shown that the VLF transmissions from WWVL satisfy many of these. There are great potentialities inherent in the use of these signals or suitable modification of them, for obtaining extremely accurate standard time synchronizations. NASA tracking stations will greatly extend their usage of VLF reception in the near future, not only to obtain automatic frequency corrections, but for the purposes of research in the area of time and frequency dissemination.

MEASUREMENT OF MAGNETIC FIELDS BY NUCLEAR RESONANCE
EE Abstr. 2110/1959; Electronic Engng (GB), V. 31, Pgs 138-40, March 1959.
G.C. Lowe

A simple feedback circuit is described which employs the phenomenon of nuclear magnetic resonance to measure magnetic fields over a wide range with a minimum of readjustment of the circuit elements to an accuracy of at least 0.01%.

A METHOD FOR THE MEASUREMENT OF THE PARAMETERS OF A TWO-LAYER STRATIFIED EARTH

EE Abstr. 301/1964; IEEE Trans. Antennas and Propagation (USA), Vol. AP-11, No. 3, Pgs 366-9, May 1963.
S.W. Maley

A two-layer stratified model is assumed for the earth. The distances involved are assumed to be sufficiently short that the earth can be considered flat. The measurement of the parameters of the top layer can easily be made from the surface, but the parameters of the lower layer are somewhat more difficult. A method is given for the evaluation of these quantities in terms of measurements of propagation between two aeriels located at the surface of the earth. The theoretical solution for the field of an aerial located at the surface of a flat stratified earth has been given by J.R. Wait. This solution is taken as the starting point; it is put into a form which explicitly shows the influence of the parameters of the lower layer. The method of least squares is then used to evaluate the unknown parameters in terms of the measurements. This process allows the use of a large number of measurements which are essentially subjected to an averaging procedure. This prevents localized irregularities in the earth's surface from unduly affecting the results.

AN OPTICALLY-PUMPED MAGNETOMETER FOR THE STUDY OF THE (MAGNETIC) FIELD IN SPACE

EE Abstr. 4542/1961; Ann. Radioelect. (France), V. 16, Pgs 3-8, January 1961.
L. Malnar, J.P. Mosnier

Describes a magnetometer based on the magnetic resonance of caesium vapour. Optical pumping is used to produce resonance and for its detection. A laboratory model was designed and its performance compared with that of a Gulf magnetometer. The sensitivity of the model is at present 1γ and is to be improved to 0.1γ .

MAGNETIC MEASUREMENTS IN SPACE

EE Abstr. 7475/1960; Electronics (USA), V. 33, No. 32, Pgs 47-51, 5th August 1960.
D. Mansir

Starts by outlining the objections of sending magnetometers into space. Describes magnetic measurements made from the Vanguard III satellite using a proton precession magnetometer which is described, together with a circuit showing how control is obtained. Future satellites will use optically pumped alkali-vapour magnetometers whose principles are outlined.

SUB-AUDIO FREQUENCY (1 TO 50 CPS) GEOMAGNETIC FLUCTUATIONS AT DENVER,
COLORADO

E. Maple
See Addendum, Page 553.

ELECTRON BEAM MAGNETOMETER

L. Marton and Others
See Addendum, Page 554.

USE OF AN OPERATIONAL AMPLIFIER WITH HELMHOLTZ COILS FOR REDUCING AC
INDUCED MAGNETIC FIELDS

Rev. of sci. Instrum (USA), V. 32, No. 11, Pgs 1192-95, November 1961.
L.A. Marzetta

A feedback system is described for cancelling magnetic fields resulting from alternating currents. The design features of an operational amplifier are offered. In addition the nature of the phase shift contributed by mutual inductance elements in the feedback path is discussed. Magnetic fields with a flux density of one milli-gauss can be reduced by about two orders of magnitude with the system.

ELECTRONIC RECORDING OF THE TRANSIENT VARIATIONS IN THE EARTH'S MAGNETIC
FIELD

Annals of the IGY, V. 4, Pergamon, Pgs 281-286, 1957.
A. Maxwell

Equipment developed at Jodrell Bank Experimental Station.

TIM: A BRUSHLESS GENERATING MAGNETOMETER

EE Abstr. 2148/1960; J. sci. Instrum (GB), V. 36, No. 11, Pgs 471-4,
November 1959
W.C. McCutchen

TIM (the turbo-inductor magnetometer) is an air-driven generating magnetometer which uses inductive output to avoid brushes and slip rings. The resulting mechanical simplicity allows this magnetometer to be made very small while the high rotation speed, which is possible because there are no brushes, makes the magnetometer quite sensitive. It is most suitable for measuring static or very nearly static magnetic fields. The output is an audio-frequency signal, and the accuracy depends chiefly on how accurately the amplitude and frequency of that signal are measured.

A RECORDING MAGNETIC VARIOMETER

Phys. Abstr. 8071/1955; Canad. J. Phys., V. 33, No. 7, Pgs 364-8,
July 1955.
J.H. Meek, F.S. Hector

The circuit and detecting head of an electronic recording magnetic variometer are described. The apparatus will give continuous and immediately observable values of variations of magnetic field as small as 10^{-5} oersted, if necessary.

A FREE NUCLEAR INDUCTION METHOD OF MEASUREMENT OF WEAK MAGNETIC FIELDS.
Zh. tekhn. Fiz. (USSR), V. 28, Pgs 910-912, 1958.
A.V. Melnikov and Others

No abstract

PICK-UP DEVICES FOR VERY LOW FREQUENCY RECEPTION
Electronics, Vol. 34, Pgs 68-69, April 1961.
G.J. Monser

The sensitivities of loop and whip antennas vary by as much as 60 db over the frequency range 10 cps-10 kc. The advantages of using a Hall device as a receiving element are discussed.

DESIGN OF A SECOND HARMONIC FLUX GATE MAGNETIC GRADIOMETER
Phys. Abstr. 7948/1961; Rev. sci. Instrum (USA), V. 32, No. 4, Pgs 444-8, April 1961.
R.M. Morris, B.O. Pedersen

An instrument for the measurement of gradients in the earth's magnetic field is described. The gradiometer, of 15 ft base length, is capable of operation for long periods with an error less than 20 γ (5 γ /m). Detectors are of the tuned, second harmonic flux gate type. An automatic ambient-field nulling feature was introduced to ease the requirement for exact matching of the magnetic characteristics of the gradient detectors.

EQUIPMENT FOR THE INT. VLF COMPARISON AND RESULTS OF MEASUREMENT OF PHASE VARIATION BETWEEN HAWAII AND TOKYO
Phys. Abstr. 24480/1962; J. Radio Res. Lab. (Japan), Vol. 10, Pgs 127-36, March 1963.
K. Nakajima, K. Suzuki, Y. Azuma, K. Akatsuka, K. Nakamura

For the purpose of performing the international comparison of the standard frequencies between JJY and other foreign stations, the standard VLF's are generally used. This report describes the outline of the equipment capable of measurement with much higher precision than 3 parts in 10¹⁰ per day and the results of phase comparison of VLF waves between the JJY standard and the frequency (19.8 kc/s) transmitted from NPM (Hawaii).

ANTENNAS FOR DETECTING MICROPULSATIONS
Nat. Bur. Stands. (US), Tech. News Bull, 45, Pg 83, May 1961.

No abstract

MEASUREMENT OF STEADY MAGNETIC FIELDS BY THE INDUCTIVE METHOD.
II MEASUREMENT OF THE TIME INTEGRAL OF THE E.M.F. WITH THE BALLISTIC
GALVANOMETER. DIRECT METHODS.
EE Abstr. 5033/1954; Arch. tech. Messen (Germany), No. 221, Pgs 129-
32, June 1954.
H. Neumann

The following are discussed: measurement of flux as a basis for the determination of induction, field strength, permeability and coil area; fundamentals of the ballistic method, errors due to too short galvanometer period; galvanometer constant and sensitivity, increasing sensitivity (amplifying methods); sensitivity control, scales and associated apparatus; calibration; air-flux correction (measurements on iron cores).

ARTIFICIAL PRODUCTION OF LIGHTNING ATMOSPHERICS. SEA-GOING LIGHTNING GENERATOR
EE Abstr. 7722/1960; Electronics (USA), V. 33, No. 30, Pgs 53-5, July 22nd 1960.
M.M. Newmann and Others

Details are given of schooner-borne equipment used with a 10,000 ft helicopter-supported aerial to produce high-power l.f. pulses similar to lightning atmosphericics. The megavolt generator used produces in the aerial a peak output power of about 30 MW, the calculated field strength of a 20 kc pulse being about 20 mV/m at a distance of 1000 km from the aerial. The generator can be triggered manually or from a time standard which is synchronised with WWV signals. A block diagram shows the general arrangement of the transmitting and receiving equipment used. Some circuit details are also given of the transmitter and of the phase shifter used for synchronising the crystal-controlled frequency standard with the WWV signals. The equipment affords a means for studying the l.f. propagation over long distances, with possible practical applications in the fields of long-range communication and navigation. The use of inverted-L or semicircular aeriels for generating "whistlers" is suggested.

MEASUREMENT OF SMALL DIRECT MAGNETIC FIELDS WITH FLUX-GATE MAGNETOMETERS
EE Abstr. 4038/1959; Rozprawy elektrotech. (Poland), V. 4, No. 3, Pgs 323-49, 1958.
P.J. Nowacki, M. Naiecz, J. Kulikowski

The operating conditions of single-core magnetometers, when supplied from a sinusoidal voltage source or from a sinusoidal current source, are explained. Some special types of single-core magnetometer are considered: with perpendicular fields and with variable impedance. Bridge-type magnetometers are also described.

AN EXPERIMENTAL PROOF OF THE MODE THEORY OF VLF IONOSPHERIC PROPAGATION
T. Obayashi, S. Fujii, T. Kidokoro.

See Section I, Page 80.

MEASURED FREQUENCY SPECTRA OF VERY-LOW-FREQUENCY ATMOSPHERICS
Phys. Abstr. 8426/1960; J. Res. Nat. Bur. Stand. (USA), V. 64D,
No. 1, Pgs 41-8, January-February 1960.
T. Obayashi

New spectroscopes recording continuously the amplitude-frequency spectra of VLF atmospherics have been developed. Two receivers cover the frequency ranges 1 to 10 kc and 5 to 70 kc sweeping the respective bands repeatedly, and their outputs are displayed on intensity-modulated cathode-ray tubes which are photographed on slowly moving film. Observations have been carried out since June 1958, and it appears that the results provide an excellent experimental basis for comparison with the mode theory of v.l.f. ionospheric propagation. It is found that the frequency spectrum of distant atmospherics indicates a pronounced absorption near 3 to 5 kc, a broad intensity maximum around 10 to 20 kc, and a general decrease towards higher frequencies with undulating peaks. The selective absorption bands appearing in the spectrum are variable according to the time of day and seasons. These changes may be interpreted loosely as an ionospheric effect which is associated with the cut-off frequency of the waveguide bounded by the earth and the ionosphere. The solar flare effect on v.l.f. atmospherics propagation is also revealed, which indicates a sudden shift of the spectrum to higher frequencies owing to the increase of ionization and the lowering of a reflecting height of the ionosphere.

THE DEVELOPMENT OF THE TECHNOLOGY OF ELECTRONIC FLUXGATE MAGNETOMETERS
EE Abstr. 5032/1954; Nuovo Cimento (Italy), Suppl. V. 11, No. 3,
Pgs 521-32, 1954.
G.D. Palazzi

Three distinct types of magnetometers are described in detail, the AN/ASQ3, the Gulf and the Valle transverse induction types. Their airborne and laboratory uses are explained with appropriate references.

A SMALL SENSITIVE MAGNETOMETER
EE Abstr. 171/1954; Proc. Instn. Elect. Engrs. (GB), II, V. 100,
Pgs 545-50, October 1953.
T.M. Palmer

A magnetometer is described which was designed primarily for measuring a magnetic field within the confined space of a permeameter. The measuring head of the instrument contains a thin solenoid through which a direct current is passed, to balance the field being measured

and produce zero field in the solenoid. With associated equipment designed especially for the magnetometer it is possible to detect a change in field strength of 2×10^{-5} oersted. The maximum field strength that can be measured is limited to about 50 oersteds by the heat developed in the solenoid by the balancing current.

RUBIDIUM VAPOUR MAGNETOMETER

J. sci. Instrm. (GB), V. 39, No. 6, Pgs 292-300, June 1962.

Phys. Abstr. 13646/1962

L.W. Parsons, Z.M. Wiatr

A rubidium vapour magnetometer has been made which measures the total geomagnetic field and records its variations continuously over the frequency band 0-1 cps with sensitivity of 5×10^{-6} Oe. Optical pumping technique is used to observe the energy separation between the Zeeman sub-levels in the ground state of ^{85}Rb atom, which is the measure of the ambient magnetic field and is equal to 220 kc for the local field of 472×10^{-3} Oe, with the line width of 200 cps. Resonance is detected when an applied r.f. field at the Larmor frequency causes redistribution of the population of the energy levels thus increasing absorption in the gas cell of the pumping radiation at 798 Å. A voltage controlled oscillator supplying the r.f. field is locked on to the Larmor frequency. Resonance radiation is obtained from a rubidium lamp excited from a 150 Mc, 2 w power supply. The gas cell contains natural rubidium. This is kept at a temperature of 34-45° C thus maintaining vapour pressure of about 10^{-6} mmHg. The design of the lamp and the gas cell is given. Further work to improve the light source and the gas cell should improve the sensitivity of the instrument. Redesign of the electronics to make the system oscillate at the Larmor frequency may also improve sensitivity and increase the frequency response of the instrument. The instrument described was demonstrated at the Institute of Physics and the Physical Society Exhibition in January 1961.

GALVANOMETRE IMMERGE ANTIVIBRATOIRE

Rev. gen. Elect. (France), V. LVII, No. 4, Pgs 141-146, April 1948.

M. Picard

Describes construction and characteristics of galvanometer which is insensitive to vibrations. This type of galvanometer is used in recording equipment for magnetic field measurements.

INTERCONTINENTAL FREQUENCY COMPARISON BY VERY LOW-FREQUENCY RADIO TRANSMISSION

J.A. Pierce

See Section I, Page 83.

A NEW METHOD OF MEASURING MAGNETIC FIELD STRENGTH
Zh. tekhn. Fiz. (USSR), V. 27, Pgs 2647-2651, 1957.
G.E. Pikus, O.V. Sorokin

Based on variation of concentration of current carriers in thin semi-conducting plate through which current passes. According to theory method may serve for fields from 5000 to 10^{-5} Oe.

EXTREMELY LOW FREQUENCY RECEPTION AT KINGSTON, R.I.
AD 270 856; University of Rhode Island, Kingston, R.I., Scientific Rept. No. 1, 17 p., plus figs., 1961.
C. Polk, F. Fitchen

Since June 1961 magnetic fields of natural origin in the 5 to 20 cps frequency range have been recorded in Kingston, R.I. The experimental equipment is described briefly, and results are presented. Variations with time cavity are indicated, and effects of solar activity are discussed. An analysis of the envelope of recorded wave trains shows only fair agreement with existing theory.

A DESCRIPTION OF THE IMPROVEMENTS RECENTLY MADE TO MAGNETOMETERS OF HIGH SENSITIVITY USED IN MAGNETIC MINERALOGY AND PALEOMAGNETISM
Phys. Abstr. 3082/1964; C.R. Acad. Sci. (France), Vol. 257, No. 5, Pgs 1037-40, 29th July 1963. In French.
J.P. Pozzi, F. Thellier

Improvements to a magnetometer using an astatic system of three magnets are described. These lead to increased sensitivities and stabilities and to the possibility of making measurements at different temperatures.

ON THE SPECTRUM OF TERRESTRIAL RADIO NOISE AT EXTREMELY LOW FREQUENCIES
EE Abstr. 6107/1962; J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 6, Pgs 581-593, November-December 1961.
H.R. Raemer

A theory of the frequency spectrum of radio noise at extremely low frequency (ELF) is presented and the results compared with recent measurements of the first five "Schumann" resonant modes (between 8 and 34 cps) made by Balser and Wagner (1960). The source of this noise is assumed to be return strokes in vertical cloud ground lightning flashes distributed randomly in time, uniformly in angular displacement along the earth relative to the observer and with statistics of stroke duration, interstroke intervals and strokes per flash taken from studies of thunderstorms reported by J.C. Williams. Thus, the mathematical model for the noise sources is an extremely simple one, being analogous to the shot

effect in electron devices. The electromagnetic model employs the familiar waveguide mode theory, assumes a sharply bounded homogeneous ionosphere, and neglects the earth's magnetic field. Agreement between the shape of the theoretical and observed spectrum is good for the first three modes and rather poor for the higher modes. It is found by matching the theoretical resonant frequencies to the observed resonances that the product of effective ionosphere height h and the square root of effective conductivity $\sqrt{\sigma_i}$ is a decreasing function of frequency. The functional dependence of this quantity on frequency is determined and used in the calculation of the mode spectrum. Discrepancies between the theory and experimental results are believed to be partially due to the artificiality of the sharply bounded homogeneous ionosphere model and to failure to give sufficient probability weighting to equatorial regions of abnormally high thunderstorm activity. These last items are the subjects of continuing work on the extension of the theory.

AN INVESTIGATION OF THE DIFFUSION OF ELECTROMAGNETIC FIELDS IN A STATIONARY CONDUCTING MEDIUM BY MEANS OF EQUIVALENT NETWORKS
EE Abstr. 627/1963; UK Atomic Energy Authority AERE Men. M1014,
14 pp. March 1962.
A.H. Read

The equations giving the spatial variation of voltage and current along a resistance - capacitance (RC) line are derived. These are compared with the equations giving the one-dimensional diffusion of electric and magnetic fields through conducting media. Two problems involving the pressure resulting from these fields are then examined and the implications of these results discussed briefly.

AN ELECTROLYTIC TANK METHOD FOR LOW-FREQUENCY LOOP ANTENNA STUDIES.
AD 18469; Stanford Research Institute, Stanford, Calif., Technical Rept. No. 31, 30 p, illus., 1953.
R.F. Reese

A quasi-static analog technique is described for determining the low-frequency magnetic field distortion caused by the presence of a conducting diffracting body. An electrolytic tank system is used to establish a uniform conduction current field into which non-conducting models are placed. The electric field at the model surface satisfies the same boundary conditions as those imposed on the magnetic field of a plane electromagnetic wave impinging upon a metallic structure. This analog system is used to determine the response and bearing error of loop antennas placed in rectangular cavities and on various geometrically regular objects. Instrumentation is discussed, and measured results are compared with calculated results to show the accuracy of the method. Finally, the quadrantal bearing error of a typical direction-finder loop antenna on a model DC-3 aircraft is measured and compared with corresponding measurements made in flight tests with a full-scale aircraft.

AN AIRBORNE ELECTRIC FIELD METER

EE Abstr. 1919/1958; Inst. Radio Engrs (USA) Trans, V. 1-6, No. 3,
Pgs 195-9, September 1957.

G.C. Rein, C.G. Stergis, T. Kangas

A brief history and description of the phenomenon to be measured is given. The airborne atmospheric electric field meter is described. It utilizes a high-impedance electrometer-triode follower circuit. Rapid response is obtained with the use of radioactive sources of ionization attached to the ends of the input probes. These sources, polonium 210 serve as potential equalizers. It is shown experimentally that at simulated high altitudes the ionization resulting from equalizers does not attenuate the meter response and that, although the presence of the meter distorts the field, it records a potential difference which differs negligibly from the potential difference which would exist in the absence of such a device. The instrument was used successfully in flights over thunderstorms during the summer of 1956. Its purpose was to aid in the accumulation of data on the earth's supply currents.

THE PROBABILITY DENSITY OF THE PHASE DERIVATIVE OF THE SUM OF A SINUSOIDAL SIGNAL AND GAUSSIAN NOISE

EE Abstr. 2034/1961; Radiotekhnika i Elektronika (USSR), V. 4,
No. 3, Pgs 540-1, March 1959.

L.T. Remizov

The probability distribution of the phase derivative of a random process consisting of the sum of a sinusoidal oscillation and normal noise is evaluated for different values of the ratio of their effective powers using the four-dimensional probability density of the envelope and phase of the signal and noise and their derivatives in time. The result is of interest in assessing the efficiency of different frequency-sensitive devices in the presence of noise.

AN INDUCTION COIL FOR MEASURING A MAGNETIC FIELD

Phys. Abstr. 21922/1963; Czech. J. Phys. B, Vol. 13, No. 7, Pgs 545-8,
1963.

I. Rezanka

The influence of the inhomogeneity of a magnetic field on measurements by the ballistical method using a cylindrical induction coil is calculated, keeping terms up to the fifth order in the linear dimensions of the coil. If the geometry of the coil is **correctly** chosen, the relative deviation due to the inhomogeneity is proportional to the fourth power of the linear dimensions and the fourth derivative of the component of the field in the direction of the axis of the winding. A numerical example for the field of a dipole is calculated.

METASTABLE HELIUM SENSITIVE MAGNETOMETER

EE Abstr. 1660/1962; Inst. Radio Engrs. (USA), Internat. Convention Record, V. 9, Pt. 9, Pgs 245-9, 1961.

J.A. Rice, Jr.

Zeeman resonance experiments in bulk materials and the use of optical pumping are described. A PbS optical detector senses the resonance signal, a modulated 1μ emission from a He discharge. The slope of the He resonance line is used in a frequency-control feedback arrangement to construct a magnetometer in which the external magnetic field strength is linear with respect to frequency output. Field tests on prototype magnetometers are discussed.

CORRELATION THEORY OF STATIONARY ELECTROMAGNETIC FIELDS, I-II.

Nuovo Cimento (Italy), V. 17, Pgs 462-490, 1960.

P. Roman, E. Wolf.

No abstract

CORRELATION THEORY OF STATIONARY ELECTROMAGNETIC FIELDS IN THE PRESENCE OF RANDOM SOURCES

AD 256 339; Boston University, Boston, Mass., Scientific Rept. No. 1, 19 p., 1961.

P. Roman

A previously developed (Nuovo Cimento 12:884, 1954) correlation theory of stationary random electromagnetic fields is extended to the case in which the fields interact with stationary random charges and currents. The basic field equations are deduced and are found to be second order partial differential equations. An analogue to the equation of continuity is derived and some illustrative examples are discussed. Wave equations, which are of the fourth order, are deduced for the electric and magnetic correlation tensors. The theory presented in this paper may have various applications for the theory of plasma.

MODERN INSTRUMENTS FOR ATMOSPHERIC-ELECTRIC MEASUREMENTS. PART II.

AD 74616; University of California, Los Angeles, California, Institute of Geophysics, Scientific Report, No. 9, 50 p., 1955.

S. Ruttenberg.

The instruments described in this report have been developed for the measurement of potential gradient, conductivity, air-earth current density and potential. Instruments were designed for battery operation for field locations where a.c. power was not available. Stability and accuracy were obtained with simple circuitry by careful consideration of battery drain and minimum amplification. Semi-automatic operation was achieved with the use of timing motors and cams, which increased

the usefulness of the conductivity instruments and provided hourly zero checks on some instruments. Successful air-earth instruments were developed, making use of long time constants in the input. Special high quality condensers, with very low leakage and dielectric absorption made this technique possible.

MEASUREMENT OF THE ELECTRICAL CURRENT IN AN OCEAN

Phys. Abstr. 9989/1957; Dokl. Akad. Nauk SSSR (USSR), V. 113, No. 4, Pgs 787-90, 1957.

G. Yu Ryzhkov

Presents the results of measurements of telluric currents in oceans, made during the voyage of the Soviet ship "Ob". Special Pb electrodes (cf. Korneva, Dokl. Akad. Nauk SSSR, V. 76, No. 1 and V. 80, No. 6, 1951) and the PPTV-1 potentiometer were used; the measuring base was 200 or 300 m (in the Antarctic), and 130 m (the length of the ship) in other places. It was found that: (1) in the Antarctic ($66^{\circ} 28.5' S$, $94^{\circ} 44.0' E$) the gradient, current density and direction of the electric current were (a) 4.2 mV/km, 1.14×10^{-9} A/cm² and 346° , (b) 5.9 mV/km, 1.63×10^{-9} A/cm² and 341° , and (c) 7.0 mV/km, 1.90×10^{-9} A/cm² and 343° , at depths of 0-10, 100 and 200 m, respectively, the vertical potential gradient being 3.5 mV/km; (2) in the region of the latitude "focus" (maximum of the latitude component of the earth's magnetic field) ($64^{\circ} 25.5' S$ and $92^{\circ} 44.0' E$): (a) 9.0 mV/km, 2.41×10^{-9} A/cm², 267° , and (b) 41.0 mV/km, 1.2×10^{-8} A/cm² and 304° , for the depths of 100 and 500 m, respectively, the vertical potential gradient being 4.9 mV/km; (3) in the region of magnetic equator ($10^{\circ} 8' N$ and $51^{\circ} 40' E$) the figures were (a) 7.1 mV/km, 3.37×10^{-9} A/cm² and 300° , (b) 55.0 mV/km, 2.19×10^{-8} A/cm² and 324° and (c) 53.8 mV/km, 2.14×10^{-8} A/cm² and 315° at the depths of 100, 500 and 550 m (sea-bottom), the vertical potential gradient being 7.5 mV/km.

FIELD STRENGTH MEASUREMENTS IN FRESH WATER

Phys. Abstr. 3167/1962; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 5, Pgs 435-7, September-October 1960.

G.S. Saran, G. Held.

Experiments were performed to measure field strength at a frequency of 18.6 kc in fresh water of conductivity 2.66×10^{-3} mshos/m down to depths of 1000 ft using monopole and loop aerials. The experimental results verify the theoretical values of field strength attenuation with depth for all aerials and of the ratio of vertical to horizontal strength for the monopole aerials.

ON THE DEVELOPMENT OF AN ELECTRIC PHOTOELECTRIC FLUXMETER
EE Abstr. 3512/1958; CR Acad. Sci. (France), V. 246, No. 5, Pgs 727-30,
3rd February 1958.
M. Sauzade

The general arrangement of the fluxmeter, photocell, amplifier, etc. is described briefly and a circuit diagram is shown. The theory of the fluxmeter used in this manner is developed and the sensitivity of the method is discussed.

MAGNETISME TERRESTRE - MESURE DES VARIATIONS RAPIDES DU CHAMP MAGNETIQUE TERRESTRE
CR Acad. Sci. (France), V. 248, No. 23, 1959.
M. Sauzade, R. Stefant.

A photoelectric fluxmeter having a sensitivity of $0.05 \gamma / \text{mm}$ is described. A system of five concentric coils with an axial ferrite core 7.5 cm^2 in cross-section, 2 m long is the basic detecting element in a circuit designed to eliminate unwanted inductive effects. Calibration and performance data for the instrument are given.

INSTRUMENTATION FOR THE MEASUREMENT OF FLUCTUATIONS IN AMPLITUDE AND PHASE OF PULSED RADIO SIGNALS
Phys. Abstr. 19837/1962; Rev. sci. Instrum (USA), Vol. 33, No. 9, Pgs 939-41, September 1962.
W. Sawchuk

Describes instrumentation for automatically measuring the phase and amplitude of randomly fluctuating pulsed radio signals reflected by the ionosphere. The phase detecting system is based on the null principle of servo-mechanics, wherein the phase difference between transmitted and received signals is considered as an error to be annulled. The equipment is designed for pulsed operation at a carrier frequency of 60 kc/s, pulse width of $100 \mu \text{ sec}$, and a repetition rate of 12 pulses sec^{-1} . Amplitude and phase data are presented on a dual channel pen recorder.

PRODUCTION OF VERY STABLE MAGNETIC FIELDS IN THE RANGE 0-50 GAUSS
Rev. sci. Instrum. (USA), V. 32, No. 11, Pgs 1190-1192, November 1961.
L.D. Schearer

An instrument is described which has the property of accurately measuring the magnitude of magnetic fields to 0.05 ugauss at the centre of a set of Helmholtz coils while simultaneously reducing by a factor of 600 stray fluctuations of the field caused by drift in the earth's magnetic field, power supply anomalies, and external magnetic noise generated by the motion of magnetic material. The device utilizes an optically pumped metastable helium magnetometer which senses the total magnetic field. The output signal of the magnetometer is used to control the current in the Helmholtz coils. The new feature of this

device are (a) its ability to discern and hence to control magnetic field variations at the microgauss level and (b) its scalar character enabling the field control to be accomplished with a single set of coils.

A PROGRAM FOR THE STUDY OF MAGNETIC AIRBORNE FERROUS METAL DETECTORS
AD 49393; The Perkin - Elmer Corporation, Norwalk, Connecticut, Letter
of 9th November 1953.
R.M. Scott

No abstract

LA METHODE "BARRE-FLUXMETRE" D'ENREGISTREMENT DES VARIATIONS MAGNETIQUES
RAPIDES
Annals of the IGY, V. 4, Pergamon, Pgs 287-301, 1957.
E. Selzer

The bar-fluxmeter of recording rapid magnetic variations at the
Observatory of Chambon-la-Forêt.

AN ELECTRICAL RECORDING MAGNETOMETER
Phys. Abstr. 2062/1958; Canad. J. Phys., V. 35, No. 12, Pgs 1387-94,
December 1957.
P.H. Serson

An instrument for recording at a fixed station variations in three
orthogonal components of the earth's magnetic field is described. The
sensitive head, containing detectors of the saturated transformer type,
can be operated out of doors at the end of a long cable. A strip-chart
recording meter provides a visible record of the three d.c. output
signals (1 volt = 100 gammas). Calibrated baseline controls permit
biasing of the magnetic detectors for any location in Canada. Tests on
10 instruments indicate a noise level of 3 gammas and a maximum drift
of 10 gammas in 10 hours.

A THREE-COMPONENT AIRBORNE MAGNETOMETER
Phys. Abstr. 2707/1958; Publ. Dominion Obs. Ottawa (Canada), V. 19,
No. 2, Pgs 15-97, 1957.
P.H. Serson, S.Z. Mack, K. Whitham.

The magnetometer described contains three orthogonal magnetic
detectors of the saturated transformer type. It is mechanically linked
to a gyro-stabilized platform which is maintained horizontal. The
system acts basically as a pendulum with a six-minute period, and the
accuracy of the platform is 2 or 3 minutes of arc under normal survey
conditions. Signals from the magnetometer are fed into an analogue
computer which displays continuously the declination in degree and the
horizontal and vertical field components in gauss. The accuracy of

measurements is estimated to be 0.1° in declination and 20 gamma in the other components. Sources of error in survey operations are discussed and it is concluded that the probable error of a survey observation as plotted on a chart is about 100 gamma in any component and is principally due to errors in navigation and plotting.

THE VECTOR-FIELD PROTON MAGNETOMETER FOR I.G.Y. SATELLITE GROUND STATIONS

J. geophys. Res. (USA), V. 65, No. 3, Pgs 913-920, March 1960.
I.R. Shapiro, J.D. Stolarik, J.P. Heppner

Vector magnetic field measurements of high accuracy can be obtained by applying homogeneous bias fields to a proton precessional magnetometer.

PECULIARITIES OF ELECTRIC MODELLING OF PROCESSES DESCRIBED BY VECTORIAL WAVE AND TELEGRAPHIC EQUATIONS

EE Abstr. 862/1955; Elektrichestvo (USSR), No. 11, Pgs 58-63, 1954.
N.I. Shtein

The method of solving boundary problems of scalar partial differential equations by means of passive electric models (analogues) is already well known. These models are LCR-networks. On the other hand, some publications dealt with the use of such models for the solution of 2- and 3-dimensional boundary problems of vectorial wave and telegraphic equations, but omitted to clarify important points, in particular that the vector of the current density in such a model represents a potential vector and that the vector which is a curl (rot) of a vector potential can only be determined by artificial methods. The principles and working of such artificial methods are explained as well as the determination of the relevant criteria of analogy, scale factors, etc., in such cases.

A NEW TEST OF THE HYPOTHESIS OF THE NATURE OF THE MAGNETIC DECLINATION
Phys. Abstr. 21085/1961; Dokl. Akad. Nauk SSSR (USSR), V. 140, No. 1,
Pgs 107-10, 1st September 1961.
V.V. Shuleikin, N.I. Sigachev

A new apparatus is described, intended to be towed by a ship at depths to over 4000 m. in the sea. It consists of a two-chambered container with a gyro-compass in one compartment and a magnetic compass in the other. The two are geared to a registering device so that the magnetic declination can be recorded directly. A figure shows the arrangement of various components in the two compartments. Another diagram exhibits typical graphs obtained at various depths in the Atlantic. The elementary theory is given of the measurements of the change in declination as the apparatus is moved from one depth to another. On descending from the surface of the sea, there proves to

be practically no change in declination to depths of 500 m, very little to depths of 900 m, but thereafter great changes occur. At 4200 m, the change from the surface values is a decrease of about 24° . This is in agreement with the theory that electric currents in the oceans are responsible for the latitudinal component of the earth's magnetic field, and therefore for the declination.

SOME STATISTICAL THEORY FOR THE ANALYSIS OF RADIO PROPAGATION DATA
EE Abstr. 1050/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 5,
Pgs 571-80, September-October 1962.
M.M. Siddiqui

The statistical theory of stationary process has wide applications in the analysis of radiowave propagation data. Assuming knowledge of the basic concepts of probability theory, characteristics of stationary processes such as covariance and spectral density functions were developed, problems of estimating these characteristics were tackled, and numerous examples were worked out to illustrate the theory.

THE DEEP DIP ELECTROMAGNETIC DETECTOR
AD 267 875; U.S. Naval Ordnance Lab., White Oak, Maryland, NOLTR 61-7,
26 p., illus., 1961.
A. Silverstein

A very sensitive magnetic loop detector has been designed and built, useful from about 5 to 10,000 cps at any ocean depth. The theory and some results are given. A comparison is made of the loop and magnetic rod antennas. The helium magnetometer is discussed for undersea use.

AN EXPERIMENTAL STUDY OF UNDERWATER ELECTRIC ANTENNA IMPEDANCES
A. Silverstein, F.G. Salton
See Section II, Page 179.

GALVANOMETER FEEDBACK SYSTEMS
J. sci. Instrum. (GB), V. 36, Pgs 223-237, 1959.
J.A. Sirs

The principles of applying feedback to a galvanometer, after optical and electronic amplification, are discussed. In particular, the galvanometer performance is examined when proportional, differential, compound and selective feedback systems are used. The latter method is compared with mechanical and series-capacitor tuning of the galvanometer response.

MEASUREMENT OF THE EARTH MAGNETIC FIELD WITH RUBIDIUM VAPOUR MAGNETOMETER

J. geophys. Res. (USA), V. 63, Pgs 513-15, 1958.
T.L. Skillman, P.L. Bender

No abstract

NUCLEAR RESONANCE GENERATOR IN THE EARTH'S MAGNETIC FIELD

Dokl. Akad. Nauk SSSR (USSR), V. 121, Pgs 998-1000, 1958. English translation in Soviet Physics - Doklady, V. 3, Pgs 806-08, 1958.
F.I. Skripov

No abstract

LOW FIELD HELIUM MAGNETOMETER FOR SPACE APPLICATION

EE Abstr. 5800/1963; IEEE Trans nuclear Sci. (USA), Vol. NS-10, No. 1, 165-71, January 1963.
R.E. Slocum, F.N. Reilly

A magnetometer utilizing an optical pumping phenomenon in gaseous helium was constructed to obtain vector field information over regions of low magnetic fields. The instrument measures fields in the range 0 ± 150 gamma with high sensitivity and little zero field offset. Interest in measuring magnetic fields in this dynamic range (0.3% of the earth's field) arises from the experimental investigation of magnetic fields in interplanetary space. Vector field values are obtained from a servo-system which uses a technique of optically pumping metastable helium atoms to obtain basic field information. The field information obtained from the optical pumping unit is used by the system to create a region of zero d.c. magnetic field in the sensor. The zero field region is obtained by driving three perpendicular sets of Helmholtz coils to buck out the ambient magnetic field. When a region of zero d.c. field exists, the current in each Helmholtz coil is proportional to the component of the ambient field along the coil axis.

A COMPARISON OF EXPLORER VI AND EXPLORER X MAGNETOMETER DATA

EE Abstr. 12070/1962; J. geophys. Res. (USA), Vol. 67, No. 5, 2045-9, May 1962.
E.J. Smith

The vector field measurements obtained by the two space-craft are contrasted in order to make a comparison in terms of geomagnetic coordinates, and to discuss the evidence for the existence of a large scale deformation of the geomagnetic field at radial distances exceeding 6 earth radii.

THE ELECTRICAL PROPERTIES OF SEA-WATER FOR ALTERNATING CURRENTS
Pro. Roy. Soc. (GB), V. 143A, No. A848, December 1933.
R.L. Smith-Rose

No abstract

CONVERSION OF THE AMPLITUDE-PROBABILITY DISTRIBUTION FUNCTION
FOR ATMOSPHERIC RADIO NOISE FROM ONE BANDWIDTH TO ANOTHER
EE Abstr. 4374/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 6,
715-20, November-December 1962.
A.D. Spaulding, C.J. Roubique, W.Q. Crichlow

The amplitude-probability distribution function of atmospheric radio noise can be predicted with reasonable accuracy for a given bandwidth using only the first two moments of the noise measured at that bandwidth. This paper presents a method for predicting this distribution function for any specified bandwidth from the moments of the noise measured at a particular bandwidth.

A SIMPLE ELECTRONIC INSTRUMENT FOR STATISTICAL RESEARCH IN THE FIELD
OF RADIO WAVE PROPAGATION
EE Abstr. 13512/1962; Elektrosvyaz' (USSR), 1961, No. 4, In Russian.
N.S. Stanulov

A description is given of an electronic instrument for the direct determination of the average value of field intensity. An ordinary d.c. electric meter was used as the indicator of average values. With known distribution of the instantaneous values of the electromagnetic field intensity, the instrument may also be used for determining the corresponding meridian values. (English trans. in: "Telecommunications" (USA), 1961, No. 4, 31-9, April.

DETECTION OF TERRESTRIAL MAGNETIC FIELD
Phys. Abstr. 4135/1961; CR Acad. Sci. (France), V. 251, No. 6, Pgs 857-9,
8th August 1960.
R. Stefant

A magnetometer consisting of five series-connected coils wound on ferrite cores with axes parallel to the horizontal component of the terrestrial field and a galvanometer-amplifier with combined passband of 5-50 cps were used. Continuous recordings of the spectrum were obtained by scanning this frequency range with a tuned twin-T network. The largest fluctuations, in the 20-40 cps range, were diurnal and were attributed to the gyromagnetic resonance of Na in the upper atmosphere. A sharp decrease occurs at 15 cps and a minor increase is observed near 5 cps.

USE OF AN INDUCTION MAGNETOMETER TO DETECT THE RESONANCE FREQUENCIES OF THE EARTH-IONOSPHERE CAVITY

Phys. Abstr. 2318/1964; Ann. Geophys. (France), Vol. 19, No. 3, 250-83 (1963). In French.

R. Stefant

Deals with fast variations of the earth magnetic field, their recording, analysis and interpretation. Special attention is given to the earth-ionosphere cavity resonance. The integrating flux-meter is described with special emphasis on (i) noise and sensitivity of the photocell galvanometer circuits and (ii) problems arising from spectral analysis in this frequency band. Dealing with the theory of the earth-ionosphere cavity resonance, special attention is given to the concept of Q-factor and a rapid method of evaluating the resonance frequencies is developed. The diurnal variation of the intensity of the various modes observed at Chambon-la-Forêt (France) and Tromsø (Norway) is shown to correspond with the storm areas over the world. The diurnal variation of the resonance frequencies is shown to be a further consequence of this world-wide evolution, and not due to local changes in ionospheric conductivities (for example at sunrise and sunset). On the contrary, the high altitude thermonuclear explosion of 9th July 1962, which produced an intense ionization of the lower ionospheric layers, resulted in an abrupt decrease of all resonance frequencies. The observed effects of this explosion are described and the results are compared with the variations of ionospheric parameters obtained by some other workers. 55 references.

RUBIDIUM VAPOUR MAGNETOMETER

EE Abstr. 1778/1964; Z. InstrumKde (Germany), Vol 71, No. 10, 283-6, October 1963. In German.

W.A. Stolz

This magnetometer employs optical pumping, and is described in more detail with emphasis placed on the theory of optical pumping.

A PULSE-POSITION MODULATOR-TYPE MAGNETOMETER

EE Abstr. 1662/1962; Trans. Amer. Inst. Elect. Engrs (USA), I, V. 80, Pgs 253-8, 1961; Commun. and Electronics (USA), No. 55, July 1961.

S. Stricker, A.A. Wulkan

A saturable-core magnetometer for measuring magnetic fields of the order of a fraction of a milliampere-turn per cm is suggested. Its operation is based on a saturable-core element, wherein position-modulated voltage pulses are induced, their shift being linearly related to the field under investigation. By means of a simple analyser, information about the unknown field contained in the position-modulated pulses is translated into a d.c. voltmeter indication. Linearity, sensitivity and zero-drift as influenced by parameter variation and temperature changes are examined. Agreement is checked between experimental results and those anticipated from theory.

NEUERE ANWENDUNGEN DES HALLEFFEKTES IN HALBLEITENDEN BINAREN
VERBINDUNGEN

Scientia Electrica (Switzerland), V. IV, No. 3, 1958.

M.J.O. Strutt

This paper deals with practical applications of Halleffect in the binary semi-conducting compounds indium-antimonide and indium-arsenide. One-phase and three-phase wattmeters measuring real as well as imaginary and apparent power are described. In the next chapter, the temperature compensation of the Halleffect is examined. Further applications are: Halleffect oscillators, a Halleffect magnetometer measuring magnetic field down to 2.10^{-8} Gauss and Halleffect mixers for broadcast and other receivers.

MEASUREMENT OF THE ELECTRIC FIELD INTENSITY USING A METHOD OF AN
AUXILIARY ELECTRODE

EE Abstr. 769/1959; Elektrichestvo (USSR), No. 7, Pgs 11-14, 1958.

M.I. Sysoev

The method is described and sources of errors considered. Measurements of electric fields can be made with an accuracy of $\pm 5\%$. The method is unsuitable for measuring very divergent fields.

PRELIMINARY STUDIES OF THE ENERGY SPECTRUM OF NEAR ATMOSPHERICS OVER
THE FREQUENCY RANGE 3-15 KC.

EE Abstr. 3254/1958; J. sci. industr. Res. (India), V. 17B, No. 2,
Pgs 47-51, February 1958.

B.A.P. Tantry, R.S. Srivastava

Narrow-band amplifiers, tuned to different sets of frequencies within the range 3 to 15 kc, were employed to obtain simultaneous responses of the individual pulses. The wave-patterns on the oscillograph screens were photographed. The wave-form pattern of the same atmospheric pulse was also recorded simultaneously employing an automatic atmospheric recorder. The distances of the sources of atmospheric were obtained from the time-intervals between the successive pulses reflected from the ionosphere. The study of the relative amplitudes of the wave-patterns shows that for most of the atmospheric recorded near the source, the amplitude distribution has a maximum between 8 and 10 kc. The amplifiers and the automatic recorder are briefly described.

WAVEFORMS OF ATMOSPHERICS

EE Abstr. 6399/1958; Proc. Nat. Inst. Sci. (India), V. 24, No. 3, Pgs 217-25, 1958.

B.A.P. Tantry, R.S. Srivastava

More than one thousand useful waveforms of atmospheric were recorded at Banaras during 1952-1955 by the automatic atmospheric-waveform recorder constructed in the laboratory. A classification of the observed waveforms has been made and interpretations are given. Besides the known types of waveforms which have already been recorded by previous investigators, the oscillographic records show evidence of "stepped" pulses form the leader of one lightning discharge of near origin, superimposed on the waveform due to a different lightning discharge. A few oscillograms also reveal a long train of sinusoidal oscillations of nearly constant frequency. A large number of oscillograms was attributed to cloud-to-cloud discharges. The observations regarding discharges within the cloud are reported elsewhere.

A VERY-LOW-FREQUENCY TRANSMISSION MEASURING EQUIPMENT FOR 10^{-3} - 10^2 C/S.

EE Abstr. 4721/1963; Proc. Inst. Elect. Engrs (GB), Vol. 110, No. 1, Pgs 64-70, January 1963.

P.L. Taylor

The problems of measuring transmission (i.e. gain and phase shift) at frequencies in the range 10^{-3} - 10^2 c/s are briefly reviewed, and an equipment which overcomes most of them is described. The oscillator is novel, and has the important property that its amplitude is immediately self-stabilizing. The phase-shifter is also novel, and is of a resistive-potentiometer type having a set of ganged brushes. It gives an adjustable phase shift with very little change in amplitude. The conditions in which a non-sinusoidal waveform lacks a specified set of harmonics are discussed.

DESCRIPTION OF RECORDING EQUIPMENT TO BE USED IN THE STUDY OF WHISTLING ATMOSPHERICS

NBS Report 3559, US Nat. Bur. of Standards, Boulder, Colorado (30th November 1955).

W.L. Taylor

The discovery, nature and cause of whistlers (atmospherics that bounce back and forth from opposite hemispheres along magnetic lines of force via the ionosphere) are reviewed and equipment designed by the Nat. Bur. of Standards for use in a project which they are setting up to verify Storey's theory (by installations in Bermuda and the Falkland Islands), described and illustrated. Simultaneous recordings will be made for a 3-5 min. period every 30 minutes for 12-24 hours, two or three times a week. Magnetic tape will be analyzed at Standford University.

VERY-LOW-FREQUENCY RADIATION SPECTRA OF LIGHTNING DISCHARGES
EE Abstr. 1856/1960; J. Res. Nat. Bur. Stand. (USA), V. 63D, No. 2,
Pgs 199-204, September-October 1959.
W.L. Taylor, A.G. Jean

Spectral analyses are given of the groundwave portion of 33 spheric waveforms recorded from cloud-to-ground lightning discharges which occurred at distances ranging between about 150 and 600 km from Boulder, Colorado. Frequencies of peak energy lie between 5 and 20 kc, which agree favourably with other published results. The average value of energy calculated from the groundwave pulses was found to be 26,600 J, which is lower than values derived from other experiments. Various parameters, such as the peak amplitude and duration of the first half-cycle are related to the radiated energy of the stroke.

THE SCALE-MODELING OF ALTERNATING ELECTROMAGNETIC FIELDS FOR PURPOSES OF GEOPHYSICAL PROSPECTING

AD 26 022; English translation from Izv. Akad. Nauk. SSSR, V. 4, Pgs 318-323, 1953, by E.R. Hope, DRB Canada.
A.G. Tarkhov

No abstract

RADIO SPECTRUM ANALYSER

EE Abstr. 3675/1954; Ann. Télécomm. (France), V. 9, Pgs 116-20, April 1954.
A. Tchernicheff

Describes apparatus for displaying on a c.r.t. the transmitted frequency spectrum of a radio-telegraph transmitter working at speeds of 50 bands or greater. The signal frequency is converted to 170 kc and then to 70 kc and is scanned over ± 3 kc in 6 or 36secs. Circuit details and oscillograms are included.

A RECORDING FLUXMETER

Phys. Abstr. 1452/1954; J. sci. Instrum. (USA), V. 30, Pgs 369-71, 1953.
R.S. Tebble

A description is given of a method of recording the deflections of a Grassot fluxmeter. The secondary coil of a mutual inductance is attached to the suspended coil of the fluxmeter and a deflection of the fluxmeter is recorded as a change in a voltage induced in the mutual inductance system. Part of the voltage is fed back to eliminate the torsion effect of the fluxmeter suspension. In the apparatus described, the output voltage is used to produce Y-deflection of a Leeds Northrup XY recorder and thus to record hysteresis (I-H) curves of ferromagnetic materials; alternative methods of recording, e.g. a c.r.c., can be used. The method is also suitable for use with other instruments, such as galvanometers, which have a rotational movement.

A COMPARISON OF SFERICS AS OBSERVED IN THE VERY LOW FREQUENCY AND
EXTREMELY LOW FREQUENCY BANDS

Phys. Abstr. 12207/1960; J. geophys. Res. (USA), V. 64, No. 12,
Pgs 2315-29, December 1959.

L.R. Tepley

A large number of sferics were photographically recorded in the very low frequency (v.l.f.) and extremely low frequency (e.l.f.) bands at a U.C.L.A. field station in Hawaii. From the characteristic v.l.f. waveforms it was clear that the v.l.f. signals were generated from lightning discharges. It was found that an observable e.l.f. component (slow tail) followed the v.l.f. component in almost all cases. It was also found that about one-third of the sferics observed were e.l.f. signals, similar in appearance to slow tails but not preceded by observable v.l.f. oscillations. Peak amplitudes were measured for both the v.l.f. and e.l.f. components of almost 3000 sferics. The results were tabulated in groups according to (1) whether the sferics were recorded during the day or during the night, (2) whether the polarity of the initial excursion of the e.l.f. signal was positive or negative, and (3) whether the v.l.f. and e.l.f. components appeared together or separately. Amplitude distribution histograms were plotted for all cases. For those sferics possessing both v.l.f. and e.l.f. components, the v.l.f. to e.l.f. peak amplitude ratios were tabulated separately as in (1) and (2) above, and ratio-distribution histograms were plotted. The more important results obtained from the histograms were as follows. No significant differences were found between the amplitude distributions for the e.l.f. waveforms that were preceded by v.l.f. oscillations and those that were not. Hence, it is probable that both groups were generated by lightning discharges. For both daytime and nighttime sferics the median value of the e.l.f. amplitude was greater for e.l.f. waveforms of positive polarity than for waveforms of negative polarity. For both daytime and night-time sferics the median value of the v.l.f./e.l.f. peak-amplitude ratio was greater for e.l.f. waveforms of negative polarity than for waveforms of positive polarity. The polarity of the e.l.f. waveform was predominantly negative at night and positive during the day (verified by a count of the polarities of almost 6000 additional e.l.f. waveforms). An attempt is made to explain the experimental results in terms of known properties of lightning discharges, and some of the difficulties in making such an interpretation are indicated.

ENQUETE SUR LES APPAREILS ENREGISTREURS DES VARIATIONS RAPIDES DU
CHAMP MAGNETIQUE TERRESTRE

Annals of the IGY, V. 4, Pergamon, Pgs 255-280, 1957.

E. Thellier

A review of various types of equipment in use for recording rapid variations of the earth's magnetic field and their application to IGY requirements.

MEASUREMENT OF MAGNETIC FIELDS BY NUCLEAR MAGNETIC RESONANCE

Phys. Abstr. 5808/1963; Rev. HF (Belgium), Vol. 5, No. 6, Pgs 143-56, 1962. In French.

J.L. van Eck

After stating the fundamental equations which describe the phenomena of nuclear resonance the main methods available for measurements in high magnetic fields are discussed. Experimental arrangements and circuits using both electronic vacuum tubes and transistors are described, including an arrangement for the very precise measurement of the field at different points in the field of an electromagnet. Methods are also examined for the measurements of very weak fields, such as the earth's field, and the accuracy which can be attained is discussed. The regions where nuclear magnetic resonance is replacing other methods of magnetic field measurement are indicated.

RESEARCH RUBIDIUM VAPOR STATION MAGNETOMETER, MODEL X-4934.

Pamphlet; Instrument Division, Varian Associates, 611 Hansen Way, Palo Alto, California.

No abstract

INDUCTION MAGNETIC PICKUPS USED IN STUDYING THE MAGNETIC FIELD OF THE EARTH

Phys. Abstr. 13820/1963; Izv. Akad. Nauk SSSR, Ser. geofiz., 1962, No. 11, Pgs 1645-50. In Russian. English trans in: Bull. Acad. Sci., USSR, geophys. Ser (USA), No. 11, Pgs 1023-6, November 1962; publ. February 1963.

N.P. Vladimirov

A description is given of the design of magnetic induction pickups developed by the Institute of Physics of the Earth at the Academy of Sciences of the USSR; their theory as well as methods of working with them under field conditions are described.

CALIBRATION OF PULSATION DETECTOR COILS

Phys. Abstr. 21088/1961; J. geophys. Res. (USA), V. 66, No. 6, Pgs 1983-4, June 1961.

K. Vozoff

Attention is drawn to the possibility of error in calibrating magnetic micropulsation detectors due to neglect of eddy-current effects. An expression for the field is derived taking these into account. It is shown that their neglect leads to a percentage calibration error of $\mathcal{E} = [1 - (A^2 + B^2)]^{1/2} \times 100$, where A and B are the real and imaginary components of the reduced field. For normal values of conductivity, and a loop of 100 metres radius, the error is less than 1% up to frequencies of the order of 100 cps.

DETERMINATION OF THE WAVE FRONT OF LIGHTNING STROKE CURRENTS FROM FIELD MEASUREMENTS

EE Abstr. 5089/1961; Trans. Amer. Inst. Elect. Engrs (USA), III, V. 79, Pgs 581-9, 1960; Power Apparatus Syst. No. 50, October 1960.

C.F. Wagner

The electric field produced by the return stroke of a lightning discharge is determined analytically, both on the basis of the neutralizing of a dipole and of a travelling-wave concept, and the results of the two methods of approach are compared. By adopting the travelling-wave method the fields are determined which are produced by current pulses of different shapes. From oscillographic current records and with certain assumption as to the junction of an upward streamer and the downward leader channels, the velocity of the return stroke and the charge distribution along the discharge channel, an analytical expression is derived for the field produced at a distance at which this is determined exclusively by the lightning current; the results thus obtained are compared with existing field records. The mechanism of the stepped leader process is discussed and the resulting fields are determined. It is concluded that the current involved in the step process is small compared with that flowing in the return stroke.

RECEIVING PROPERTIES OF A WIRE LOOP WITH A SPHEROIDAL CORE

Canad. J. Tech., V. 31, Pgs 9-14, January 1953.

J.R. Wait

The relative gain of a low frequency loop antenna is calculated for a spheroidal shaped core. The cases considered are where the loop axis is coaxial and where it is at right angles to the spheroid axis of symmetry. The core losses are assumed to be negligible. It is shown that elongated cigar-shaped and flat dish-shaped cores can utilize effectively the magnetic properties of modern ferromagnetic materials.

ON THE FEASIBILITY OF MEASURING GROUND CONDUCTIVITY FROM AN AIRCRAFT

Def. Res. Tele. Est., Ottawa, Canada, 9th March 1953.

J.R. Wait

No abstract.

THE RECEIVING LOOP WITH A HOLLOW PROLATE SPHEROIDAL CORE

Canad. J. Tech., V. 31, Pgs 132-139, June 1953.

J.R. Wait

The relative gain of a low frequency loop with a hollow spheroidal core is calculated. The case where the loop axis is coaxial with the spheroidal axis of symmetry is considered. The core losses are assumed to be negligible. It is shown that a hollow core is more efficient than a solid core for the same mass of ferromagnetic material.

ON THE MEASUREMENT OF GROUND CONDUCTIVITY AT VLF
Inst. Radio Engrs. (USA), Trans., V. AP-6, No. 3, Pgs 273-277, July 1958.
J.R. Wait, A.M. Conda

The applicability of the four electrode methods of measuring ground conductivity at very low radio frequencies is discussed. The general theory is extended to include anisotropic in the substrata. In view of the spurious coupling between the current and potential line in conventional configurations, an alternative array is proposed which is arranged so that the inductive coupling is zero. A number of charts are computed which facilitate the interpretation of the measured or apparent conductivity in terms of a two-layer earth.

A COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL DATA ON PHASE VELOCITY OF VLF RADIO WAVES

J.R. Wait
See Section I, Page 113.

COMMENTS ON K. VOZOFF'S PAPER "CALIBRATION OF PULSATION DETECTOR COILS"
J. geophys. Res. (USA), V. 66, No. 10, Pg 3603, October 1961.

J.R. Wait

No abstract

NOTE ON L.F. PORTABLE ANTENNAS OPERATING OVER ICE AND SNOW COVERED TERRAIN

Publications Listing, July 1954-March 1963; Central Radio Prog. Lab., Boulder Laboratories, Nat. Bur. Stand., Boulder, Colorado, Appendix C, V. 4, Pgs 62-66.

J.R. Wait

IMPROVEMENT IN THE MAGNETIC DETECTING POWER OF IRON-CORED SEARCH COILS
Nature (GB), V. 183, Pgs 173-174, 1959.

D.F. Walker

An eight-fold increase in detecting power may be obtained by fitting permeable collector cones to the ends of the rod on which search coils are wound. The increase is related almost linearly to the diameter of the cone.

PROSPECTING BY USE OF NATURAL ALTERNATING MAGNETIC FIELDS OF AUDIO AND SUB-AUDIO FREQUENCIES

Canad. Mining Metallurg. Bull., August 1958.
S.H. Ward and Others

An account of a new method of investigating the electrical properties of the earth's crust is presented. The method, called AFMAG, employs, as a source, natural alternating magnetic fields of audio and

sub-audio frequencies. Measurements of the distortion of these fields caused by geological features are made with the aid of search coil detectors at several discrete frequencies. Many results of field surveys made with the method are presented and they illustrate its advantages and limitations when applied to the search for massive sulphide mineralization. The advantages far outweigh the limitations and in fact indicate that a major breakthrough in geophysical exploration technique and instrumentation has been made.

UNIQUE DETERMINATION OF CONDUCTIVITY, SUSCEPTIBILITY, SIZE, AND DEPTH
IN MULTIFREQUENCY ELECTROMAGNETIC EXPLORATION

Phys. Abstr. 11641/1959; Geophysics (USA), V. 24, No. 3, Pgs 531-46,
July 1959.

S.H. Ward

The response of a conductive, magnetic sphere in a uniform, alternating magnetic field, is a function of the conductivity, permeability, and radius of the sphere and of the frequency of the alterations. Over one range of frequencies, eddy-current density in any given sphere and secondary magnetic fields of the sphere are relatively constant and high. Over a much lower range of frequencies eddy currents are negligible, but the secondary magnetic fields may be of large constant amplitude but of polarity reversed to that of the higher frequency range. At some intermediate frequency the secondary magnetic fields will be entirely quadrature with respect to the inducing field. Utilization of this peculiar frequency dependence and of the geometry of the secondary magnetic fields permits unique determination of the conductivity, permeability, radius and depth to the centre of a buried sphere. The procedure for obtaining these variables is described in this article. It is shown that by completing a gravity survey as well as an electromagnetic survey over a dense, magnetic, conductive spherical ore body, it is possible to determine the above variables, plus density, uniquely. Precise identification of the material of the sphere is seen as a possible result of the application of this technique.

A FIELD EXPERIMENT WITH A RUBIDIUM-VAPOUR MAGNETOMETER

J. geophys. Res. (USA), V. 67, No. 5, Pgs 1889-1898, May 1962.

Phys. Abstr. 15983/1962.

S.H. Ward

A field experiment in the vicinity of a small deposit of massive magnetite has served to illustrate the nature of the results obtainable with a rubidium-vapour magnetometer in a natural micropulsation field superimposed upon a natural non-uniform unidirectional magnetic field. The ultimate purpose of this type of experiment is to explore the feasibility of using this instrument to measure the ratio of induced to remanent magnetism for a buried natural ferromagnet. The results indicate that (1) magnetic "amplification" of micropulsations occurs

in the vicinity of ferromagnetic masses. (2) a change in the direction of either the unidirectional earth's main field or the micropulsation field leads to a change in the component of the micropulsation field recorded, (3) stability of the magnetometer platform must be constant to within 0.01 mm, and (4) the signal-to-noise ratio of the magnetometer tends to degenerate. This last effect can be minimized by appropriate orientation of the direction heads, but it is a phenomenon which occurs only under the rare condition of an outcropping massive magnetite body.

A NUCLEAR MAGNETOMETER

Phys. Abstr. 3218/1958; J. sci. Instrum. (GB), V. 35, No. 3, Pgs 88-93, March 1958.

G.S. Waters, P.D. Francis

The basic principles of the nuclear free precession magnetometer are briefly described, and full details given of the coils, switching circuits and transistorized amplifying equipment of such a magnetometer. Accuracy of absolute measurement of the earth's total field is $\pm 10 \mu$ G, and even better, when only relative measurements are required. Setting-up of the instrument, which requires no calibration, and taking only few seconds. Suggestions are made for possible further applications of the free precession technique.

FLUXGATE RECORDING OF THE TRANSIENT VARIATIONS IN THE GEOMAGNETIC FIELD AT JODRELL BANK (GEOMAGNETIC LATITUDE 56.0° N).

EE Abstr. 6399/1959; Jodrell Bank Ann. (GB), V. 1, No. 5, Pgs 223-31, March 1958.

C.D. Watkins

Measurements of the earth's magnetic field have been made at Jodrell Bank since 1950 using instruments of the fluxgate (saturable core) magnetometer type. The paper describes the construction and operation of such an instrument and refers to some of its applications.

MEASURED STATISTICAL CHARACTERISTICS OF VLF ATMOSPHERIC RADIO NOISE

EE Abstr. 3158/1957; Proc. Inst. Radio Engrs (USA), V. 45, No. 1, Pgs 55-62, January 1957.

A.D. Watt, E.L. Maxwell

Instrumentation for measuring the cumulative distribution of the amplitudes and spacings of pulses in the instantaneous envelope of the atmospheric noise field strength is described. In general, the v.l.f. atmospheric noise observed at 22 kc in a 1 kc band during the autumn of 1955 from 9° N to 71° N latitude was found to have a maximum variation in average power level, including the effects of both time and geographic location, of about 48 dB. The dynamic range of the instantaneous noise envelope, measured during a 20-30 minute period of time, is defined to be the ratio of the field strength

exceeded 0.000 1% of the time to that exceeded 90% of such periods of time. This dynamic range in a 1 kc band, for the 66 periods measured, varied from 59 to 102 dB. The average dynamic range in the Arctic was 68 dB and the tropics 81 dB. The noise envelope at the low amplitude levels is found to be Rayleigh distributed, while that at the higher levels approaches a distribution having a much greater change in level for a given change in probability. In general, at higher levels, the spacing between pulses does not appear to be random at temperate and arctic locations, but the noise pulses observed in the tropics appear to be more randomly spaced. When the bandwidth of the receiver is reduced, the dynamic range approaches 21.18 dB, the value expected for the Rayleigh distributed envelope resulting from a thermal noise input. The bandwidth at which this occurs will depend on the character of the atmospheric noise at the time of observation, but appears from our measurements at 22 kc to be approximately 0.2 kc.

PERFORMANCE OF SOME RADIO SYSTEMS IN THE PRESENCE OF THERMAL AND ATMOSPHERIC NOISE

Proc. IRE, Vol. 46, No. 12, Pgs 1914-1923, December 1958.

A.D. Watt, R.M. Coon, E.L. Maxwell, R.W. Plush

The performance of several basic types of communication systems are determined experimentally, and in some cases theoretically, under typical conditions with steady or fading carriers, and in the presence of thermal or atmospheric noise. The relative efficiency of various carriers and the interference factor of various types of noise are found to be dependent upon the characteristics of the particular communication system as well as the characteristics of the carrier and noise themselves.

Methods are considered for calculating errors expected from a given system, based upon the amplitude distribution of the noise envelope.

AUDIO-FREQUENCY ELECTROMAGNETIC HISS RECORDED AT BOULDER IN 1956.

Geof. pura e Appl. (Italy), V. 37, No. 169, 1957.

J.M. Watts

More than half of the important magnetic disturbances of the year were marked by the reception of a hissing noise at some time during the storm. A report of the general characteristics of the noise, a description of the recording and analysis methods used, and examples of the types of record presentation are given.

AN OBSERVATION OF AUDIO-FREQUENCY ELECTROMAGNETIC NOISE DURING A PERIOD OF SOLAR DISTURBANCE

J. Geophys. Research, Vol. 62, No. 2, Pgs 199-206, June 1957.
J.M. Watts

An analysis of hiss recorded during a magnetic storm shows that the spectrum peaked near 3 kc, that the high frequency limit was variable during the period, and that a curious procession of narrow bandwidth tones gliding upward occurred during part of the period.

A TECHNIQUE FOR FINDING THE DIRECTION OF ARRIVING WHISTLERS

Paper presented at IRE-URSI Symposium, San Diego, California, 19th-21st October 1959.

J.M. Watts, J.H. Crary

The results of preliminary experiments using rotating goniometers have shown that some whistlers arrive from an apparently small angular source, thereby allowing the null technique to be used in determining the direction of arrival. The use of the sound spectrograph in detecting and measuring the null pattern is shown on sample records. The possible explanations for the absence of nulls for some whistlers are discussed, together with the type of error to be expected.

DIRECTION FINDINGS ON WHISTLERS

Letter in J. Geophys. Research, Vol. 64, No. 11, Pgs 2029-2030, November, 1959.

J.M. Watts

Efforts to study the direction of arrival and polarization of whistlers have led to confusion, presumably because of the complexity of the signals and their transient behaviour. This letter describes on technique which shows promise in that it has given results on the direction of some whistlers.

LOCATION OF DEEP-LYING UNEXPLODED BOMBS

Phys. Abstr. 8805/1954; Z. angew. Phys. (Germany), V. 6, No. 3, Pgs. 120-7, 1954.

H. Wegener, R. Fleischmann

The following problem is posed: an unexploded bomb lies deeply buried in the earth and is to be removed. It is required to know (1) the position of the bomb; (2) the direction of the bomb's axis in space, and (3) the volume of the bomb. The answers to these questions are obtained by field determinations of the change of the earth's magnetic field due to the presence of the bomb, carried out by use of Fürster's differential probes (Z. angew. Phys. V. 2, No. 210, 1950) which can be inserted into boreholes to a depth of 20 metres. The

mathematic theory of the method is discussed by replacing the bomb by a dipole, and the practical application of the theory is illustrated in the recovery of an unexploded bomb that fell in Hamburg.

DETECTION OF LOW-INTENSITY MAGNETIC FIELDS BY MEANS OF FERROMAGNETIC FILMS

EE Abstr. 6997/1963; J. appl. Phys. (USA), Vol. 34, No. 4, (Pt 2), Pgs 1163-4, April 1963.
F.G. West, W.J. Odom, J.A. Rice, T.C. Penn

"Magnetism" Conference Paper, Pittsburgh, 1962 (see Abstr. 5883 of 1963). Describes a sensitive field magnetometer which utilizes a ferromagnetic film as the sensitive element. Typical vacuum-evaporated films of Ni-Fe of approximately 80% Ni composition are used. These films are chosen to have small directional dispersion in the uniaxial anisotropy. It is well-known that in the absence of other magnetic fields the application of a cyclically varying field (of amplitude greater than the anisotropy field) perpendicular to the average anisotropy axis causes the film to split into domains parallel to that axis. The net flux which cuts a sensing coil, the axis of which is parallel to the domains, remains zero during such cyclic magnetization. If there is a small component of field along the anisotropy axis, however, the net flux is proportional to that field. The induced voltage in the sensing coil indicates the direction and magnitude of the axial component of an ambient field. This principle forms the basis of the present device. In practice, a sinusoidal r.f. (4 M/c/s) field drives the film along the perpendicular direction. A modulation field is applied along the average anisotropy axis. The output of the sensing coil is a modulated r.f. signal which is diode-rectified and phase-detected. In the absence of an ambient field along the anisotropy axis, the detected signal is of a frequency twice that of the modulation field. An ambient field along the axis causes the fundamental frequency of the modulation field to appear. The amplitude of the fundamental is proportional to the ambient field for small fields, while the phase is determined by the direction of the field. Fields having frequencies from d.c. to roughly 0.1 the modulation frequency can be detected in this manner. The smallest field so far detected by this device is of the order of 10^{-4} Oe in a d.c. to 1 c/s bandpass.

INTERFERENCE FIELD STRENGTH METER

EE Abstr. 151/1961; Hochfrequenztech. u. ElektAkust. (Germany), V. 68, No. 6, Pgs 217-21, January 1960.
H. Wiechmann

The design of a sensitive instrument for the measurement of the low-frequency magnetic field is explained. It consists of a probe coil, an amplifier and a commercial-type valve voltmeter. The coil is made of 8000 turns of very thin copper wire wound on a small plastic body. The amplifier has the bandwidth 50-250 cps and the frequency response follows the law 1/f. The noise contribution above the highest

frequency is not substantial, but special care is taken to eliminate the frequencies below 50 cps. The circuit diagram of the amplifier is given. The calibration magnetic field is obtained at the centre of a ring carrying current.

SAMPLING MAGNETOMETER BASED ON THE HALL EFFECT

Phys. Abstr. 13642/1962; J. appl. Phys. (USA), Suppl. to Vol. 33, No. 3, Pgs 1278-9, March 1962.
H.H. Wieder

A pulsed sampling magnetometer is described, based on the Hall effect in vacuum evaporated films of InSb. Pulsed operation of thin film Hall effect detectors provides an increase in sensitivity over c.w. operation of conventional Hall devices. This is due, in part, to the improved thermal dissipation of the film, the reduction in joule heating, and the greatly improved noise discrimination because of stroboscopic sampling. A sensitivity of better than 10^{-4} V/gauss over a frequency range between 100 c/s to 5 Mc/s and an angular orientation sensitivity of 10^{-5} V/degree were obtained in devices built to date.

SUBTERRANEAN COMMUNICATION BY ELECTRIC WAVES

H.P. Williams
See Section I, Page 127.

CONDUCTIVITY MEASUREMENTS OF THE EARTH AT ELF

EE Abstr. 300/1964; IEEE Trans Antennas & Propagation (USA), Vol. AP-11, No. 3, Pgs 364-5, May 1963.
R.H. Williams, C.J. Benning

Describes a simple method for determining the effective conductivity of a relatively flat conducting earth at elf. The method is based on the quasi-static approximations to the Hertz vector potential for both the vertical and horizontal magnetic dipole. From these approximations, expressions for the magnetic field are obtained. By taking the ratio of the vertical component to the horizontal component, a single relation is obtained for conductivity which is independent of the magnetic dipole moment. The relation is also independent of the source and receiver height provided they are located near the boundary.

A ROTATING COIL FLUXMETER

Phys. Abstr. 313/1953; J. sci. Instrum (GB), V. 29, Pgs 374-5, November 1952.
M.S. Wills

The instrument consists of a search coil mounted on a hollow flexible shaft and rotated at a constant speed of about 3000 r.p.m.

in the unknown magnetic field. The alternating e.m.f. is picked up by means of a transformer the primary of which is attached to, and revolves with, the search coil while the secondary is stationary. The secondary e.m.f. is amplified and measured by an electronic voltmeter giving a reading proportional to the flux linkage. The maximum sensitivity of the present instrument is 1.63×10^5 maxwell-turns for full scale deflection, but could be increased. The amplifier is compensated for speed variations arising from changes in frequency of the a.c. mains. The instrument is absolute and the method of calibration using a sub-standard dynamo-meter is described.

THE ORIGINS AND NATURE OF MICROSEIMS IN THE FREQUENCY RANGE 4 TO 100 CPS

Phys. Abstr. 5226/1953; Proc. Roy. Soc. (GB), V. 217A, Pgs 176-88, 8th April 1953.
C.D.V. Wilson

Microseims in the frequency band 4 to 100 cps, commonly encountered in seismic prospecting, have been investigated in various parts of England, urban and rural. A diurnal variation in background level, indicating man-made sources, was found everywhere within 2 miles of a major road or community. The main sources were found to be the traffic, heavy machinery, aircraft, wind and rain, with traffic prevailing. In rural areas at night-time a steady background of about 10^{-6} cm/sec r.m.s. particle velocity was found, with occasional superimposed activity lasting 4 to 30 sec. The latter has been shown mostly to be local and of geophysical origin, the precise nature of which is unknown. Various possible causes are discussed, both of this and of the minimum background.

A PULSE-POSITION MODULATOR-TYPE MAGNETOMETER

Commun. and Electronics (USA), No. 55, Pgs 253-258, 1961.
A.A. Wulkan

No abstract

AN ELECTRODYNAMIC MAGNETIC FIELD GRADIOMETER EMPLOYING A MICROVIBRATION TECHNIQUE

J. sci. Instrum. (GB), V. 35, Pgs 375-377, 1958.
Y.L. Yousef, H. Mikhail

The instrument utilizes the alternating electrodynamic forces experienced by a small probe coil fed by a low-frequency voltage. Magnetic field inhomogeneity can be measured to an accuracy of at least 10^{-3} G/cm.

A METHOD FOR ANALYZING VALUES OF THE SCALAR MAGNETIC INTENSITY

J. geophys. Res. (USA), V. 63, Pgs 477-90, 1958.
A.J. Zmuda

No abstract.

PART IV

PART IV

GEOMAGNETIC FLUCTUATIONS, SOLAR ACTIVITY, EARTH CURRENTS

CORRELATION OF AUDIO-FREQUENCY ELECTROMAGNETIC RADIATION WITH AURORAL ZONE MICROPULSATIONS

Phys. Abstr. 10437/1960; Nature (GB), V. 185, Pgs 148-51, January 1960.
J. Aarons, G. Gustafsson, A. Egeland.

The occurrence of auroral zone micropulsations of the earth's magnetic field, observed at Kiruna, have been found to correlate well with e.m. radiation in the audio frequency band (10 cps-10 kc). There are two distinct low frequency bands, the lower ("noise" centred on 750 cps) showing a smaller band-width than the upper ("hiss" with maximum intensity in the range 2.3-3.4 kc). It is suggested that the lower band may arise from radiation by protons, although it may be another component of the "hiss".

MORPHOLOGY OF SSC AND SSC PHENOMENA

J. of Geomagnetism and Geoelectricity (Japan), V. X, No. 4, 1959.
S. Abe

In general we may consider that it is very rare that ssc is not observed in any part of the world at the time of sudden commencement of magnetic storms. The electric current systems for the world distribution of the preliminary impulse and the main impulse of the sudden commencement vectors are derived. These current-systems will be situated in the earth's upper atmosphere except the current representing the worldwide increase in the horizontal component of geomagnetic field of extra-terrestrial origin. The dependency of occurrence frequency of ssc on local time and latitude can reasonably be explained by the characteristics modes in these current-systems. A theoretical interpretation of ssc and ssc phenomena will be possible by combining the merits of various different theories.

IONOSPHERIC EFFECTS PRODUCED BY SOLAR FLARE RADIATION

Phys. Rev. 102, 917, 1st May 1956.

V. Agy

No abstract

A STUDY OF THE AUDIO-FREQUENCY RADIO PHENOMENON KNOWN AS "DAWN CHORUS"
Phys. Abstr. 5557/1958; Austral. J. Phys., V. 10, No. 2, Pgs 286-98,
June 1957.
G. McK Allcock

The main characteristics of dawn chorus, as observed at Wellington, New Zealand, between July 1955 and October 1956 are presented. These are: no general correlation with whistlers; a strong correlation with simultaneous local magnetic variations; a pronounced diurnal variation in activity, with the peak occurring near 0400 hr local time; and possibly a weak seasonal variation in activity. The correlation of observations of dawn chorus at Wellington with those at other places is discussed. It is concluded that dawn chorus signals are propagated along lines of force of the earth's magnetic field, and that the signals are probably initiated by the entry of charged solar particles into the outer ionosphere at times of magnetic disturbance.

SOLAR ACTIVITY AND WHISTLER DISPERSION

Phys. Abstr. 6456/1959; J. geophys. Res. (USA), V. 63, No. 3, Pgs 573-6,
September 1958.
G. McK Allcock, M.G. Morgan

Measurements of the time delay between the atmospheric "bonk" of a lightning flash, and the appearance of the highest audible component of the accompanying whistlers, show similar variations from month to month, for all locations for which sufficient data exist. The form of this variation correlates strongly with the sunspot number, with a time lag of one or two months. The change in dispersion is attributed to a general change in the electron density throughout the outer ionosphere. It is suggested that this provides further evidence in favour of the statement that "the earth may be revolving around the sun within the solar corona".

GEOMAGNETIC ACTIVITY AND THE RECEPTION OF WHISTLERS IN POLAR REGIONS

Phys. Abstr. 6917/1962; J. geophys. Res. (USA), V. 66, No. 11, Pgs
3953-5, November 1961.
G. McK Allcock

By considering the number of schedules during which whistlers are heard, rather than the number of whistlers recorded in unit time, a negative correlation with geomagnetic activity is obtained. The present paper reports that an even more marked inverse relationship is obtained at Scott Base, 79° S. There is also a strong diurnal variation that is seasonably independent. A diagram is presented which shows the variation of whistler activity with time and k-index. For a given k-index, whistler activity is a minimum at 1800 hours UT.

A COMPREHENSIVE MODEL OF AURORAL AND GEOMAGNETIC DISTURBANCES
Phys. Abstr. 15270/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-I,
Pgs 173-5, January 1962.
W.I. Axford, J.A. Fejer, C.O. Hines

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

I. Earth Storm (see Abstr. 9939 of 1962). The model of the magnetosphere employs a "geomagnetic tail" for field lines using at high latitudes. Motions in the magnetosphere are attributed to viscous interaction between the solar wind and the outer magnetosphere. The interaction leads to a transport of ionization towards the tail in the outer regions, with a return path in the inner magnetosphere. Because of a combination of rotational and convective motions an oddly-shaped flow pattern is established. This is illustrated by figures showing equatorial cross-sections of the magnetosphere.

THE ELECTROMAGNETIC FIELD OF A ROTATING UNIFORMLY MAGNETIZED SPHERE
Phys. Abstr. 1273/1953; J. appl. Phys. (USA), V. 23, Pgs 1294-9,
December 1952.
A. Banos, R.K. Golden

The problem discussed here is a first step towards a more complete understanding of the modern theories of geomagnetism which are based on the differential rotation of the earth's crust with respect to its inner core and on magneto-hydrodynamical effects in the core. This paper considers first the computation of the electric and magnetic fields that a stationary observer attributes to a uniformly magnetized sphere which, in his frame of reference, rotates at constant angular velocity about an axis parallel to the direction of magnetization. It is found that, neglecting the terms of order v^2/c^2 , the observed magnetic fields are identical to the fields of the stationary sphere, but in addition there is an external electric field identical to that produced by an axial quadrupole located at the origin. The interior electric field is directed towards the axis of rotation and its magnitude is proportional to the distance from the axis. Next, when the rotating magnet is surrounded by a stationary concentric shield, it is found that the electric fields vanish in the interior of the shield and in outer space in contrast to the results that one would find on the assumption that the shield was being "cut" by the lines of magnetic induction of the rotating magnet. Finally, the limiting case is considered in which the inner radius of the shield approaches the radius of the sphere, an insulating layer still being maintained between them. Here, again, no electric fields are found outside the rotating magnet.

THE GEOMAGNETIC MEASURES FOR THE TIME-VARIATIONS OF SOLAR CORPUSCULAR RADIATION, DESCRIBED FOR USE IN CORRELATION STUDIES IN OTHER GEOPHYSICAL FIELDS

Annals of the IGY, V. 4, Pergamon, Pgs 227-236, 1957.

J. Bartels

Indices for individual stations; indices for the whole word.

SOME UNUSUAL RADIO OBSERVATIONS MADE ON 23RD FEBRUARY 1956.

J.S. Belrose, M.H. Devenport, K. Weekes

See Section I, Page 10.

OBSERVATIONS OF GEOMAGNETIC FLUCTUATIONS IN THE PERIOD RANGE 0.3 TO 120 SECONDS

Phys. Abstr. 14168/1960; J. geophys. Res. (USA), V. 65, No. 5, Pgs 1413-22, May 1960.

H. Benioff

Data are presented from a 5 year series of observations of geomagnetic fluctuations in the period range 0.3 to 120 sec approximately. These were carried on with flux rate variographs using pickup coils with 1 sec period galvanometers recording photographically at a trace speed of 1 mm/sec with maximum sensitivity of 0.05 gamma/sec per trace millimetre. Four characteristic types of oscillations are included in this study: Type A oscillations, approximately sinusoidal in form, range in period from 0.3 to 2.5 seconds and in southern California occur at night only. They exhibit a negative correlation with sunspot numbers. Type B oscillations are nearly sinusoidal in form with periods ranging from about 3 to 8 seconds. They appear to be associated with the local occurrence of aurorae. Type C oscillations are nearly sinusoidal in shape with periods ranging from about 7 to 30 seconds. In southern California they occur in daylight and exhibit a strong correlation with sunspot numbers. Type D oscillations are transients in the form of single or multiple pulses or trains of several oscillations. The pulse breadths or oscillation periods range from about 40 to 120 seconds or more. They are strictly nocturnal in southern California with a sharp peak in the rate of occurrence at local midnight. Some characteristics of sudden-commencement components in the observed period range are mentioned briefly.

A STUDY OF THE GEOMAGNETIC FIELD IN THE 5-50 CPS BAND

Phys. Abstr. 4772/1960; CR Acad. Sci. (France), V. 250, No. 5, Pgs 893-5, 1st February 1960.

R. Benoit, Tran The Hien.

Gives the details of a study of the rapid, micropulse variations in the intensity of the earth's magnetic field in the region of Saigon.

CORRELATED MICROPULSATIONS AT MAGNETIC SUDDEN COMMENCEMENT

J. Geophys. Research, Vol. 65, No. 2, Pgs 613-618, February 1960.
W.K. Berthold, A.K. Harris, H.J. Hope

By the use of very large loops of wire, many square miles in area, nearly simultaneous micropulsations were recorded in Arizona and New Jersey during the initial phase of magnetic storm. Evaluation of the two records (15 minutes recording time) by cross correlation showed a time difference in arrival of common signals of 2 - 3 secs. A similar difference was observed for the sudden commencement itself. The method used is simple and relatively unaffected by interference. The maximum sensitivity $1.7 \times 10^{-4} \text{ gamma sec}^{-1} \frac{\text{mm}}{\text{V}}$, could be used only during magnetically quiet periods.

At two other sudden commencements, a remarkable resemblance was found in the fine details at the variations present. The overall study includes effects from both natural and man-made causes. Another paper will discuss the man-made causes.

THE RELATION OF MAGNETIC MICROPULSATIONS TO ELECTRIC-CURRENT AND SPACE-CHARGE SYSTEMS IN THE LOWER IONOSPHERE

H.A. Bomke

See Section III, Page 213.

ON THE ELECTRIC FIELD INDUCED BY THE VERTICAL COMPONENT OF GEOMAGNETIC VARIATION

Phys. Abstr. 2936/1954; Dokl. Akad. Nauk SSSR (USSR), V. 90, No. 3, Pgs 367-70, 1958.

A.P. Bondarenko

A theoretical formula is developed by considering the existence of strata of different electrical properties. Graphs are given based on published data to show that this correlation is satisfactory.

RELATIONS BETWEEN THE ELECTRIC AND MAGNETIC FIELDS OF VERY LONG PERIOD INDUCED IN A MEDIUM OF VARIABLE CONDUCTIVITY

Geof. pura e Appl. (Italy), V. 44, No. 3, Pgs 119-134, September-December 1959.

L. Bossy, A. De Vuyst

A model of ground conductivity distribution is derived which closely represents the conditions indicated by observations of geomagnetic and geoelectric pulsations.

THE MICROSTRUCTURE OF ISC OF GEOMAGNETIC STORMS

J. Phys. Soc. Japan, Vol. 17, Suppl. A-II, Pgs 45-7, January 1962.

Phys. Abstr. 13083/1962.

J. Bouška

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). The sudden commencement of geomagnetic storm (SC) is one of the most important geomagnetic phenomena. Owing to its wide view of the problems a recent work by Chapman and Akasofu (1959) is of great interest. Outstanding results have been achieved in this field by Japanese geophysists Kato, Watanabe, Saito, Fukushima and others (1958-61). The author of this paper is investigating some characteristics of the initial phase of geomagnetic storm following immediately after SC.

THE CONJUGACY OF MAGNETIC DISTURBANCE VARIATIONS

J. Geophys. Research 68, Pgs 1011-1013, February 1963.

G.M. Boyd

No abstract

VERY LOW FREQUENCY NOISE AT BRISBANE

Phys. Abstr. 24031/1962; Nature (GB), Vol. 194, 962, 9th June 1962.

H.E. Brown, G.G. Cairns

The existence of noise bursts coincident with magnetic disturbance is reported. The frequency of the observations lies in the 5 kc/s region. The maximum noise signal was $0.05 \mu\text{V sec m}^{-1}$, the 6 dB bandwidth being 800 c/s. Three disturbances are reported.

PRINCIPLE OF THE MAGNETO-TELLURIC METHOD, A NEW GEOPHYSICAL PROSPECTING METHOD.

Phys. Abstr. 8806/1953; Ann. Geophys. (France), V. 9, Pgs 96-125, April-June 1953.

L. Cagniard

For a given subsoil at a given spot, quantitative relations may be established between the horizontal components of the electric field and the magnetic field when any sort of telluric current is flowing in the subsoil. From them the electrical resistivity and the thickness of the subjacent geologic strata may be deduced. The new method seems to offer the following advantages: speed, low cost, unlimited depth of investigation, and easy quantitative interpretation.

BASIC THEORY OF THE MAGNETO-TELLURIC METHOD OF GEOPHYSICAL PROSPECTING
Phys. Abstr. 9804/1954; Geophysics (USA), V. 18, Pgs 605-35, July 1953.
L. Cagniard

From Ampere's law (for a homogeneous earth and from Maxwell's equations using the concept of Hertz vectors (for a multilayered earth), solutions are obtained for the horizontal components of the electric and magnetic fields at the surface due to telluric currents in the earth. The ratio of these horizontal components, together with their relative phases, is diagnostic of the structure and true resistivities of sub-surface strata. For two sections which are geometrically similar and whose corresponding resistivities differ only by a linear factor, the phase relationships are the same and the apparent resistivities differ by the same proportionality constant which relates the corresponding true resistivities. This "principle of similitude" greatly simplifies the representation of a master set of curves, such as is given for use in geologic interpretation.

CONSEILS, POUR L'ANNEE GEOPHYSIQUE, SUR L'INSTALLATION DE STATIONS
D'ENREGISTREMENT DES VARIATIONS TELLURIQUES RAPIDES
Annals of the IGY, Pergamon, V. 4, Pgs 306-321, 1957.
L. Cagniard

Recording rapid variations in earth currents, with a detailed description of equipment used in France.

HIGH ALTITUDE MEASUREMENTS OF THE EARTH'S MAGNETIC FIELD WITH A PROTON
PRECESSION MAGNETOMETER
L.J. Cahill, Jr., J.A. Van Allen.
See Section III, Page 215.

INVESTIGATION OF THE EQUATORIAL ELECTROJET BY ROCKET MAGNETOMETER
L.J. Cahill, Jr.
See Section III, Page 215.

RECENT METHODS FOR MEASURING THE ELEMENTS OF THE EARTH'S MAGNETIC
FIELD
Phys. Abstr. 4821/1964; Stud. Cercetari Stiint, Fiz. Stiint. Tehn.
(Rumania), Vol. 13, No. 1, Pgs 51-64, 1962. In Rumanian.
N. Calinicenco, I. Viscrivan.

Describes the following methods with their performance characteristics and limitations:- saturated core magnetometers; utilization of the Hall effect; magnetostrictive methods; two methods utilizing the deviation of free electrons in a magnetic field and, finally, nuclear resonance methods. 14 references.

STUDIES OF MAGNETIC FIELD MICROPULSATIONS WITH PERIODS OF 5 TO 30 SECONDS

J. geophys. Res. (USA), V. 64, No. 11, November 1959.
W.H. Campbell

Magnetic field micropulsations with periods of 5 to 30 sec were studied for 7 months of 1958 at a station in southern California with a 2-m-diameter coil antenna of 21, 586 turns. The local diurnal amplitude fluctuations attained maxima at 0945 and 1400 hours. Twenty-seven-day solar dependence and correlations with magnetic and ionospheric F-layer disturbances were evident. The storm time variation for micropulsation storms showed a secondary maximum at 65 min.

MAGNETIC MICROPULSATIONS AND THE PULSATING AURORA

Phys. Abstr. 1585/1961; J. geophys. Res. (USA), V. 65, No. 2, Pg 784, February 1960.
W.H. Campbell

Preliminary observations show some correlation between micropulsations both of the earth's magnetic field and of the intensity of the 3914 Å N_2^+ band and the 5577 Å OI line of the auroral spectrum at College, Alaska.

NATURAL ELECTROMAGNETIC ENERGY BELOW THE ELF-RANGE

Phys. Abstr. 12213/1960; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 4, Pgs 409-11, July - August 1960.
W.H. Campbell

The transition of natural signals from spherics slow tails to geomagnetic micropulsations was observed between 2.0 and 0.2 cps. Micropulsations with periods of 5 to 30 sec have characteristics which closely relate to solar terrestrial disturbance phenomena. The low latitude diurnal amplitude variation has maximums at 0945 and 1000 l.m.t. Similar groups of oscillations appear in Alaska and California. Simultaneous pulsation of λ 3914 aurora and magnetic field micropulsations has been observed in Alaska.

SOME AURORAL ZONE DISTURBANCES AT TIMES OF MAGNETIC MICROPULSATION STORMS.

Phys. Abstr. 15280/1962; J. Phys. Soc. Japan, Vol. 17, Supply. A²-I, 112-16, January 1962.
W.H. Campbell

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

I. Earth Storm (see Abstr. 9939 of 1962). Thirty-one occasions in the year ended September 1960 when micropulsations of 5 to 30 sec period increased rapidly in amplitude at College, Alaska, were examined in relation

phenomenon most likely of outer atmospheric origin but apparently unrelated to solar-terrestrial disturbances. Sudden bursts of large amplitude field fluctuations spread throughout the frequency range are closely related to high latitude particle precipitation, enhanced ionospheric absorption, and auroral luminosity; these fluctuations seem to be of ionospheric origin. Regular oscillations between 0.2 and 0.3 c/s appearing over broad sections of the earth with related phase on days of high solar-terrestrial activity are presently the best candidate for magneto-hydrodynamic interpretation. During the International Quiet Sun Year (IQSY) a configuration of world stations will be operated along a latitudinal line covering about 180° at three sites in the boreal auroral zone, along a longitudinal line near 75° to 80° W longitude and conjugate stations corresponding to L shell values of about 6.5 and 4, and at an equatorial site.

MAGNETIC FIELD MICROPULSATIONS AND ELECTRON BREMSSTRAHLUNG

W.H. Campbell

See Section III, Page 216.

ON THE DYNAMO THEORY OF GEOMAGNETIC FIELD VARIATIONS

Phys. Abstr. 11575/1954; J. geophys. Res. (USA), V. 59, Pgs 1-14, March 1954.

S.K. Chakrabarty, R. Pratap

The dynamo theory developed by Stewart, Schuster and Chapman in order to explain the geomagnetic field variations no doubt gives qualitative explanations for the observed variations but differs appreciably in details. In the present paper, the analysis of Chapman has been modified and the dynamo equations have been solved without introducing approximations which are difficult to justify. The solution of the dynamo equation has been given in the most general form, which can be used for any given "ionospheric conductivity" and "atmospheric oscillations". The results obtained have been compared with those of Chapman, which show the effect introduced in the final result by the approximations used by Chapman. The results have been utilized also to calculate the diurnal variations in horizontal and vertical intensities, and these have been compared with the observed data. The results show that with a reasonable assumption for the conductivity and the atmospheric oscillations, the dynamo theory can very well explain the observed facts.

CORRELATION OF SHORT-PERIOD FLUCTUATIONS OF THE EARTH'S MAGNETIC FIELD AND INSTANTANEOUS FREQUENCY MEASUREMENTS

Phys. Abstr. 19262/1962; J. geophys. Res. (USA), Vol. 67, No. 5, Pgs 2066-72, May 1962.

K.L. Chan, D.P. Kanellakos, C.G. Villard, Jr.

It is shown that short period ($\frac{1}{2}$ to 5 mins) fluctuations in the instantaneous received frequency of stable h.f. c.w. transmissions are usually well correlated with magnetic field changes. Frequency fluctuations over different

transmission paths separated by several hundred kilometers are also well correlated. Selected examples during periods of sudden commencements, geomagnetic storms and micropulsations are presented to illustrate the phenomenon.

THE EARTH'S MAGNETISM

2nd ed. 1951. \$1.90, Wiley
S. Chapman

RAPID GEOMAGNETIC FLUCTUATIONS AT TUCSON, ARIZONA.

Trans. Amer. Geophys. Union, V. 35, No. 5, Pgs 711-21, October 1954.
E.J. Chernosky, E. Maple, R.M. Coon

Oscillatory fluctuations (micropulsations), appearing as trains of waves in the frequency range of $1/2$ to $1/32$ cps, were present about 20 pct of the time with amplitudes of 0.01γ or more, in records of the vertical component of field made at Tucson with a large buried loop in the summer of 1947. The amplitudes of the oscillations were inversely proportional to their frequencies, and $1/20$ cps oscillations occurred more often than those of other frequencies. The highest frequencies occurred at night and were related to times of large magnetic disturbance; the lowest frequencies occurred during the day at times of low or moderate activity, and the intermediate frequencies showed a transition of behaviour. Random fluctuations, having no characteristic wave forms, had amplitudes which varied as the square root of the fluctuation duration. Average amplitudes of the three largest fluctuations per 15-min scaling interval decreased from 0.08γ at 60-sec duration to 0.01γ at one second; maximum amplitudes were about 10 times these values. The random fluctuations also showed diurnal variations and a dependence on the degree of magnetic disturbance. A few audio-frequency measurements are also reported.

CHANGES IN THE GEOMAGNETIC FIELD ASSOCIATED WITH MAGNETIC DISTURBANCE

Phys. Abstr. 13068/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-I, 25-32, January 1962.
E.J. Chernosky

Cosmic Ray and Earth-Storm Conference, Kyoto, 1961.

I. Earth storm (see Abstr. 9939 of 1962). A decrease in the magnetic horizontal component intensity (H) lasting for several hours to a day or more is usually associated with the existence of a magnetic disturbance. In this paper a study is made of the longer term changes in H and Z and occurrences of quiet days, disturbed days, storm sudden commencements, sudden impulses, small changes, etc. for several days before as well as during the disturbance. It is found that H rises, and Z generally falls, for three or four days before the disturbance as if in anticipation of it. The rise in H is lowest at middle latitudes and greatest near the

auroral zone. The behaviour of H and the other parameters studied suggest that the pre-disturbance variations may be linked to the disturbance mechanism.

VERY-LOW-FREQUENCY PHASE OBSERVATIONS OF SOLAR FLARE IONIZATION IN THE D REGION OF THE IONOSPHERE.

EE Abstr. 1252/1964; J. Geophys. Res. (USA), Vol. 68, No. 19, 5421-35, 1st October 1963.

C.J. Chilton, F.K. Steele, R.B. Norton

Sudden phase anomalies produced by solar flares were observed simultaneously on several long vlf propagation paths. The paths providing useful data are NBA (18 kc/s) Panama to Boulder, Colorado; to Maui, Hawaii; to Frankfurt, Germany; and to College, Alaska; and GBR (16 kc/s) Rugby, England, to Boulder; and NPG (18.6 kc/s) Seattle to College, Alaska. The observations show that during a solar flare the magnitude of the mean change of reflection height Δh on each sunlit path can apparently be related to the mean of $\log \sec \chi$ along the path, where χ is the solar zenith angle. Different flares, however, produce different curves of Δh versus the mean of $\log \sec \chi$. These results are discussed in terms of a layer produced below the normal height of reflection, and the energy (wavelength) and intensity (flux density) of the X-rays that produced the new layer are estimated.

EFFECT OF LIGHTNING DISCHARGES ON MAGNETOGRAPHS

Phys. Abstr. 2875/1957; Nature (GB), V. 178, Pg 815, 13th October 1956.

A.K. Daas

Following an earlier report (Nature V. 176, 5th November 1955) of "minor oscillations" recorded during a thunderstorm on a magnetograph, repeated similar disturbances were noted in records obtained in the Kodaikanal laboratory. In several cases visual correlation with lightning discharges could be established.

SOME RESULTS OBTAINED BY MEASURING THE MAGNETIC FIELD AT THE EARTH WITH A SPACE ROCKET

Dokl. Akad. Nauk. SSSR (USSR), V. 129, Pgs 77-80, 1st November 1959.

S. Dalginov, N.V. Pushkov

No abstract.

INFLUENCE OF THE TOTAL ECLIPSE OF THE SUN ON 15TH FEBRUARY 1961 ON THE TRAVEL TIME OF VERY LONG WAVES

B. Decaux, A. Gabry, J. Lachâtre, J. Lucas

See Section I, Page 29.

SUDDEN IMPULSES IN TELLURIC CURRENTS AND THEIR RELATION TO THE SUDDEN IMPULSES OF THE TERRESTRIAL MAGNETIC FIELD
Phys. Abstr. 6640/1955; Rev. Geofis. (Spain), V. 13, Pgs 155-66, April-June 1954.

L. De Miguel Y Gonzalez Miranda

It has been observed that in the earth-current records there is a far greater sensitiveness than in the magnetic ones when recording certain kinds of disturbances, such as the polar ones. These may even be unnoticed in a magnetic record, when they are of vibratory kind, but they can be easily observed on an earth-current record. Earth current equipment in all the magnetic observatories would therefore be useful in the study of these disturbances.

EAST-WEST EFFECT ON VLF MODE TRANSMISSION ACROSS THE EARTH'S MAGNETIC FIELD

D. Dobrott, A. Ishimaru
See Section I, Page 31.

A PRELIMINARY REPORT ON GEOMAGNETIC MEASUREMENTS FROM THE THIRD SOVIET ARTIFICIAL EARTH SATELLITE

Phys. Abstr. 13063/1962; Iskusst. Sputniki Zemli (USSR), 1958, No. 2, 50-3. In Russian.
S. Sh. Dolginov, L.N. Zhuzgov, N.V. Pushkov.

Geomagnetic measurements were carried out from Sputnik III in accordance with the IGY programme. The magnetometers are not described but their working range is reported as 48000 γ with a zero drift of 2 γ per hour. A typical experimental curve for the altitude range 250-750 km is reproduced.

HYDROMAGNETIC THEORY OF GEOMAGNETIC STORMS

J. geophys. Res. (USA), V. 64, No. 12, Pgs 2239-52, 1959.
A.J. Dressler, E.N. Parker

A hydromagnetic theory is presented which explains the average characteristics of geomagnetic storms.

METHOD OF FAST-REGISTERING VARIATIONS OF EARTH CURRENTS WITH THE AID OF ELECTRODES AND GALVANOMETER

Izv. Akad. Nauk. Turkmenskoi SSSR (USSR), No. 1, Pgs 3-10, 1958.
V.G. Dubrovskii

Method of high-speed registration using a spiral scan; in Russian; summarized in English in Soviet Bloc IGY Information No. 10, April 18, 1958.

DIURNAL VARIATION OF THE EARTH'S MAGNETIC FIELD AT TAMANRASSET BETWEEN
1948 AND 1955 (HORIZONTAL COMPONENT)
Ann. Geophys. (France), Vol. 18, No. 1, 110-15 (1962). In French.
F. Duclaux

This was studied in two ways. First the Egedal method was used which indicated the semi-diurnal lunar variation for three seasons of the year, and the whole year. This variation is always weak; about one gamma, maximum in winter and minimum in summer. The study of the influence of several factors proves a possible action of magnetic activity and the moon-earth distance, both of which would increase the amplitude. The second method consists of finding out the total lunar and solar variation after a setting of the sequence according to the age of the moon. This total amplitude is larger at the equinoxes than in summer and in winter; it varies between 30 and 50 gammas. In separating this total variation in components, lunar and solar variations are obtained in the lunar day. The semi-diurnal lunar variation which had been found in the first part is equal to this, which proves its validity; the diurnal variation is of the same order. The semi-diurnal and diurnal solar amplitude are ten times larger.

SUB-AUDIBLE GEOMAGNETIC FLUCTUATIONS

Nature Vol. 181, Pgs 1258-1259, 3rd May 1958.
H.J. Duffus, P.W. Nasmyth, J.A. Shand, C. Wright

Oscillations of the natural electromagnetic background in the frequency range 0.1-30 c/s were detected. By playing back tape recordings at 1000 times the speed of recording, the low frequencies are shifted into the audible range to give both rising and falling whistlers. The whistlers appear to be especially frequent during magnetic storms; during quiet periods the whistlers are usually of the falling type.

SOME OBSERVATIONS OF GEOMAGNETIC MICROPULSATIONS

Phys. Abstr. 2708/1958; Canad. J. Phys. V. 36, No. 4, Pgs 508-26,
April 1958.
H.J. Duffus, J.A. Shand

New observations are reported of the diurnal variation, direction, frequency spectrum, and geographical distribution of geomagnetic micropulsations (Pv and Pt). It is argued from a comparison of published data that these phenomena have primarily a solar time dependence, and may occur locally. At the two stations, separated by 60 longitude degrees, related signals were only occasionally observed. The phase characteristics of such related signals, together with differences in directional characteristics reported by other observatories, put serious strain on recent theories of the outer atmospheric origin of micropulsations.

INFLUENCE OF GEOLOGICAL FEATURES ON VERY LOW FREQUENCY GEOMAGNETIC FLUCTUATIONS

Nature (GB), V. 186, No. 4719, Pgs 141-142, 1960.
H.J. Duffus, J.A. Shand, C.S. Wright

No abstract

FLUCTUATIONS OF THE GEOMAGNETIC FIELD IN THE FREQUENCY RANGE 0.02 TO 3 CPS

Canad. Pacific Naval Laboratory, Rept. No. 60-7, July 1960.
H.J. Duffus, J.A. Shand, C.S. Wright

No abstract

LONG PERIOD FLUCTUATIONS OF THE GEOMAGNETIC FIELD

Canad. Pacific, Naval Laboratory, Report. No. 60-3, 1960.
H.J. Duffus, J.A. Shand, C.S. Wright.

No abstract

SHORT-RANGE SPATIAL COHERENCE OF GEOMAGNETIC MICROPULSATIONS

Phys. Abstr. 6961/1962; Canad. J. Phys. V. 40; No. 2, Pgs 218-25, February 1962.
H.J. Duffus, J.A. Shand, C.S. Wright.

An experiment designed to measure the coherence of natural geomagnetic signals at two stations 10 km apart is described. A qualitative measurement was performed on a section of 1 cps signal (of unusual occurrence) and a quantitative measurement on a section of normal daytime record. The coherence tends to be high for moderate signal levels.

SPATIAL VARIATIONS IN GEOMAGNETIC MICROPULSATIONS

Phys. Abstr. 24057/1962; Canad. J. Phys. Vol. 40, No. 9, 1133-52, September 1962.
H.J. Duffus, J.K. Kinnear, J.A. Shand, C.S. Wright.

Micropulsation fields measured simultaneously at pairs of stations are compared in order to describe their recognizable geographical extent and the perturbations due to local terrain. Some characteristics of coastal and inland sites are shown. The micropulsation field gradients were too small to be measured over a homogeneous earth but were clearly evident near the sea-coast. Estimates are made of the extent of the anomaly at the seacoast, and of the fraction of the signal accounted for by geology of the site. Separations between sites range from 1 km up to 1750 km. The distribution of the micropulsation amplitude in different directions and its dependence on period are shown for each

site. Its correlation with K_p is also shown. The data refer only to regular micropulsations of period from about 500 secs down to 2 secs, observed simultaneously at pairs of stations situated in mid-latitudes.

THE CAUSE OF MAGNETIC STORMS AND BAYS

J. geophys. Res. (USA), V. 65, Pgs 3589-3592, 1960.

R.A. Duncan

No abstract.

SOME STUDIES OF GEOMAGNETIC MICROPULSATIONS

Phys. Abstr. 21090/1961; J. geophys. Res. (USA), V. 66, No. 7, Pgs 2087-94, July 1961.

R.A. Duncan

Oscillations of the geomagnetic field with periods between 1 second and a few minutes were studied by means of large ground loops at Hobart, Adelaide, Camden, and Townville, Australia. Records were made both on charts and on slowly moving magnetic tape; the tape recordings were analysed for frequency components on a "Sonagraph" sound and spectroscope. The period of the continuous oscillations known as Pc's showed a diurnal variation and a marked dependence on latitude, shorter periods occurring at lower latitudes. The damped trains of oscillations, occurring predominantly around local midnight, known as Pt's were followed by magnetic bays with an average delay of about 15 min. During storms, "sweepers" - oscillations with a progressive change of frequency and sometimes with harmonic overtones - were observed.

THE PROPAGATION OF ALFVEN WAVES THROUGH THE IONOSPHERE

Scientific Rept. 57, Contract AF 19(122)-44, Ionosphere Research Laboratory, The Pennsylvania State University, University Pk, Pa, 15th February 1954.

J.W. Dungey

As a preliminary to a study of micropulsations, it is necessary to investigate the propagation of Alfvén waves through the ionosphere. General results are obtained for waves travelling parallel to the magnetic field, and approximations are then made, which are valid for periods of the order of a minute. Numerical values are given for the ionosphere and results are given for the simple case when the magnetic field is vertical. An approximate discussion is also given of waves propagated obliquely to the magnetic field.

INFLUENCE OF POLAR CAP ABSORPTION EVENTS ON VLF PROPAGATION

A. Egeland, B. Hultqvist, J. Ortner

See Section I, Page 33.

ON REGISTERING VARIATIONS OF THE GEOMAGNETIC FIELD IN THE RANGE 0.1-10 C/S
Phys. Abstr. 18572/1963; Izv. Akad. Nauk SSSR, Ser. Geofiz, 1962; No. 5,
677-8. In Russian. English trans. in: Bull, Acad. Sci. USSR, geophys.
Ser (USA), No. 5, 437-8, May 1962 (publ. September 1962).
Yu. M. Egorov

A brief description of the apparatus developed at the Borok Geophysical
Station for registering geomagnetic variations in the range 0.1-10 c/s.

SPACED OBSERVATIONS OF RADIO NOISE FROM THE OUTER ATMOSPHERE
Phys. Abstr. 4793/1960; Nature (GB), V. 184, Pgs 1391-2, 31st October
1959.

G.R.A. Ellis, D.G. Cartwright, J.R.V. Groves

Simultaneous recordings of atmospheric radio noise at a frequency
of 4.5 kc have been made at two stations in Australia, 1000 km apart.
Results indicate that, in general, bursts occur simultaneously at the
two sites, rather than at the same local times. However, a distinct
time delay was found for the one occasion on which a burst was observed
during a major geomagnetic storm and aurora.

LOW FREQUENCY ELECTROMAGNETIC RADIATION ASSOCIATED WITH MAGNETIC
DISTURBANCES

Planet, Space, Sci. Vol. 1, No. 4, Pgs 253-258, September 1959.

G.R.A. Ellis

Continuous observations of the amplitude and spectrum of naturally
occurring radiation in the band 2-40 kc/s were made during the period
June to December 1958 near Sydney, Australia. A large number of
isolated noise bursts lasting for some hours were detected. The
intensity ranged from 6×10^{-19} to $6 \times 10^{-17} \text{ W m}^{-2}(\text{c/s})^{-1}$ at 4.6 kc/s.
Three main types of bursts were identified and classified on a basis of
their spectra which usually extended from 3 to 5 kc/s, 4 to 8 kc/s and
2 to 30 kc/s, respectively. Major bursts which were always of the
latter two types, were clearly associated with strong auroral and magnetic
activity and some showed a reproducible sequence of amplitude variation
lasting about 36 hours. On three occasions, a detailed correspondence
between the intensity of the noise and of simultaneously occurring red
oxygen airglow was observed. Theories of the origin of the noise are
discussed.

DIRECTIONAL OBSERVATIONS OF RADIO NOISE FROM THE OUTER ATMOSPHERE

Nature, Vol. 184, pgs 1307-1308, 24th October 1959.

G.R.A. Ellis, D.G. Cartwright

Directional finding apparatus has been set-up in order to try to
locate the origin of very low frequency (4.5 kc/s) emissions associated
with geomagnetic field disturbances. Most disturbances seem to come
from north to south and the angular size of the sources has been estimated
at between 30° and 70° .

DIRECTIONAL OBSERVATIONS OF 5 KC RADIATION FROM THE EARTH'S OUTER
ATMOSPHERE

Phys. Abstr. 14315/1960; J. geophys. Res. (USA), V. 65, No. 3, Pgs 839-43, March 1960.

G.R.A. Ellis

Low-frequency radio noise bursts associated with geomagnetic disturbances have been observed with a network of direction-finding receivers in south-eastern Australia during September and October 1959. Over a range of longitudes from 135° E to 155° E, 18 noise bursts came from apparent sources at latitudes greater than 42° S. On 8 occasions, isolated discrete noise sources with an average geographical size of 550 km were detected at latitudes between 34° S and 42° S.

OBSERVATIONS ON ATMOSPHERIC NOISE

Nature, Vol. 186, Pg 229, 16th April 1960.

G.R.A. Ellis

Observations made at Camden, N.S.W., in the range 4-6 kc, show that the start of noise bursts usually coincides with bay-like variations in the magnetic field.

GEOMAGNETIC DISTURBANCES AND 5 KILOCYCLES PER SECOND ELECTROMAGNETIC
RADIATION

Phys. Abstr. 14174/1960; J. geophys. Res. (USA), V. 65, No. 6, Pgs 1705-10, June 1960.

G.R.A. Ellis

A comparison is made between variations of the geomagnetic field and bursts of 5 kc radio noise recorded at Camden, N.S.W., between June 1958 and October 1959. During this period 8 noise storms were recorded. All occurred during the main phase of a geomagnetic storm, beginning on the average 3 hours after the start of the main phase. Of 97 isolated noise bursts of less than $\frac{1}{2}$ hours' duration, 43 were associated with positive bays in the record of the magnetic H component. No consistent delay between the noise burst and the bay was observed. Noise bursts were not in general associated with geomagnetic micro-pulsations of less than 1-minute period, although some correlation with quasi-sinusoidal magnetic variations with periods between 10 and 60 minutes was noted. During the period of the observations 30 magnetic sudden commencements were followed by noise bursts or storms after an average delay of 8.5 hours. On four occasions, a noise burst started immediately after a sudden commencement occurring between 1200 and 1800 hours GMT.

A LONG-WAVE ANOMALY ASSOCIATED WITH THE ARRIVAL OF COSMIC-RAY PARTICLES OF SOLAR ORIGIN ON 23RD FEBRUARY 1956.

Phys. Abstr. 950/1957; J. atmos. terrest. Phys. (GB), V. 8, No. 4-5, Pgs 291-3, May 1956.

M.A. Ellison, J.H. Reid

A sudden decrease in received signal-strength on 24 kc was recorded at Edinburgh the onset coinciding in time (0345 U.T.) with the arrival of the solar cosmic-ray particles in the dark terrestrial hemisphere. The result was to produce an "artificial sunrise" effect for D-layer reflections that corresponded to a drop of 10-15 km in the reflection-height. The time-interval (cosmic-ray max. minus solar flare max.) was about 0.3 hr, i.e. shorter than any of the four previously recorded examples of a similar nature.

THE EFFECT OF A FAULT ON THE EARTH'S NATURAL ELECTROMAGNETIC FIELD

Phys. Abstr. 5184/1963; Geophysics (USA), Vol. 27, No. 5, Pgs 651-65, October 1962.

I. d'Erceville, G. Kunetz

The main purpose of this paper is to study the effect on a natural electromagnetic field of a lateral variation in the physical properties of the ground. An exact mathematical solution is given for two media of different resistivities in contact along a vertical plane (fault) overlying a horizontal basement that is taken as being either infinitely resistive or infinitely conductive, or at infinite depth. Results are given in the form of curves along profiles perpendicular to the fault. Some practical inferences are drawn from the shape of the curves and from their comparison.

SOME RESULTS CONCERNING THE BEHAVIOUR OF LONG DISTANCE VLF CIRCUITS DURING POLAR CAP ABSORPTION EVENTS

Phys. Abstr. 20954/1961; Ark. Geophys. (Sweden), V. 3, Paper 21, Pgs 489-96, 1961.

K.W. Eriksen, B. Landmark

"Polar cap absorption" symposium paper. During the polar cap absorption events of May and July 1959, marked reductions of the field strength occurred on some long distance v.l.f. circuits recorded in Norway.

ANALYSIS OF THE MAGNETIC AND TELLURIC EFFECTS OF THE "ARGUS EXPERIMENT" RECORDED AT FRENCH STATIONS

Phys. Abstr. 1582/1961; Ann. Geophys. (France), V. 16, No. 2, Pgs 264-71, 1960.

S. Eschenbrenner and Others

The "Argus Experiment" (three high-altitude small nuclear detonations fired ~ 480 km above the South Atlantic Ocean), produced arti-

ficial magnetic and telluric perturbations of the earth's field, which were received very distinctly at six French stations widely spread over the earth between France and the Antarctic. Comparison of these records with publications by the American organizers of the experiment (Abstr. 10427/1960) reveals the unexpected fact that pulsed magnetic signals like those originated by the detonations (a dozen irregular oscillations, of period 1-3 secs.), can travel at great speed and without much attenuation in all directions, across or along the earth's magnetic field lines. For this reason, and as a start for subsequent studies, a detailed computation of the signals as they were recorded, is reported and tabulated followed by photographic reproductions of the original records.

A 27 KC SUDDEN ENHANCEMENT OF ATMOSPHERIC ANOMALY

Phys. Abstr. 6404/1959; J. geophys. Res. (USA), V. 63, No. 4, Pgs 866, December 1958.

W.A. Feibelman

Shows a recorded trace for 1st May 1958 indicating a sharp drop in signal level followed by a gradual rise, in two instances, following solar flares. Normally signal enhancement is observed.

GEOMAGNETIC AGITATION AND OVERHEAD AURORA

Phys. Abstr. 13832/1962; Ionosphere Conference, London, 1962, (see Abstr. 11422 of 1963), Pgs 143-50.

W.L. Flock, A.E. Belon, R.R. Haycock

The association of auroral activity with ionospheric currents and corresponding geomagnetic agitations was studied by making use of the high sensitivity and time resolution obtainable with telluric current recordings. Simultaneous records were taken at College, Alaska, of telluric currents and overhead optical aurora. Telluric currents at Barrow, Alaska, were compared with overhead radio aurora, as observed with a 41 Mc/s radar, 540 km distant at Kotzebue, Alaska. Onsets of telluric current micropulsations accompany sudden increases in auroral luminosity. Telluric current and luminosity micropulsations show closely corresponding periods in the range 3-15 sec. The correlations are the highest under conditions of overcast sky, indicating that the telluric currents respond to ionospheric currents throughout a large region of the sky. Onsets and other major features of radio aurora and telluric currents correspond closely, often to the nearest minute.

SOME ASPECTS OF THE FIRST HIGH-FREQUENCY GEOMAGNETIC RECORDINGS OBTAINED AT GARCHY

Phys. Abstr. 6649/1961; CR Acad. Sci. (France), V. 251, No. 7, Pgs 962-4, 17th August 1960.

H. Fournier

"High frequency" geomagnetic variations (greater than 1 cps) have very different properties from variations with lower frequency. They are continuous, more or less random, and display no abrupt changes in amplitude or period. A 0.12 sec oscillation is present at all times.

GEOMAGNETIC STORM SUDDEN-COMMENCEMENT RISE TIMES

Paper presented at 41st Annual Meeting, American Geophysical Union, Washington, D.C., 27-30 April 1960.

W.E. Francis, A.J. Dessler, E.N. Parker

The world-wide sudden commencement of magnetic storms is attributed to a hydromagnetic wave generated by the impact of a sharp increase in solar wind pressure on the geomagnetic field. This hydromagnetic wave then propagates to the earth's surface where it is observed as a sudden commencement. Since the hydro-magnetic waves will be generated over a very broad area, signals generated at different positions along the source will arrive at a given point on the earth at substantially different times. This spread in arrival times will produce a sudden-commencement rise time which is longer than either the rise time of the hydromagnetic wave (less than 10 sec) or the time required for the solar plasma to sweep past the earth (about 30 sec). Ray tracing calculations of the propagation time of the hydromagnetic wave have been carried out for the special case of propagation in the equatorial plane. Ray paths have been traced between various points on an extended source at several earth radii to a given point on the earth's surface. The results show that this hydromagnetic model fits the observed one to 4-minute sudden-commencement rise time.

MORPHOLOGY OF MAGNETIC STORMS

Phys. Abstr. 13072/1962; J. Phys. Soc. Japan, Vol. 17, Supply A-I, 70-7, January 1962.

N. Fukushima

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

I. Earth Storm (see Abstr. 9939 of 1962). The average morphology of magnetic storms with SC was well studied by Sugiura and Chapman (1960), especially for the disturbance observed in moderate and low latitudes. In the present paper some important features of the magnetic disturbance field on the earth are pointed out especially for the part of the disturbance field, which has its origin in the electric current in the ionospheric region caused by the impinging of energetic particles into the auroral zone ionosphere from outside. The main points described are: the reversal of the direction of electric current across the polar cap in a short time during the sudden commencement; equatorial anomaly of the disturbance field in the early part of magnetic storms; characteristics of the polar elementary storm as the fundamental element of the polar disturbance field; small local disturbances taking place very often in high latitudes and their remarkable seasonal dependence of occurrence tendency; and the presence of persistent polar-cap disturbance of considerable magnitude caused by the persistent solar wind.

THE VERY LOW-FREQUENCY EMISSIONS GENERATED IN THE EARTH'S EXOSPHERE
 Phys. Abstr. 7213/1959; Proc. Inst. Radio Engrs (USA), V. 47, No. 2,
 Pgs 211-31, February 1959.
 R.M. Gallet

Naturally occurring, very low-frequency signals not associated with lightning discharges, and strongly correlated with solar activity, were recognized nearly as long as the atmospheric whistlers which have their genesis in lightning discharges. Whereas whistlers have been satisfactorily explained, until recently these other phenomenon have not. From the examination of a large quantity of high resolution spectrograms, it has been deduced that a major fraction, if not all, of these other "noises" are excited in the exosphere by streams and bunches of high-speed ionized particles precipitating into the ionized atmosphere in the presence of the earth's magnetic field. The electromagnetic waves excited are then propagated in the manner of whistlers. The excitation mechanism is similar to the operation of a travelling-wave tube. Two frequencies are simultaneously generated, and given by:

$$\omega = \left[\frac{\omega_H}{2} \pm \left\{ 1 \pm \left(\frac{\omega_P}{\omega_H} - \frac{V}{c} \right)^2 \right\}^{1/2} \right]$$

Their values depend only on the three parameters: local electronic density in the exosphere, local magnetic field intensity, and particle velocity V. For a large range of conditions, corresponding to middle latitude observations, the low frequency explains many types of noise, and reduces to:

$$\omega_1 = \left(\frac{V}{c} \right)^2 \frac{\omega_P^2}{\omega_H}$$

Most of the observations require particle velocities of the order of 10,000 km/sec. The shape of the spectrum is also very sensitive to the ambient electronic density distribution. A model in which the ratio of electron density to magnetic field strength is almost constant, along a line force in most of the exosphere, seems indicated by several types of noise. Such a model satisfies also the whistler data. The problem of the production of bunches and streams of particles is briefly discussed.

STUDIES OF NATURAL ELECTRIC AND MAGNETIC FIELDS

J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 4, July-August 1960.

G.D. Garland, T.F. Webster

Simultaneous measurements of short-period natural electric field variations across western Canada are reported. From these it is indicated that the effect of the varying depth to the Precambrian rocks is the dominant factor. Analysis of the simultaneous magnetic and electric measurements gives a resistivity for the Precambrian basement in excess of 30×10^5 ohm meters.

GENERATION OF VERY LOW FREQUENCY NOISE IN THE EXOSPHERE BY THE CHERENKOV EFFECT

Phys. Abstr. 3068/1961; CR Acad. Sci. (France), V. 251, No. 10, Pgs 1122-4, September 1960.

R. Gendrin

Considerations of the trajectory followed by the energy of a very low frequency wave directed along the magnetic field show that there are two modes of propagation, of which one is difficult to observe for the case of isotropic emission of all frequencies. It is suggested that the Cherenkov effect caused by relatively slow solar particles may be the mechanism whereby noise is generated and propagated in this mode.

RECORDING AND SPECTRAL ANALYSIS OF VERY LOW FREQUENCY OSCILLATIONS OF THE TERRESTRIAL MAGNETIC FIELD IN THE RANGE 1 TO 50 C/S.

Phys. Abstr. 13062/1962; C.R. Acad. Sci. (France), Vol. 254, No. 10, 1852-4, 5th March 1962. In French.

R. Gendrin, R. Stefant.

Describes the construction of recording apparatus for recording ultra low frequency oscillations of the terrestrial magnetic field. With the instruments, signals of 4 to 5 c/s with a duration of some 10 seconds were detected in a general background of 8 c/s.

FREQUENCY ANALYSIS OF PEARL-TYPE PULSATIONS

Phys. Abstr. 1486/1963; C.R. Acad. Sci. (France), Vol. 255, No. 4, Pgs 752-4, 23rd July 1962. In French.

R. Gendrin, R. Stefant.

Sensitive recordings of these pulsations made at one station in France and another near Tromsø for five months were analysed and the results of about 30 cases are summarized. The most characteristic feature is a periodically repeating sequence of short-duration pulses whose frequency rapidly increases. The product $f_m t$, where f_m is the mean frequency of the oscillation and t the period of the sequence, remains approximately steady over several days. Neither rotation of the plane of polarization, nor propagation along geomagnetic field lines, of the hydromagnetic waves which produce these oscillations can account for all the facts.

THEORY OF RAPID STRUCTURED PULSATIONS IN THE EARTH'S MAGNETIC FIELD
Phys. Abstr. 2317/1964; Ann. Geophys. (France), Vol. 19, No. 3,
197-214 (1963). In French.
R. Gendrin

Following experiments which point out the fine structure of some fast oscillations observed in the study of the earth's magnetic field, a theory is set up on the motion of bunches of trapped particles. The correlation found between the mean frequency of emission and the repetition period of the pattern is explained by the bounce frequency and the drift period. Correct orders of magnitude are obtained only for protons, the energy of which is between 4 and 30 MeV, situated on magnetic shells with McIlwain's L between 4 and 1.5. First figures are for high latitude observations, second ones for middle latitudes. Number and distribution of particles, as function of L, agree with recent satellite and rocket measurements on the low energy component of the first van Allen zone. The injection mechanism is not specified, but the diffusion gives an explanation about shape and duration of recorded emissions. Expected consequences of this theory are discussed and other experiments suggested.

A METHOD FOR PROCESSING RECORDS OF FLUCTUATIONS OF THE EARTH'S NATURAL ELECTROMAGNETIC FIELD WITH A VIEW TO DEEP SOUNDING
Izv. Akad. Nauk SSSR, Ser. Geofiz., 1963, No. 722-9. In Russian. English trans in: Bull. Acad. Sci. USSR, Geophys. Ser. (USA), No. 5, 447-50, (May 1963: publ. September 1963).
M.B. Gokhberg

Proposes a new method for processing the non-stationary perturbations of the natural electromagnetic field for purposes of geomagnetic investigations. The method only makes use of the most clearly expressed onsets of a perturbation of the field, independently of its further behaviour.

ELECTROMAGNETIC PHENOMENA OF NATURAL ORIGIN IN THE 1.0-150 C/S BAND
Nature, Vol. 177, Pgs 1219-1220, 30th June 1956.
P.A. Goldberg

To determine characteristics of natural activity at low audio and sub-audio frequencies, observations of geo-electro-magnetic activity in the 1.0-150 c/s band were made at an isolated place in eastern Oregon. The activity was found to be due to disturbance almost wholly of a burst-like form. Both the north-south and vertical magnetic components were similar as regards rate and duration of bursts, the magnitude being of the order of 10^{-8} gauss and the rate about 20 bursts/sec, although for the north-south component the magnitude is about 3×10^{-7} gauss. A highly regular and diurnal nature of the variation of activity is indicated, but with minor differences from day to day. The principle minimum occurs at

0700 hr. L.M.T. and a secondary at 2100-2200 hr. A very strong major maximum occurs at 1400-1600 hr. and a minor maximum at 2300-0100 hr. The burst character of these disturbances is suggestive of atmospherics due to lightning activity. The form of the curve giving the diurnal variation indicates that for the daytime ionosphere the lowest level of ionization affecting very low-frequency propagation between points on the sunlit hemisphere begins to be effective about two hours after ground sunrise.

EFFECTS OF COSMIC RADIATION ON THE EXTREMELY LOW-FREQUENCY PROPERTIES OF THE MESOSPHERE.

Phys. Abstr. 11414/1963; J. geophys. Res. (USA), Vol. 68, No. 1, Pgs 101-10, 1st January 1963.
P.A. Goldberg,

At extremely low frequencies (1 to 3000 c/s), relatively slight amounts of ionization can produce notable effects on electromagnetic phenomena in the terrestrial system. Representative atmospheric conditions are examined to find minimum conditions that can produce such strong e.l.f. effects at geophysically quiet periods. On the basis of analyses of ion production parameters, it is found that even for quiet nights when only cosmic radiation is important for producing ionization in the mesosphere, large refractivities can be produced in this portion of the atmosphere below the ionosphere. For even a minimum electron detachment condition the refractive index of the mesosphere has the large magnitude of 4 at an altitude 75 km. For a more inclusive ion production condition with a maximum detachment factor that collates with vlf observations, strong refractivity effects occur at quite low altitudes: 35 km at 1 c/s, 50 km at 10 c/s, 55 km at 100 c/s, and 65 km at 1000 c/s. At very low frequencies (10 kc/s and above) effective altitudes for the night-time lower ionosphere take on values normally assumed. During daytime and active solar periods it is indicated that strong refractivity effects will occur at altitudes below 30 km.

THE THEORY, MEASUREMENT, AND APPLICATIONS OF VERY LOW-FREQUENCY MAGNETOTELLURIC VARIATIONS

EE Abstr. 2698/1963; Proc. Inst. Radio Engrs (USA), Vol. 50, No. 11, Pgs 2347-63, November 1962.
A.W. Green, Jr., B.H. List, J.F.P. Zengel

Past and present observations of magnetic and telluric field variations are reviewed. The related E and H fields for very low-frequency (0.001 - 1.0 c/s) vertically incident waves and the characteristics and probable origin of these waves are discussed. Methods of measuring these fields are reviewed briefly. The applications of magneto-telluric waves in geophysics are described and the magneto-telluric effects of high-altitude nuclear explosions are examined in detail.

SUR L'INFLUENCE DE LA SELF-INDUCTION DES BOBINAGES A NOYAU MAGNETIQUE
UTILIZES POUR L'ENREGISTREMENT DES VARIATIONS RAPIDES DU CHAMP
MAGNETIQUE TERRESTRE

G. Grenet

See Section III, Page 233

MEASUREMENT OF WEAK MAGNETIC FIELDS OF TERRESTRIAL TYPE

P. Grivet

See Section III, Page 234.

NOTES ON PEARL-TYPE MICROPULSATIONS

Phys. Abstr. 13831/1963; J. geophys. Res. (USA), Vol. 68, No. 2,
Pgs 589-91, January 1963.

R.R. Heacock

Sonograms showing the spectra of pearl-type magnetic micropulsations (having frequencies of the order of 1 c/s) often reveal a characteristic fine-structure. Usually they consist of a sequence of rapidly-rising frequencies. It is shown how this effect could be produced by the movement and gradual dispersion of a bunch of electrons injected into an orbit in the radiation belts. The incidence of such events in relation to magnetic storms is discussed briefly.

TELLURIC CURRENT MICROPULSATION BURSTS

Phys. Abstr. 23575/1963; J. geophys. Res. (USA), Vol. 68, No. 3,
Pgs 953-4, 1st February 1963.

R.R. Heacock, V.P. Hessler

The spectrum of the micropulsations at College, Alaska, following the 9th July 1962 nuclear explosion was similar to that observed in many naturally-occurring bursts of micropulsations.

AURORAL-ZONE TELLURIC-CURRENT MICROPULSATIONS, $T < 20$ SECONDS

Phys. Abstr. 18482/1963; J. geophys. Res. (USA), Vol. 68, No. 7,
Pgs 1871-84, 1st April 1963.

R.R. Heacock

Telluric-current micropulsations were recorded at Barrow, College, Fort Yukon, Meanook, and Palmer. The diurnal variation data suggest a spiral pattern of occurrence in the auroral zone for the aurorally associated micropulsations ($T = 3-20$ sec). A spiral pattern of pearl-type micropulsation occurrence may exist at low latitudes. Many pearl events having sudden onsets and very large amplitudes were found to be well-correlated with simultaneous cosmic noise absorption. Simultaneous pearl "necklaces" were recorded. The occurrence of pearls at College seems to be negatively correlated with the occurrence of aurora. Evidence was found of increased ionization in the F-layer at times of extremely large-amplitude pearls.

THE LONGEST ELECTROMAGNETIC WAVES

Phys. Abstr. 485/1963; Sci. American, Vol. 206, No. 3, Pgs 128-37,
March 1962.

J.R. Heirtzler

Discusses electromagnetic waves (micropulsations) with wave-length $\sim 10 - 10^{10}$ m and frequency $\sim 1 - 10^{-2}$ c/s. The origin of these waves is unknown, but they promise to be useful in geophysics.

MAGNETIC FIELD MEASUREMENTS WITH THE EXPLORER X SATELLITE

Phys. Abstr. 13064/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II,
546-52, January 1962.

J.P. Heppner, N.F. Ness, T.L. Skillman, C.S. Scearce.

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). This paper summarizes the results of a preliminary analysis of Explorer X magnetic field data. Explorer X (1961 Kappa), launched at 15:17 GMT, 25th March 1961, was instrumented with a rubidium vapour magnetometer and two flux-gate saturable core magnetometers for field measurements, a plasma probe for measurement of the flux of low energy protons, and optical aspect system for precise determination of the satellite's orientation relative to the sun.

CHARACTERISTICS OF TELLURIC CURRENT AT LAND AND SEA BASED STATIONS

Phys. Abstr. 17117/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-I,
Pgs 32-4, January 1962.

V.P. Hessler

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

I. Earth Storm (see Abstr. 9939 of 1962). Results are summarized of measurements of telluric currents in Alaska, just south of the auroral zone, and in the Arctic drifting stations Charlie and Arlis I. High correlation with magnetic D or H traces, and with magnetic activity, was observed. The sea currents did not show the principal direction effect which is characteristic of land observations, but visual observation of auroral arcs was often correlated with parallel currents in the sea. Assuming an infinite current sheet of uniform density and of thickness equal to the depth of the sea, calculations show that 30-50% at Charlie and 16% at Arlis I of the surface magnetic disturbance could be attributed to current in the sea.

DIURNAL VARIATION OF THE EARTH'S MAGNETIC FIELD AT SEA

Phys. Abstr. 24058/1962; Nature (GB), Vol. 195, 365-6, 28th July 1962.

M.N. Hill, C.S. Mason

Using a recording proton precession magnetometer contained in an

anchored buoy, measurements of the geomagnetic field were made during several days in June 1961, at four depths from 450 to 2200 fathoms on, and at the foot of, the slope of the continental shelf in the western approaches to the English Channel. Simultaneous recordings were made on land near Plymouth. Comparison of the magnetograms shows that in magnetically quiet conditions the range of the daily variation at sea is about twice as great as on land, but less in disturbed conditions. The difference in the daily variations, sea minus land, show a component of period between 11 and 14 hrs which may be caused by electrical currents induced in the sea by tidal motion.

GEOMAGNETISM AND THE IONOSPHERE

Phys. Abstr. 13705/1963; Ionosphere Conference, London, 1962 (see Abstr. 11422 of 1963), Pgs 103-15.

C.O. Hines

Interactions between the geomagnetic field and the ionosphere are reviewed. These occur on the largest scale, under the influence of the interplanetary plasma, to determine the overall configuration both of the field and of the distant ionosphere. They include rotational interactions on the same scale, which serve to maintain much and perhaps all of the ionospheric medium co-rotating with the earth. On a somewhat smaller but still global scale they include tidal and storm phenomena, which alter both the field and the ionospheric characteristics and which probably play a major part in auroral and related phenomena. They occur in more localized fashion within ionospheric irregularities of various types, and on a shorter time scale in magnetically dominated waves, both hydromagnetic (in micro-pulsations) and magneto-ionic (vlf emissions). Salient features of all these interactions are discussed briefly, following an introductory review of the hydromagnetic and equipotential techniques that permit a succinct description of most of them.

SUMMARY: GEOMAGNETISM AND THE IONOSPHERE

Ionosphere Conference, London, 1962 (see Abstract 11422 of 1963) Pgs 233-6.
Phys. Abstr. 13706/1963.

C.O. Hines

Closing summary by the chairman of session named in the title.

THE IVANOV-TROYICKAYA EARTH CURRENT OSCILLATIONS

AD 70693; Translator's Comments

E.R. Hope

No abstract.

MAGNETOTELLURIC FIELDS IN THE FREQUENCY RANGE 0.03 TO 7 CYCLES PER KILO-
SECOND. I. POWER SPECTRA

Phys. Abstr. 15274/1962; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 4,
487-94, July-August 1962.

C.W. Horton, A.A.J. Hoffman

Power spectra of the horizontal components of the magnetic field and the telluric field are computed for data recorded on 1st and 2nd September 1957 at the Soviet Magnetic Observatory in Tbilisi. Power spectra of the East-West telluric field component are computed for 20th September 1957 for Soviet stations located at Lvov, Tbilisi, and Ashkhabad. All analyses are based on microfilm copies, furnished by the IGY World Data Centre A. Each power spectrum shows a frequency dependence over a frequency range of 0.03 to 7 cycles per kilosecond of the form P_{of}^{-n} where n varies from 1.1 to 2.5. The coherency between orthogonal components of the telluric and magnetic fields is computed for the data from Tbilisi. Magneto-telluric power spectra from USSR, Canada, Texas, and Massachusetts are plotted on a common graph to show the frequency dependence over the range 0.03 to 400 cycles per kilosecond. See also following abstract.

MAGNETOTELLURIC FIELDS IN THE FREQUENCY RANGE 0.03 TO 7 CYCLES PER KILO-
SECOND. II. GEOPHYSICAL INTERPRETATION.

Phys Abstr. 15275/1962; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 4,
495-7, July-August 1962.

C.W. Horton, A.A.J. Hoffman

The power spectra computed in Part I (see preceding abstract) for Tbilisi, USSR, are used to compute apparent resistivity in accordance with a formula developed for Cagniard. It is found that both components of the telluric field yield a value of 6 ohm m for the apparent electrical resistivity of the earth. The data does not extend over a sufficiently wide range of frequency to permit conclusions about the stratification. There is no evidence of horizontal anisotropy of the earth's resistivity. The magnetic power spectrum for the earth's ambient field is corrected for the transmission losses in the ionosphere to yield the power spectrum of the magnetic field incident on the earth. The major part of the variation with frequency is eliminated by this correction.

EQUATORIAL MICROPULSATIONS AND IONOSPHERIC DISTURBANCE CURRENTS

Phys. Abstr. 24033/1962; Nature (GB), Vol. 195, 269-70, 21st July 1962.

R. Hutton

The correlation between P_c activity and the disturbance daily variation, S_d , has been determined. The correlation coefficient between these two variables during the period 03.21 hours was found to be 0.6. It is concluded that the most probable time of onset of P_c activity is at 06, 12 and 18 hours. The night-time correspondence is not so good and it is suggested that the night maxima are related to some other form of pulsational activity.

THE S VARIATION OF EARTH CURRENTS NEAR THE MAGNETIC EQUATOR, ITS SEASONAL CHANGES, AND ITS RELATION TO VARIATIONS OF THE MAGNETIC FIELD
Phys. Abstr. 23579/1963; J. geophys. Res. (USA), Vol. 68, No. 9, 2403-10, 1st May 1963. (Equatorial Aeronomy Symp. Huancayo, 1962, (see Abstr. 21041 of 1963)).

R. Hutton

The harmonic coefficients of the earth-current variations at two stations in Ghana are presented and discussed. The ratio of the two principal harmonics of the variations at Legon are found to exhibit a seasonal variation, which is interpreted as arising from a shift in the position of the electrojet axis. Chapman and Whitehead's (1923) expressions relating earth-current variations with variations of the magnetic field are discussed, with reference to corresponding relations deduced by Tikhonov and Lipskaya (1952).

EQUATORIAL MICROPULSATIONS

Phys. Abstr. 15279/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II, 20-3, January 1962.

V.R. Hutton

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). The main characteristics of regular pulsations measured at Legon, Ghana, are discussed. An earth current was found to provide a satisfactory method of extreme sensitivity for the detection of small-amplitude, pulsational activity.

PULSE-DISTURBANCES IN EARTH CURRENTS

AD 70693; English translation from Dokl. Akad. Nauk., V. 8, No. 5, Pgs 807-10, 1951, by E.R. Hope, DRB, Canada.

A.G. Ivanov

No abstract

CHARACTERISTICS OF GEOMAGNETIC PULSATIONS

Phys. Abstr. 13085/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II, 55-63, January 1962.

J.A. Jacobs

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). The classification of geomagnetic micropulsations is discussed, and the question is raised of a revision of the definitions of changes in the geomagnetic field over a much broader spectrum. The paper then gives an account of the research, both observational and theoretical, at present being carried out in the field of micropulsations at the Institute of Earth Sciences, University of British Columbia.

GEOMAGNETIC MICROPULSATIONS WITH PERIODS 0.3-3 SEC ("PEARLS")
Phys. Abstr. 19268/1962; Nature (GB), Vol. 194, 641-3, 19th May 1962.
J.A. Jacobs, E.J. Jolley

The geomagnetic micropulsations called "pearls" may occur as separate bursts lasting 1 - 2 mins and as a continuous series of pulsations lasting for an hour or more. The appearance of pearls is not very common. In the summer of 1960 the authors studied the pearl activity at a number of observatories and found that the pulsations moved westward at an approximate rate of 14° /hr. It seems from closer studies that the onset of pearls depends entirely on local time but it is also possible that the westward movement expresses the azimuthal drift of charged particles trapped in the geomagnetic field. Several possible causes of pearl activity are briefly discussed.

PROPAGATION OF HYDROMAGNETIC WAVES IN THE LOWER EXOSPHERE AND THE ORIGIN OF SHORT PERIOD GEOMAGNETIC PULSATIONS

J. Atmos. terrest. Phys. (GB), Vol. 24, 413-34, June 1962.
J.A. Jacobs, T. Watanabe

The exospheric region below an altitude of about 2000 km, where the Alfvén velocity has a very steep upward gradient, amplifies hydromagnetic waves coming from outer space with certain special periods. The longest characteristic period, corresponding to the fundamental mode, is of the order of from 1 to several seconds, which is comparable to the period of that particular group of geomagnetic micropulsations called pearls. The fundamental period has a frequency-width of the order of $0.02-0.08 \text{ sec}^{-1}$, which is of the right order of the time-scale of fluctuations of the envelope of the pearls. The amplifying ratio also gives the correct order of magnitude of the intensity of pearls as observed at the earth's surface.

NOTATION AND CLASSIFICATION OF GEOMAGNETIC MICROPULSATIONS

Phys. Abstr. 2325/1964; J. Geophys. Res. (USA), Vol. 68, No. 14, Pgs 4373-4, 15th July 1963.
J.A. Jacobs, J.E. Lokken, C.S. Wright

A reclassification of these phenomena is suggested on a frequency basis using the names of the radio-frequency bands with the prefix μ e.g. μ VLF, etc.

TRAPPED CHARGED PARTICLES AS THE ORIGIN OF SHORT PERIOD GEOMAGNETIC PULSATIONS

Phys. Abstr. 25955/1963; Planet. Space Sic. (GB), Vol. 11, No. 8, 869-78, August 1963.
J.A. Jacobs, T. Watanabe

A peculiar fan-shaped structure in the dynamic spectrum of short-

period geomagnetic pulsations with frequencies from fractions of a c/s to several c/s is interpreted theoretically. It is concluded that such geomagnetic pulsations are caused by hydromagnetic oscillations in the lower exospheric region excited by several bunches of charged particles, trapped in the Earth's magnetic field and moving with velocities of the order of several hundreds to a thousand kilometres per second.

OBSERVED MAGNETIC EFFECTS FROM METEORS

A.W. Jenkins, C.A. Phillips, E. Maple, Jr.
See Section III, Page 240.

MORPHOLOGICAL STUDY OF GEOMAGNETIC PULSATIONS

Phys. Abstr. 13081/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II, 34-9, January 1962.

Y. Kato, T. Saito

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). Using the rapid-run and the ordinary magnetograms obtained during IGY, at the observatories distributed fairly well over the world, continuous pulsations of type I (range in period from 10 to 50 sec), II (50-150 sec) and III (150-900 sec) are analysed with pt-type pulsation. Type II pc shows remarkable enhancement in the daytime as type I pc, while type III pc has two vague maxima in the morning and the evening. The geomagnetic latitude is higher, the range of all three types of pulsations is larger, especially for type III pc, there is a sharp maximum in the auroral zone. For pt-type pulsation, its latitudinal dependence is compared with that of bay disturbance. The detail mode of world-wide synchronous oscillation according as the progress of pt shows that the direction of each oscillation is apt to point towards the midnight meridian in the northern or southern auroral zone.

GEOMAGNETIC PULSATION AND HYDROMAGNETIC OSCILLATIONS OF EXOSPHERE

Phys. Abstr. 19265/1962; J. Phys. Soc. Japan, Vol. 17, Supply A-II, 71-3, January 1962.

Y. Kato

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). A brief description is given of the characteristics of the various types of geomagnetic micro-pulsations. It is suggested that the continuous pulsations (PC) are associated with disturbances in the distant magnetosphere as associated with disturbances in the distant magnetosphere as observed from space probes, while the discrete pulsations (PT) are due to hydromagnetic waves generated when trapped electrons are precipitated into the atmosphere.

HYDROMAGNETIC WAVES IN THE EARTH'S EXOSPHERE AND GEOMAGNETIC PULSATIONS
Phys. Abstr. 13082/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II,
39-43, January 1962.
Y. Kato, T. Tamao

Cosmic Rays and Earth Storm Conference, Kyoto, 1961.
II. Joint Sessions (see Abstr. 9940 of 1962). In the first place the qualitative discussion on the physical characters in the exosphere are given. Using the propagation equation of hydromagnetic waves (HM-waves) in the particular coordinates and assuming Johnson's model of the exosphere, refractive indices for downward propagation of external HM-waves with specified period and wavelength in the lower altitudes are obtained as a function of altitudes. It is shown that HM-waves propagating to the perpendicular direction to lines of force will be reflected at the particular level corresponding to their period, and a part of their energy will be transported into the lower region (high latitudes) by means of transverse waves propagating parallel to the line of force through this level. It is suggested that primary source of daytime continuous pulsations are attributed to large amplitude HM-disturbances in the outermost exosphere as found by Sonett et al. (Abstr. 12133 of 1960). Since these disturbances may have considerable wide band width of spectrum, $T \approx 1 \text{ sec} \sim 3 \times 10^2 \text{ sec}$, observed characteristics of daytime pulsations at the surface will be explained in terms of the filtering effect of the dispersive inner exosphere. It is also suggested that damped type pulsation, pt's, may be caused by the hydromagnetic compression of the local hot gas in the outer exosphere near the equatorial plane in the dark hemisphere, and this compression will occur as a result of the precipitation of trapped energetic electrons from this local region to the auroral zone.

GEOMAGNETIC MICROPULSATIONS

Phys. Abstr. 11091/1962; Austr. J. Phys., V. 15, No. 1, Pgs 70-84,
March 1962.
Y. Kato

Incorporating world-wide data, a summary of observational knowledge on geomagnetic pulsations is given. Continuous pulsations (pc) are observed in daytime, and the amplitude of the pc increases with latitude, reaching a maximum in the auroral zone. Pulsation trains (pt) are observed at night and their amplitude attains a maximum in the auroral zone. The pt pulsation seems to be emitted from a local centre in the auroral zone near midnight, and there is a close correlation between the noise bursts of hiss and the occurrence of the pt pulsations. The primary source of pc pulsation is attributed to intense hydromagnetic disturbances in the outermost exosphere such as were found by Sonett et al. (Abstr. 10390, 12133 of 1960) by magnetic surveys from rockets.

S.E.A. PHENOMENA DUE TO NUCLEAR EXPLOSION

EE Abstr. 8277/1960; Mem. Fac. Engng Nagoya Univ. (Japan), V. 11, No. 1-2, Pgs 86-8, November 1959.

A. Kimpara

S.E.A. (sudden enhancement of atmospherics) phenomena were observed on the records of atmospherics at 21 and 27 kc at Toyokawa twice on 12th August 1958, the maxima occurring at 0436 and 1051 U.T. The phenomena were not found at 10 kc. Outbursts on solar radio-wave frequencies of 9400, 3750, 2000 and 1000 Mc were also observed, with maxima near 0430 U.T. Previous experience has indicated that when s.e.a. phenomena are observed at 21 and 27 kc exclusively and not at 10 kc, they are correlated with Dellinger fade-outs, i.e. with the occurrence of abnormal D layers, such as may result from nuclear explosions in the upper atmosphere. S.E.A. phenomena due to the explosion on 1st August 1958 were not observed in the records of atmospherics, which showed simultaneous increases at 10, 21 and 27 kc. At that time the neighbourhood of Japan was subject to heavy meteorological disturbances, which probably masked any s.e.a. phenomena.

GEOMAGNETIC PULSATIONS AND THE EXOSPHERE. I. STATISTICAL RESULTS.

EE Abstr. 1490/1964; Rep. Ionosphere Space. Res. Japan, Vol. 17, No. 2, 67-76, June 1963.

T. Kitamura

A frequency-time analysis of geomagnetic giant pulsations (Pg's) is made on the basis of IGY data and the following four types are found: (1) A type having an increasing frequency with time (called here ascending tone). (2) A type having a constant frequency with time (descending tone). (3) A type having a constant frequency with time. (4) A type having an irregular frequency with time. By examining in more detail the frequency character of Pg's from this point of view, one can often find a phenomenon like a beat having regularly varying amplitudes with time. The first half of it shows the ascending tone character and the latter half shows the descending tone, or vice versa. If the occurrence frequency of Pg's is plotted against local time, two maxima are found; one is in the morning (9h LT) and the other, in the evening (19h LT). The ascending type Pg's have a tendency to occur more often in the morning, whereas the descending ones occur more frequently in the evening. In order to interpret these phenomena, the authors have considered the following mechanisms: (1) dispersion, (2) doppler, (3) variable frequency, and (4) cavity, and it is found that the cavity mechanism is the most reliable.

REGISTRIERUNG BESONDERS NIEDERFREQUENTER ELEKTRISCHER SIGNALE WAHREND DER SONNENFINSTERNIS AM 15 FEBRUAR 1961

Z. angew. Phys. (Germany), V. 13, No. 10, Pgs 478-480, October 1961.

H. König, E. Haine

No abstract.

ABSOLUTE MEASUREMENT OF THE HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FIELD WITH THE AD. SCHMIDT THEODOLITE

Phys. Abstr. 13065/1962; Publ. Inst. Roy. Meteorol. Belgique A, No. 25, 100 pp, 1961. In French.

E. Lahaye, A. De Vuyst

Measurement of the horizontal component, H , by the Gauss method depends upon determination of the product MH and the ratio $M:H$, M being the magnetic moment of the magnet used in the two sets of observations. A large normal Schmidt theodolite is used at Dourbes to measure $M:H$. Schematically it has two platforms whose axes of rotation, are parallel to the axis of rotation of the theodolite. The three axes are in the same vertical plane. The centres of the platforms are a certain distance from the axis of the theodolite. The magnet is placed on one platform with its geometric centre on the axis of rotation of the platform. The magnetic axis of the magnet can thus be oriented to any azimuth. The Schmidt theodolite allows a precise determination of $M:H$ and especially of the factor $1 + k$ which occurs in the calculation of the ratio. The expression $1 + k$ is determined by means of a function represented by a Fourier series from values provided by orienting the magnet in different azimuths. Schmidt's theory is repeated but a different and simpler experimental method is used for the calculation of $1 + k$. The measurements of MH and $M:H$ are given. The method and the results of observations to obtain the characteristic properties of the two magnets employed and finally a table of observations relating to measurements of $1 + k$ for the two magnets are given.

MAGNETIC AND TELLURIC PERTURBATIONS RECORDED AT TAMANRASSET FOLLOWING THE NUCLEAR HIGH ALTITUDE EXPLOSIONS CALLED "EXPERIMENT ARGUS" (AUGUST-SEPTEMBER 1958)

Phys. Abstr. 1583/1961; Ann geophys. (France), V. 16, No.2, Pgs 289-90, 1960.

L. Launay, M. Beccaria

No abstract

THE SPATIAL DISTRIBUTION OF RAPID GEOMAGNETIC FLUCTUATIONS

Phys. Abstr. 1487/1963; Geophys. J. (GB), Vol. 7, No. 1, 102-10, September 1962.

J.A. Lawrie

A sample of all types of rapid fluctuation during a typical magnetic storm is drawn from Witteveen recordings. A statistical examination is made of the fluctuations and of the precisely simultaneous magnetic field changes recorded at several other stations. To explain the principal features, a model current system is suggested, which appears to be related to the current system of micropulsations.

THE SPATIAL DISTRIBUTION OF RAPID GEOMAGNETIC FLUCTUATIONS, II.
Phys. Abstr. 13837/1963; Geophys. J. (GB), Vol. 7, No. 3, 328-41,
February 1963.
J.A. Lawrie

(For Part I see above abstract). A detailed examination was made of some examples of rapid irregular magnetic field changes which occurred during a typical geomagnetic storm, selected from 180 mm/hr recordings.

POSSIBLE MAGNETIC EFFECTS FROM HIGH-ALTITUDE EXPLOSIONS OF ATOMIC BOMBS
Soviet Physics-IETP (USA), V. 2, No. 1, Pg 219, 1960.
O.I. Leipunskii

No abstract

BOMB-EXCITED "WHISTLERS"
EE Abstr. 2703/1961; Proc. Inst. Radio Engrs (USA), V. 48, No. 10,
Pgs 1778-9, October 1960.
B.A. Lippmann

The field strengths produced by nuclear explosions in the kiloton range are sufficient to give rise to "whistlers" modes of propagation. Propagation will take place along the lines of force of the magnetic field with a lateral spread of about 2000 km. The signal will be detectable at either of the points on the earth's surface where it is cut by the line of force, although because of the large natural background in this frequency range, the whistlers mode is unlikely to provide a major method of explosion detection. It could, however, furnish information about explosions in the atmosphere or in outer space.

ON CERTAIN RELATIONSHIPS BETWEEN HARMONICS OF THE PERIODIC VARIATIONS OF THE TERRESTRIAL ELECTRIC AND MAGNETIC FIELDS
AD 70 673; Izv. Akad. Nauk SSSR (USSSR), Geophysical Series, V. 1, Pgs 41-47, 1953. Translated by E.R. Hope, DRB, Canada.
N.V. Lipskaya

A number of experimental laws are established for terrestrial electromagnetic field variations, and theoretical calculations of the possible relationships between them are given, based on the simplest possible scheme for the electrical cross-section of the earth's crust. In papers (1) and (2), we derived approximate expressions relating the elements of the harmonics of the terrestrial electric and magnetic field variations to the electrical characteristics of the underlying medium (ground). In the present paper, an analysis is given of some of the said relationships, and these relationships are compared with observations.

CONNECTION BETWEEN MICROPULSATIONS AND THE IONOSPHERE

Phys. Abstr. 21096/1961; Nature (GB), V. 191, Pgs 584-5, August 1961.
C.M. Lock, P.J. Stevens

Simultaneous recording of geomagnetic micropulsations at two widely spaced stations (6750 km) which are not geomagnetically conjugate shows that Pt type disturbance occurs simultaneously at the two stations whilst oscillations of the Pc type, although occurring at approximately the same time, do not exhibit the same coherence. Coherence between Pc start-up time and sunrise has been found, the effect being latitude-dependent. Finally the generation of the two types of disturbance is considered.

THE CLASSIFICATION OF MICROPULSATIONS

Paper presented at the Conference on Telluric and Geomagnetic Field Variations. University of Texas, Austin, Tex., 21st October 1961.
J.E. Lokken, J.A. Shand, C.S. Wright.

No abstract.

SOME CHARACTERISTICS OF ELECTROMAGNETIC BACKGROUND SIGNALS IN THE VICINITY OF ONE CYCLE PER SECOND

Phys. Abstr. 13684/1963; J. Geophys. Res. (USA), Vol. 68, No. 3, Pgs 789-94, 1st February 1963.
J.E. Lokken, J.A. Shand, C.S. Wright

Near 1 c/s the natural background consists of a comparatively steady, low-level "white" continuum relieved occasionally by the intrusion of either regular or impulsive geomagnetic signals, as well as by the normal occurrence of sferics. The amplitude and frequency of the intrusions depend on latitude. Characteristic, regularly repeating signal-reinforcement patterns are sometimes observed in austral and boreal regions. Such patterns are displaced in time at conjugate points by one-half their repetitive period.

A NOTE ON THE CLASSIFICATION OF GEOMAGNETIC SIGNALS BELOW 30 CYCLES PER SECOND

Phys. Abstr. 19257/1962; Canad. J. Phys., Vol. 40, No. 8, Pgs 1000-9, August 1962.
J.E. Lokken, J.A. Shand, C.S. Wright

Simultaneous measurements in the frequency range 0.003 to 30 c/s at a number of widely spaced stations led to the identification of two general micropulsation classes, impulsive and regular, as well as to an adjacent but independent extremely low frequency background. The signal bandwidths and the dependence on geomagnetic latitude and longitude serve to distinguish the classes.

THE ELECTRICAL FIELD INDUCED BY OCEAN CURRENTS AND WAVES, WITH APPLI-
CATIONS TO THE METHOD OF TOWED ELECTRODES

Papers in Physical Oceanography and Meteorology, published by Mass.
Inst. of Technology and Woods Hole Oceanographic Institution, V. XIII,
No. 1, 37 p., 1954.

M.S. Longuet-Higgins, M.E. Stern, H. Stommel

No abstract

THE CONDUCTIVITY OF THE IONOSPHERE AND GEOMAGNETIC VARIATIONS

Phys. Abstr. 8120/1953; Naturwissenschaften (Germany), V. 40, No. 5,
Pg 239, 1953.

I. Lucas

Outlines an explanation for the large lunar magnetic variations
observed at stations near the magnetic equator and also for the narrow
zone of high conductivity (about $\pm 7^\circ$ wide) about this equator.

THEORY OF THE ORIGIN OF THE VERY LOW-FREQUENCY RADIO EMISSIONS FROM THE
EARTH'S EXOSPHERE

Phys. Abstr. 12905/1959; Phys. Rev. Letters (USA), V. 2, No. 12, Pgs
491-2, June 1959.

J.W. MacArthur

A new theory of the dawn chorus is presented, which considers the
electromagnetic waves as being radiated from a rotating cloud of protons,
gyrating round the earth's magnetic field. Allowance for the Doppler
frequency shift shows that the equations derived by Gallet (Abstr. 7213/
1959) on the basis of a different theory involving a travelling-wave tube
type of interaction can be obtained as limiting cases.

MICROPULSATION STUDIES AT BRISBANE, QUEENSLAND. I. PEARL PULSATIONS AND
"SCREAMERS".

Phys. Abstr. 13833/1963; Ionosphere Conference, London, 1962 (see Abstr. 11422.
of 1963), Pgs 163-8.

J.S. Mainstone, R.W.E. McNicol

Frequency-time plots of micropulsations in the 0.5 c/s region, recorded
at Brisbane (35° S geomagnetic latitude) exhibit a characteristic striped
pattern. This pattern consists of rapid upward frequency sweeps over a
limited, well-defined range. The modulated wave form of pearl pulsations
may be explained in terms of this structure. The time between successive
frequency sweeps is constant (160-170 sec) but the slope of the sweep is
variable. A characteristic train of pulsations with frequencies generally
in the 1 c/s range, lasting for periods of up to 5 or 6 hours, constitutes a
"screamer". Screammers may consist of several bursts of activity whose

average frequency rises appreciably from one burst to the next, but within each of which the frequency falls. Pearls with a recurrence period of 145 sec have been reported from Canada (60° N geomagnetic latitude); the period found in Brisbane is ≈ 160 sec. A disturbance originating in the auroral zone, and propagated as hydromagnetic waves towards the equator, may account for this agreement over a considerable range of latitudes.

SHORT-PERIOD VARIATIONS OF THE HORIZONTAL COMPONENT OF THE GEOMAGNETIC FIELD AT POINT BARROW, ALASKA.

Trans. Amer. Geophys. Union, V. 34, Pg 334, 1953.

E. Maple

Variations in the horizontal component of the earth's magnetic field were measured at Pt. Barrow, Alaska, in July and August of 1950. The amplitudes of the variations were approximately inversely proportional to their frequencies. The average of the three largest signals in each three hour period decreased from about 20 gammas at 0.0075 cps to about 0.5 gammas at 1 cps. The amplitudes of the variations correlated closely with the three-hour K indices of the Pt. Barrow observatory of the U.S. Coast and Geodetic Survey. Diurnal trends will also be discussed. The voltage induced by the variations in a search coil was recorded on magnetic tape. The records were played back at increased tape speed, and the resulting signal was analyzed electrically by means of an amplifier having ten narrow band-pass channels covering the desired frequency range. The output of five of the frequency channels were examined in detail, the other five channels indicated no appreciable departures from the trends thus obtained.

GEOMAGNETIC FLUCTUATIONS AT FREQUENCIES OF 3 TO 45 CPS AT POINT BARROW, ALASKA.

Trans. Amer. Geophys. Union, V. 37, Pg 354, 1956.

E. Maple

About one month's data on geomagnetic fluctuations in the sub-audio frequency range of three to 45 cps were obtained at Point Barrow, Alaska, in the fall of 1952. The amplified output of a detector coil was recorded on magnetic tape. A play-back, the signal was filtered and average values of fluctuation strength were obtained for each of five frequency bands. This work was done while the author was at the U.S. Naval Ordnance Laboratory. The results indicate that the largest fluctuations throughout the frequency range are associated with magnetic activities as measured by the K index. The present data are not sufficient to define quantitatively the nature of this relationship, which does not appear to be a simple one. The most interesting feature of the results is that the largest sub-audio frequency fluctuations tend to occur several hours before the large magnetic disturbances ($K \geq 7$). One occurrence of this type at a low latitude has been reported by Aarons.

The present data indicate that the phenomenon is much more common in the auroral zones. Some implications of the data concerning the possible particle-radiation origin of the fluctuations will be discussed.

'SUB-AUDIO FREQUENCY GEOMAGNETIC FLUCTUATIONS AT COLLEGE, ALASKA.
Trans. Amer. Geophys. Union, V. 38, Pg 399, 1957.
E. Maple.

Measurements of the integrated level of the fluctuations in a 20 to 45 cps band have been under way since December 1956 with the co-operation of the Geophysical Institute, University of Alaska, and are being continued. At most times, the fluctuations originate in distant lightning strokes as reported by Halzer and Deal. The average diurnal variations is that to be expected from the worldwide variation of thunderstorm activity and the directional characteristics of the detector coil. Unusually high fluctuation levels (greater than about 140 pct of the average level to be significant) precede by several hours the main magnetic disturbances (as measured by the local K index) with which they are associated. Of the two large disturbances (K=7) which occurred during the first 47 days of data, only one was preceded by a significant high fluctuation level (160 pct maximum of average level). Two lesser disturbances (sustained levels of K=6) occurred, and both were preceded by significant increases (210 pct maximum in each case). Smaller disturbances (including single occurrences of K=6) were not associated with significantly high sub-audio fluctuation levels. The magnetic disturbance effect appears weaker than that previously observed at Point Barrow, which suggests a strong dependence on geomagnetic latitude.

GEOMAGNETIC OSCILLATIONS AT MIDDLE LATITUDES. I. THE OBSERVATIONAL DATA
Phys. Abstr. 10391/1960; J. geophys. Res. (USA), V. 64, No. 10, Pgs 1395-1404, October 1959.
E. Maple

Oscillations are defined comprising only the more regular of the short-period geomagnetic fluctuations (periods from 1 to 200 seconds) and may be recognized as representing electromagnetic energy in narrow frequency bandwidths and identified by objective criteria. The characteristics of these oscillations as indicated by the available observational data, are examined with a view toward the eventual identification of their resonant sources. Three distinct frequency "bands" are observed. Two of them, a 20 sec band (that is, oscillations having similar characteristics and having periods centred about 20 sec) and a 70 sec band, are predominantly day-time phenomena, whereas the third, an 8 sec band, occurs at night. The 8 sec oscillations show a strong positive correlation, both in amplitude and duration, with the K index; this correlation is less pronounced for the 20 sec band and is absent (or perhaps negative) for the 70 sec band. An additional night-time band containing periods longer than about 95 sec is not yet definitely established.

SUB-AUDIO FREQUENCY (1 TO 50 CPS) GEOMAGNETIC FLUCTUATIONS AT DENVER,
COLORADO

E. Maple

See ~~Addendum~~, Page 553.

ONE TO 50 CPS GEOMAGNETIC FLUCTUATIONS

Paper presented at the Conference on Telluric and Geomagnetic Field
Variations. University of Texas, Austin, Texas, 21st October 1961.

E. Maple

No abstract

ASSOCIATION BETWEEN AURORAE AND VERY-LOW-FREQUENCY HISS OBSERVED AT
BYRD STATION, ANTARCTICA

Phys. Abstr. 18504/1960; Nature (GB), V. 187, Pgs 751-3, 27th August
1960.

L.H. Martin, R.A. Helliwell, K.R. Marks

Observations made at Byrd Station, Antarctica, during 1959 indicates
the existence of a close association between aurorae and v.l.f. hiss. The
mid-frequency of the hiss-band appears to depend on auroral type: for
example, red aurorae are associated with hiss of mid-frequency, 9.6 kc.
Other works (Duncan and Ellis, 1959) have previously reported similar
association. The origin of the v.l.f. radio emission is not yet under-
stood.

OBSERVATIONS OF "WHISTLERS" AND "CHORUS" AT THE SOUTH POLE

Phys. Abstr. 21395/1960; Nature (GB), V. 187, Pgs 1018-19, 17th September
1960.

L.H. Martin

The seasonal variation of "chorus" with maximum activity occurring
in mid-summer, suggests direct dependence on solar radiation probably
being initiated by solar corpuscular radiation impinging on the outer
ionosphere. The "whistlers" appear to be produced at lower latitudes,
reaching the receiver by reflections between the earth and lower iono-
sphere, and the seasonal and diurnal variation be due to the correspond-
ing variations in D region absorption over the path of propagation. Low-
frequency hiss associated with aurorae was also observed. The frequency
of hiss may decrease with geomagnetic latitude.

INCREASE OF IONIZATION ASSOCIATED WITH GEOMAGNETIC SUDDEN COMMENCEMENTS

Letter to Editor of J. Geophys. Research 66, 3958-3961, November 1961.

S. Matsushita

No abstract.

ON GEOMAGNETIC SUDDEN COMMENCEMENTS, SUDDEN IMPULSES AND STORM DURATIONS
Phys. Abstr. 9132/1963; J. Geophys. Res. (USA), Vol. 67, No. 10, 3753-77,
September 1962.
S. Matsushita

After a study of the morphology of geomagnetic sudden commencements during the IGY, their accompanying phenomena, such as sudden increases of cosmic noise absorption, bursts of bremsstrahlung X-rays, and commencements of geomagnetic micropulsations, are examined. Geomagnetic sudden impulses observed during the IGY are then studied similarly. Four types are found, three of which are completely analogous, both in their morphologies and in their accompanying phenomena, to the corresponding types of sudden commencements. The average duration of the storm depression of the horizontal geomagnetic field, usually attributed to the ring current, is also studied. Storms during years of great solar activity are found to be about three times longer than those during years of little solar activity. The spectrum of storm durations is found, it is concluded that even sudden impulses belong to the family of storms. Possible causes of all these related phenomena, including increases of cosmic noise absorption and micropulsations, are discussed.

ON THE NOTATIONS FOR GEOMAGNETIC MICROPULSATIONS
Phys. Abstr. 25953/1963; J. geophys. Res. (USA), Vol. 68, No. 14, 4369-72,
15th July 1963.
S. Matsushita

A new system of notation is suggested, whereby regular oscillations are subdivided according to period, and more irregular phenomena according to the other geophysical events with which they are usually associated.

MORPHOLOGY OF THE GEOMAGNETIC PULSATION
J. Geomagn. Geoelect. (Japan), V. X, No. 3, 1959.
T. Matanabe

Report covers: General features of geomagnetic pulsations; Pc and pt pulsations; Giant pulsations; and Vibrations.

ELECTRONIC RECORDING OF THE TRANSIENT VARIATIONS IN THE EARTH'S MAGNETIC FIELD
A. Maxwell
See Section III, Page 246.

NATURAL NOISE FIELDS FROM 1 CPS TO 100 KC

EE Abstr. 1276/1964; IEEE Trans Antennas & Propagation (USA), Vol. AP-11, No. 3, Pgs 339-43, May 1963.

E.L. Maxwell, D.L. Stone

Vertical electric and horizontal magnetic r.m.s. noise field intensities have recently been measured by the authors over the frequency range of 30 c/s to 50 kc/s for all seasons of the year and for all time blocks. This data is combined with that of other workers in the field to present the natural noise density spectra from 1 c/s to 100 kc/s for central United States regions. The portion of the data between 10 and 100 kc/s is found to be in close agreement with CCIR Report 65, "Revision of Atmospheric Radio Noise Data" Seasonal and diurnal variations at these locations are seen to become small below 1 kc/s. In addition to r.m.s. data, the authors measured the peak envelope occurring within 5-minute time intervals in a 7-c/s bandwidth. Under certain conditions, rapid changes in the peak envelope to r.m.s. dynamic range were noted between 3 and 8 kc/s. This phenomenon is discussed with respect to source characteristics and propagation.

MICROPULSATION STUDIES AT BRISBANE, QUEENSLAND. II. PULSATIONS OF THE PC AND PT TYPE

Phys. Abstr. 13834/1963; Ionosphere Conference, London, 1962 (See Abstract 11422 of 1963), Pgs 169-76.

R.W.E. McNicol, J.S. Mainstone, J.R. Wilkie

Micropulsations in the period range 4-100 sec were recorded with equipment sensitive down to 0.001γ sec on both paper chart and magnetic tape. Analysis of the tapes was made with a Kay Electric sonograph frequency spectrum analyser, the tapes being speeded up by a factor of 44,000 on replay, so that one complete day's record appeared on each sonogram. It was found that Pc pulsations were strongest during daylight hours, and had an amplitude which depended on magnetic Kp index, being approximately 0.3γ peak-to-peak when $K_p = 3$. The spread in the frequency spectrum of the Pc pulsations depended both on time of day and Kp index, being greatest at mid-day ranging then up to a maximum value which was proportional to Kp, being about 0.1 c/s when $K_p = 3$. The lower limit of the frequency spectrum was almost independent of Kp index and time of day, being usually about 0.02 c/s. When $K_p = 0$ the pulsations were not detectable on the chart records but could be seen weakly on the sonograms during the daylight hours only, confined throughout this time to the frequency range 0.02 to 0.04 c/s. Pulsations of Pt type could be distinguished from Pc on the sonograms by their characteristically short duration and more widely spread frequency spectra. It was found that Pt's occurred most often in the late afternoon and at night, being most common around 2100 hours L.M.T. The occurrence of Pt's also depended on the degree of magnetic activity, and was closely correlated with the occurrence of magnetic bays, the amplitude range of the Pt being proportional to the value of dH/dt for the associated bay.

DETERMINATION OF THE LOCATION OF THE IONOSPHERE CURRENT SYSTEM RESPONSIBLE FOR GEOMAGNETIC EFFECTS OF SOLAR FLARES

J. Atmos. Terrest. Phys. Vol. 4, Nos. 4/5, Pgs 141-147, December 1953.
A.P. Mitra, R.E. Jones

A new method for locating the ionospheric current system associated with solar flares is presented. The new method depends on the time of maximum intensity of a geomagnetic flare effect and the enhancement of electron density at the relevant level.

It is found that the flare current system is located either at 100-130 km (if one assumes the flare effect is essentially one of enhancement of the Sq-current) or at 60 km (if it is an independent system).

CORRELATION OF MAGNETIC M-STORMS WITH THE MONOCHROMATIC CORONA

Phys. Abstr. 7340/1953; Observatory (GB), V. 73, Pgs 75-7, April 1953.
R. Müller

If there are no significant sunspot phenomena on the sun, a maximum of magnetic activity is found to occur 3.7 days before the central meridian passage of a solar region of high coronal intensity; or 3.1 days after the appearance of bright coronal emission at the east solar limb (in agreement with earlier results of Roberts, Shapley and Trotter). A similar effect is found for the minimum epochs of both phenomena.

SIMILARITY AND SIMULTANEITY OF MAGNETIC DISTURBANCE IN THE NORTHERN AND SOUTHERN HEMISPHERES

Phys. Abstr. 13069/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-I, 35-9, January 1962.
T. Nagata, S. Kokubun, N. Fukushima

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

I. Earth Storm (see Abstr. 9939 of 1962). The comparison of geomagnetic disturbances in the northern and southern hemispheres is made for the average disturbance daily variation SD in the polar regions, and for individual disturbances observed at some selected stations in high latitudes. The SD-field pattern in the southern hemisphere is almost a mirror image of the northern one with respect to the geomagnetic equatorial plane. The magnetic activity at a station in the northern hemisphere shows the best correlation with that observed at geomagnetically conjugate point in the southern hemisphere. Two selected conjugate pairs of stations, one on the poleward side and the other on the equatorial side of the normal auroral zones, are especially examined. The correlation of individual simultaneous disturbances is fairly good even at the time of large magnetic storms for the equatorial pair of stations. On the other hand, the correlation becomes poor for the polar-side pair of stations in daytime and during disturbed periods, although the night-time variations show almost one to one correspondence at these stations.

MAGNETIC FIELD FLUCTUATIONS ON THE EARTH AND IN SPACE

Phys. Abstr. 13080/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II, 27-33, January 1962.

N.F. Ness, T.L. Skillman, C.S. Scarce, J.P. Heppner

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). The recent development of rubidium vapour magnetometers as practical instruments for measuring magnetic fields has led to extremely precise and accurate determinations of magnetic fields on the earth and in space. Because of the unique manner in which the data is presented in the frequency domain, the data is very amenable to analysis by automatic digital computers. As a result, measurements of fluctuations of the terrestrial magnetic field have enabled accurate determinations of the frequency spectrum characteristics of the fluctuations. Magnetometer measurements of the field in space were made from the space probe Explorer X launched 25th March 1961. The terrestrial measurements were continuous over intervals of several days. These data were sampled once per second. Power spectrum analyses indicated distinct frequency bands in which the fluctuating magnetic field energy is concentrated. Data collected at the Fredericksburg Magnetic Observatory show a strong spectral peak for fluctuations with a period of around 10 seconds. These peaks are found to be both amplitude and frequency modulated on a daily basis. Additional spectral peaks were observed and studied in the terrestrial data. The data obtained from measurements in space are less extensive at present. Hence, they do not allow sophisticated analyses to be performed as indicated above. Time correlations with terrestrial data were made to study these fluctuations. The fluctuation of the field was then viewed with respect to the existence and propagation characteristics of hydromagnetic waves.

WORLD WIDE CHANGES IN THE GEOMAGNETIC FIELD

Phys. Abstr. 13071/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-I, 39-44, January 1962.

A. Nishida, J.A. Jacobs

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

I. Earth Storm (see Abstract 9939 of 1962). It is found that world-wide changes in the geomagnetic field are not limited to SSC or SI, and are frequently observed. Not only an increase, but also a decrease in the horizontal intensity occurs on a world wide scale. The morphology of this phenomenon is studied, and is found that there is a pronounced similarity with that of SSC and SI. This is consistent with the idea that there is a permanent interaction between the solar corpuscular stream and the geomagnetic field.

GEOPHYSICAL EFFECTS OF HIGH-ALTITUDE NUCLEAR EXPLOSIONS

EE Abstr. 1852/1960; Nature (GB), V. 183, Pgs 1476-8, 23rd May 1959.
T. Obayashi, S.C. Coroniti, E.T. Pierce

The time of the 1st August 1958, explosion on Johnston Island coincided with a loss of signal on three transmitters (15 Mc, Honolulu; 10 Mc, Honolulu; 13.76 Mc, San Francisco) as received at Hiraio, Japan, although the path from San Francisco to Japan is ~ 3600 km from Johnston Island (and more remote from the geomagnetic conjugate of Johnston). The explosion of 12th August 1958 coincided with a pronounced effect for the Honolulu transmitter on 15 Mc (a less marked effect for the other Honolulu transmitter, and no significant effect for the San Francisco station). Besides, an enhancement of the level of atmospherics on 28 kc was detected at the time of explosion. These effects are similar to those caused in the ionosphere by a solar flare.

GEOMAGNETIC-STORM CORRELATION BETWEEN THE NORTHERN AND SOUTHERN HEMISPHERE

Phys. Abstr. 1491/1963; J. Geomagn. Geoelect. (Japan), Vol. 14, No. 1, Pgs 22-32, 1962.

T. Ondoh, H. Maeda

The correlation of geomagnetic storms observed in the northern hemisphere with those in the southern hemisphere is studied on the basis of IGY data in two different ways, viz. storm-time variations and storm-to-storm variations of the correlation. It is found for both cases that the closer the corresponding northern and southern stations are to geomagnetically conjugate points in the auroral zones, the better correlation is seen between them. On the other hand, it is also found that the geomagnetic-storm correlation between northern and southern stations close to conjugate points is very good without depending on the magnitude of storms and the local time of storm commencements, whereas that far from conjugate points it is highly dependent on the relative position of corresponding northern and southern stations. These results may suggest that the distant geomagnetic field is almost symmetric about the geomagnetic equatorial plane, even if it is distorted during geomagnetic storm.

THE GREAT EARTH STORMS IN NOVEMBER 1960 AS OBSERVED AT KIRUNA GEOPHYSICAL OBSERVATORY

Scientific Report 1, Contract AF 61(052)-418, Kiruna, Geophysical Observatory of the Royal Swedish Academy of Science, Kiruna, Sweden, 7th February 1961. AD-261 706.

J. Ortner, A. Egeland, and Hultqvist.

The great earth storms caused by the solar flares, which occurred during the period 10th-20th November, 1960, as observed at Kiruna Geophysical

Observatory, situated at the southern boundary of the auroral zone, are reported and discussed. Possibly physical connections between the various parameters recorded at Kiruna by means of a riometer, a VLF receiver; ionospheric sounder equipments, an oblique auroral reflection receiver, magnetometers and cosmic-ray telescopes are discussed. The observations made during this period are compared with the results obtained during other polar cap absorptions events of the recent years.

VLF EMISSIONS AND GEOMAGNETIC DISTURBANCES AT THE AURORAL ZONE.
II. CHORUS INCREASES AND GEOMAGNETIC PULSATIONS AT THE AURORAL ZONE

T. Ondoh
See Part V, Page 433.

THE GEOMAGNETIC STORM EFFECT ON POLAR CAP ABSORPTION
Phys. Abstr. 20946/1961; Ark. Geophys. (Sweden), V. 3, Paper 21,
Pgs 429-34, 1961.
J. Ortner, H. Leinbach, M. Sugiura

"Polar cap absorption" symposium paper.

MAGNETIC IMPULSES AND SUN-EARTH RELATIONS
Phys. Abstr. 13067/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-I,
21-4, January 1962.
I. Paghis

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.
I. Earth Storm (see Abstr. 9939 of 1962). Earlier work (Proceedings of the Symposium on Physical Processes in the Sun-Earth environment, Ottawa, 27-38 - July 1959), using the magnetic 3-hourly ap, index during a relatively quiet period in 1952, revealed periodicities of from one to four days in the earth's magnetic field variations. There was a close connection between these periodicities and the occurrence of magnetic impulses. The present paper examines the occurrence of magnetic impulses from 1949-59. The time interval between these impulses is not random, but shows marked periodicities, even when considered over the entire sunspot cycle. These results are supported by an investigation of the time interval between flares and SSC's during IGY.

THE INFLUENCE OF CONTINENTS AND OCEANS ON GEOMAGNETIC VARIATIONS
Phys. Abstr. 15276/1962; Geophys. J. (GB), Vol. 6, No. 4, 441-9,
June 1962.
W.D. Parkinson

During bays and similar magnetic variations the vectors representing changes in the geomagnetic field tend to lie on or close to a plane. The orientation of this plane varies from one observatory to another. At coastal observatories it almost invariably tilts upwards towards the nearest deep ocean.

SOME ELF (EXTREMELY LOW FREQUENCY) PHENOMENA

Phys Abstr. 12212/1960; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 4,
Pgs 383-6, July-August 1960.

E.T. Pierce

Properties of the electric and magnetic field in natural extremely low frequency phenomena are briefly discussed. The e.l.f. fluctuations in the electric field are then treated from two aspects; the electromagnetic changes associated with atmospherics and the electrostatic variations in atmospherics electricity. A final section attempts to integrate the general subject of e.l.f. effects of natural origin.

RISE TIMES VERSUS MAGNITUDES OF SUDDEN COMMENCEMENTS OF GEOMAGNETIC STORMS

Phys. Abstr. 19263/1962; J. geophys. Res. (USA), Vol. 67, No. 6,
2189-92, June 1962.

P.R. Pisharoty, B.J. Srivastava

A study of the rise times versus the magnitudes of the positive sudden commencements of 41 randomly selected geomagnetic storms recorded at Alibag ($\Phi = 9.5^\circ$, $\lambda = 143.6^\circ$, geomagnetic coordinates) for the period 1949-1960 is presented. The study shows rise times of 1 to 6 mins and shows that the rise-times have an inverse relationship with the magnitudes of the SC's - the rise-time being smaller as the magnitude is larger, and vice versa. The Chapman and Ferraro (1931, 1940) theory of the SC predicts rise-times of less than about 2 mins with an inverse relationship between rise-time and amplitude. On the other hand, numerical computations by Dessler and co-workers (1959, 1960) from a hydromagnetic model have shown this inverse relationship and have shown rise-times of the order of 1 to 6 mins, which appear to fit better with the data of the Alibag presented in this paper.

DIURNAL AND CYCLIC VARIATIONS OF THE INTENSITY OF NATURAL RADIO NOISE OF VERY LOW FREQUENCY

EE Abstr. 4777/1961; CR Acad. Sci. (France), V. 252, No. 9, Pgs 1365-7,
27th February 1961.

C. Renard

Statistical studies of recordings made at Kerguelen during 1959-60 revealed a diurnal variation of intensity of dawn chorus (with a maximum at 8 h 40 m L.M.T.) and a semi-diurnal variation of hiss (with maxima at 9 h and 21 h 40 m L.M.T.). Possible production mechanisms are discussed.

THE EFFECT OF THE OCEAN ON RAPID GEOMAGNETIC CHANGES

Phys. Abstr. 21099/1961; Geophys. J. (GB), V. 5, No. 1, Pgs 1-15, May 1961.

T. Rikitake

With the aid of two-dimensional experiments and mathematical theory, the electromagnetic induction in a conductor covered by a conducting sheet is studied. Applying the results to the effect of the ocean on rapid geomagnetic changes, it turns out that the previous estimate of the ocean effect based on the induction in a single sheet is an over-estimate. C.S. Cox's model (unpublished), by which he explained the anomaly of geomagnetic variations in Japan as the effect of the ocean at its margin, is also criticized. The writer is of the opinion, contrary to Cox, that the anomaly is likely to be caused by the induced electric currents at some depth in the earth's interior beneath Japan.

ON NOISE REGISTERED WITH RAPID EARTH-CURRENT FLUCTUATIONS

Phys. Abstr. 23578/1963; Izv. Akad. Nauk SSSR, Ser. geofiz., 1962, No. 7, 943-5. In Russian. English trans. in: Bull. Acad. Sci. USSR, geophys. Ser. (USA), No. 7, 601-2, July 1962, published October 1962). I.I. Rokityanskii.

One of the difficulties encountered in registering earth-current fluctuations having periods of the order of 1 sec and less is the high noise background. The article gives a general description of the noise at Alushta (in Russia) which is mainly due to electric welding in construction work, other local industrial disturbance and the small motors in the telegraph office. It is stated that industrial interference has a characteristic irregular appearance and cannot be confused with useful signal. The trolley-bus traffic only occasionally seriously interferes with the registration of earth-currents.

DISTRIBUTION OF RAPID PERIODIC MICROPULSATIONS AS A FUNCTION OF AMPLITUDE

Phys. Abstr. 2324/1964; Izv. Akad. Nauk SSSR, Ser. Geofiz. 1963, No. 4, 590-5. In Russian. English trans. in: Bull. Acad. Sci. USSR, Geophys. Ser. (USA), No. 4, Pgs 365-9, April 1964; publ. August 1963. I.I. Rokityanskii

The results of reading rapid periodic fluctuation (pc) amplitudes from a lengthy sensitive recording of earth currents studied for the purpose of obtaining a mathematical expression of the distribution of the number of pc cases as a function of amplitude. The expression obtained, a Poisson distribution, is used for determining the (mean or average) amplitude of rapid periodic micropulsations recorded on a device of relatively low sensitivity.

GEOMAGNETIC RAPID VARIATIONS DURING IGY AND IGC

Phys. Abstr. 13084/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II,

Pgs 47-55, January 1962.

A. Romaná, J.O. Cardus

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). Presents some of the results which were obtained with the monthly data sent of IAGA Com. 10 on Geomagnetic rapid variations for the period of IGY and IGC (July 1957 - December 1959). The phenomena reported are: (1) pulsations (pt) and bays, (2) storms, sudden commencements and sudden impulses, (3) solar flare effects and (4) pulsations from rapid-run magnetograms (pt and pc). Solar flare effects are not dealt with because the data reported are too incomplete and storm sudden commencements are not dealt with because the hour of occurrence of them has already been reported and no new feature, such as daily or seasonal variation could be derived from the existing material.

RESEARCH ON RELATIONSHIPS BETWEEN NATURAL ATMOSPHERIC RADIO PHENOMENA AND GEOMAGNETIC FIELD

Danish National Committee of U.R.S.I.; Contract AF 61(514)-1309.

J. Rybner, E. Ungstrup

See Section V, Page 442.

EFFECT OF ATOMIC TESTS ON RADIO NOISE

Phys. Abstr. 4817/1960; Nature (GB), V. 184, Pgs 538-9, 15th August 1959.

C.A. Samson

Two high-altitude atomic explosions over Johnston Island in the Pacific, shortly after midnight on 1st and 12th August 1958, appear to have had a rather pronounced effect on the radio noise recorded at Kekaha, Hawaii, about 700 miles N.W. of Johnston Island. In the hour following the blast, the noise decreased by as much as 32 dB at some frequencies at a time of day when it would normally be rising or holding steady. Recovery to normal levels apparently occurred in a matter of hours at 13 kc and 5 Mc but at 51, 160, 545 kc and 2.5 Mc a changed pattern was evident for several days, with level at night much below normal. Similar effects were observed in the case of second explosion. The length of time over which there was an apparent increase in the night-time absorption of noise suggests that high-altitude nuclear explosions may have a rather persistent effect on radio communications at certain frequencies.

MORPHOLOGICAL STUDIES ON SUDDEN COMMENCEMENTS OF MAGNETIC STORMS USING THE RAPID-RUN MAGNETOGRAMS DURING THE IGY

Phys. Abstr. 1489/1963; J. Geomagn. Geoelect (Japan), Vol. 14, No. 1, 1-15, 1962.

Y. Sano

Morphological studies on sudden commencements of magnetic storms are carried out using the data of rapid-run magnetograms during the IGY. The present paper contains two main parts; the first is an investigation of magnetic horizontal disturbance vectors of sudden commencements and the second is an analysis of corresponding partial equivalent current systems. Horizontal disturbance vector diagrams of about 30 sudden commencements at nine stations, which are distributed in a half region of the northern hemisphere, are investigated. In several cases, the corresponding possible equivalent current systems of DS fields are obtained and discussed by drawing them as consistently as possible with the horizontal disturbance vectors at every station concerned.

MICROPULSATIONS AND HYDROMAGNETIC WAVES IN THE EXOSPHERE

Phys. Abstr. 17196/1962; J. geophys. Res. (USA), Vol. 67, No. 5, Pgs 1751-61, May 1962.

F.L. Scarf

Recent evidence indicates that the steady state hydromagnetic wave spectrum in the lower exosphere is sharply cut off for frequencies above 1.5-3 c/s. It is argued that the spectrum has this form essentially everywhere below $R \approx 5R_e$ (geocentric) and that no model without a loss mechanism can reproduce the cut-off, because the ordinary and extraordinary circularly polarized waves are strongly coupled. Thermal damping is investigated by means of the collisionless Boltzmann equation; it is found that this effect may explain the observed cut-off if the proton temperature near $5R_e$ is of the order of 10^{20} K, with a density $N \approx 10^2 - 10^3 \text{ cm}^{-3}$. It is suggested that the above $5R_e$ the exosphere is not in thermal equilibrium, so that the long-range damping cannot occur.

VARIATIONS IN FREQUENCY OF MAGNETIC MICROPULSATIONS OF PERIODS BETWEEN 0.5 AND 3 SEC ASSOCIATED WITH VARIATIONS IN THE INTENSITY OF THE MEAN FIELD (PORT-AUX-FRANÇAIS STATION, KERGUELEN ISLANDS).

Phys. Abstr. 4825/1964; C.R. Acad. Sci. (France), Vol. 257, No. 4, Pgs 952-3, 22nd July 1963. In French.

R. Schlich

It was found that when the intensity of the main field increases, the period of micropulsations nearly always decreases and vice versa.

ON MICROPULSATIONS OF PERIODS BETWEEN 1.5 AND 6 SEC OBSERVED IN VERY HIGH LATITUDES (ADELIE LAND)

Phys. Abstr. 4826/1964; C.R. Acad. Sci. (France), Vol. 257, No. 5, Pgs 1128-30, 29th July 1963. In French.

R. Schlich

A note discussing some aspects of observations made during 1957-59. Topics include amplitude, frequency, morphology and seasonal and diurnal variations of frequency of occurrence.

GEOMAGNETIC AND GEOELECTRIC VARIATIONS

Phys. Abstr. 4216/1955; J. atmos. terrest. Phys. (GB), V. 6, No. 1, Pgs 33-45, January 1955.

J.G. Scholte, L. Veldkamp

The geomagnetic variations and their relation to earth-currents have been investigated, especially the pulsations with periods of 10 to 10^2 sec. A world-wide survey of a few examples of pulsations indicates that the source of the phenomenon may be the ionospheric vibrations caused by a disturbance of the ionization equilibrium. The connection with the electric field induced in the earth was studied by measuring the ratio of amplitudes of the N-S component H_N of the magnetic field and the E-W component E_W of the electric field; the phase-difference between these quantities has been determined for a great number of pulsations. As it was doubted if the theory of plane waves reflected by a plane earth was valid in this case, the earth's radius being small compared with the wavelength of these vibrations, the reflection by a sphere has been investigated theoretically. The results are very similar to those of the plane-earth theory, with the exception of the ratio between horizontal and vertical magnetic components. The values of E/H and of the phase-difference between electric and magnetic variations depend on the structure of the earth; it is therefore possible to derive some knowledge of the upper layers from the measurements. In this way some information with respect to the distribution of the conductivity in the ground at the observatory Witteveen has been obtained.

A STUDY OF THE DISTRIBUTION OF GEOMAGNETIC MICROPULSATIONS

Canad., Pacific Naval Lab. rept. No. 15, 1959.

J.A. Shand, C.S. Wright, H.J. Duffus

No abstract.

A NOTE ON GEOMAGNETIC AND IONOSPHERIC RECORDS

Phys. Abstr. 21642/1962; Canad. J. Phys. Vol. 40, No. 8, Pgs 1046-8,
August 1962.

J.A. Shand

Simultaneous recordings of ionospheric soundings and of the Z component of geomagnetic micropulsations from two separated stations were compared. The study showed that there is a relationship between the degree of magnetic activity and the ionic concentration in the upper and lower layers of the ionosphere. The records are compared in some detail, results being given for both normal and disturbed conditions.

SOLAR ACTIVITY, WORLD DAYS, AND COMMUNICATIONS

Ciencia, 16, Pgs 286-289, 1956.

A.H. Shapley

No abstract

A NEW TEST OF THE HYPOTHESIS OF THE NATURE OF THE MAGNETIC DECLINATION

V.V. Shuleikin, N.I. Sigachev

See Section III, Page 258.

DIRECTIONAL PROPERTIES AND PHASE RELATIONS OF THE MAGNETOTELLURIC FIELDS AT AUSTIN, TEXAS.

J. geophys. Res. (USA), V. 66, No. 3, Pgs 879-888, March 1961.

H.W. Smith, L.D. Provazek, F.X. Bostick, Jr.

No abstract

THE DISTANT GEOMAGNETIC FIELD. I. INFINITESIMAL HYDROMAGNETIC WAVES

Phys. Abstr. 17213/1962; J. geophys. Res. (USA), Vol. 67, No. 4,
Pgs 1191-1207, April 1962.

C.P. Sonett, A.R. Sims, I.J. Abrams

The presence of magneto-acoustic (oblique), and transverse hydro-magnetic waves is demonstrated at geocentric distances of 3.7 to 7 earth radii on the sunlit hemisphere. The frequencies present extend to 13 rad/sec, which is the upper cut-off for the passband of the magnetometer used in this experiment. The mixed mode is identified with the ordinary transverse (Alfven) wave, and the pure transverse mode with the extraordinary wave. The power spectra display discrete lines from which coupling of modes can be deduced. Typical wave energy densities vary from 10^{-13} to 10^{-12} erg/cm³ over 1 c/s. On the assumption that the available sample typifies the magnetospheric volume to 7 Re the hydro-magnetic radiation energy appears to be of the order of 10^{18} ergs over

1 c/s. At a mean hydromagnetic velocity of 3×10^7 cm/sec, and assuming that all this radiation was entrant upon the ionosphere, the energy input would be some 10^{-5} erg/cm² sec between 0 and 1 c/s. In addition to many discrete lines in the spectra, there is some continuum radiation. Finite line-width provides a measure of broadening possibly due to positive ion Landau dumping. The spectra suggest excitation of the far magnetosphere.

A NOTE ON THE DS VARIATION OF GEOMAGNETIC STORMS: A CRITICAL EXAMINATION OF METHOD OF ANALYSIS

Phys. Abstr. 1490/1963; J. Geomag. Geoelect. (Japan), Vol. 14, No. 1, Pgs 16-21, 1962.

M. Sugiura

The determination of DS variation of magnetic storms as a function of storm time is critically examined. The regular changes in the phase angles of harmonics for DS, found by Yokouchi (Memoirs of Kakioka Magnetic Observatory (Japan), Vol. 8, No. 2, 13, (1958)) are attributed to irregular features that are not adequately averaged out. This apparently paradoxical circumstance is explained with an example.

SYMPOSIUM ON PULSATIONS AND RAPID VARIATIONS IN GEOMAGNETISM AND EARTH CURRENTS

J. Geomag. Geoelect. (Japan), V. 10, Pgs 135-225, 1959. Test of papers read at a symposium in Tokyo, 3rd-4th April 1959.

No abstract.

PRELIMINARY RESULTS OF THE CORRELATION OF SOLAR FLARES AND SUDDEN ENHANCEMENT OF ATMOSPHERICS (SEA)

Phys. Abstr. 9077/1962; Atti. Convegno Annu. Assoc. Geofis., Italy, Pgs 27-31, November 1960.

G. Tagliaferri, G. Righini

The correlation is investigated for the year 1959. It is found that not all flares produce an SEA effect and vice versa. A possible explanation in terms of the extension of the X-ray spectrum emitted from the flares is discussed.

GEOMAGNETIC PULSATIONS AND THE EARTH'S EXOSPHERE

Phys. Abstr. 1485/1963; Rep. Ionosphere Space Res. Japan, Vol. 15, No. 3-4, Pgs 293-312, December 1961.

T. Tamao

A short summary of observational results of geomagnetic pulsations is first given. Taking into account recent knowledge of physical characteristics for the exosphere and the qualitative discussion on propagation of hydromagnetic waves in this medium, it is pointed out that the primary source

of daytime pulsations is attributed to large amplitude disturbances in the outermost exosphere found by Sonett et al. in distant magnetic surveys. Since these disturbances may have considerable band width of spectrum ($T \approx 1 \text{ sec} - 3 \times 10^2 \text{ sec}$) the latitude distribution of intensity and period pulsations may account for the complex dispersive character of the propagation of hydromagnetic waves in the non-uniform, anisotropic exosphere. The rate of total energy dissipation of daytime pulsations confined in the magnetic cavity, $2 \times 10^{19} \text{ erg/sec}$, is supplied for the inflow of these disturbances with an energy density of 10^{-8} erg/cm^3 and a velocity of 10^7 cm/sec through the surface of the cavity. Interaction between extra-terrestrial charged particles and the earth's atmosphere was studied semi-quantitatively from the microscopic and the macroscopic standpoint, in relation to the possibility of excitation of night-time pulsations. It is suggested that pt's are caused by hydromagnetic interaction between the current and the geomagnetic field in the outer exosphere, the former forming part of the three-dimensional solenoidal current-system responsible for the bays and flowing radially in the region concentrated within the geomagnetic equatorial plane. The resulting emission of energy of hydromagnetic waves is sufficient to explain the rate of total energy dissipation of pt's, $5 \times 10^{18} \text{ erg/sec}$, if the intensity of the ionospheric current in the auroral belt corresponding to the negative bay is of the order of $10^{-4} \text{ e.m.u./cm}$.

HYDROMAGNETIC EMISSIONS, X-RAY BURSTS AND ELECTRON BUNCHES. I. EXPERIMENTAL RESULTS.

Phys. Abstr. 24061/1962; J. geophys. Res. (USA), Vol. 67, No. 9, Pgs 3317-33, August 1962.

L.R. Tepley, R.C. Wentworth

Recent experimental results are presented concerning the occurrence, structure and frequency-latitude dependence of hydromagnetic emissions (HM) (regular oscillatory micropulsations in the frequency range 0.4-7 c/s). Results are also presented for the occurrence of noise bursts (irregular micropulsations in the same frequency range). Evidence is considered suggesting that both HM emissions and noise bursts are generated by related mechanisms. The experimental results are summarized as follows: (1) Occurrence. First, short HM emission bursts sometimes occur about 1 min. after the sudden commencement of magnetic storms. Second, simultaneous occurrence with X-ray bursts and increased riometer absorption was noted. (2) Structure. Hydromagnetic emissions tend to occur in distinct frequency bands. The bands are usually characterized by a fine-structure consisting of a superposition of repetitive wave trains of a few minutes' duration and rapidly increasing frequency. (3) Frequency-latitude dependence. An inverse relationship was found between the highest observed HM emission frequency and the geomagnetic latitude at which the signal is observed.

TERRESTRIAL ELECTRIC FIELD VARIATIONS

AD 70 673; English translation of Dokl. Akad. Nauk. SSSR (USSR), V. 87, No. 4, Pgs 547-550, 1952, by E.R. Hope, DRB, Canada.

A.N. Tikhnov, N.V. Lipskaya

The present paper deals with the study of the relationship between the diurnal variations of the natural electromagnetic fields of the earth; it is a development and continuation of reference (1).

SHORT PERIOD FLUCTUATIONS IN THE ELECTROMAGNETIC FIELD OF THE EARTH

Phys. Abstr. 7903/1954; English translation of Dokl. Akad. Nauk. SSSR. (USSR), V. 91, No. 2, Pgs 241-4, 1953.

V.A. Troitskaya

A particular type of fluctuation of the electric field unaccompanied by changes in the magnetic field has been studied. Short trains of oscillations occur with a maximum frequency at about 19 hr universal time. It is suggested that these are caused by particles emitted by the sun focused by the earth's magnetic field.

TWO OSCILLATORY MODES OF THE TERRESTRIAL MAGNETIC FIELD AND THEIR DIURNAL GMT CYCLE

AD 70693; English translation of Dokl. Akad. Nauk SSSR (USSR), V. 93, No. 2, Pgs 261-264, 1953.

V.A. Troitskaya

An analysis of Russian observatory records has shown the existence of rapid variations in both the electrostatic and magnetic field. The first type is a continuous oscillation between about 0 and 12 hr. Universal time with a maximum amplitude at 2-4 hr. and a period of 10 to 40 sec. The second type is a train of pulses with a period of 40-63 and occurs mainly between 12 and 24 hr. with a maximum at about 18-19 hr.

EARTH CURRENTS

English translation of Priroda, V. 5, Pgs 81-85, 1955, by E.R. Hope, DRB, Canada.

V.A. Troitskaya

No abstract.

CHARACTERISTIC INTERVALS OF OSCILLATIONS WITH DECREMENT PERIOD OF 10-1 SEC: IN THE ELECTROMAGNETIC FIELD OF THE EARTH, AND THEIR RELATIONSHIP TO PHENOMENA IN THE UPPER ATMOSPHERE

Dokl. Akad. Nauk SSSR (USSR), V. 128, Pgs 917-920, 1959.

V.A. Troitskaya, M.V. Mel'nikova

The most characteristic elements of the ultra-short period oscillations are those with periods of 2-4 sec, which can last for several tens of minutes.

PULSATION OF THE EARTH'S ELECTROMAGNETIC FIELD WITH PERIODS OF 1 TO 15 SECONDS AND THEIR CONNECTION WITH PHENOMENA IN THE HIGH ATMOSPHERE.

Phys. Abstr. 15346/1961; J. geophys. Res. (USA), V. 66, No. 1, Pgs 5-18, January 1961.

V.A. Troitskaya

The first results of investigations of earth's current pulsations in the range of periods of 1 to 15 seconds are presented. Data of earth current stations located in the Arctic (5 stations), in the Antarctic (2 stations), and in middle latitudes of the USSR (10 stations), as well as data of high-sensitivity installations for magnetic-field (Z) registration at 3 stations, were used. Several characteristic types of pulsations were defined in this range of periods, and their correlation with phenomena in the high atmosphere was studied, among them: (a) short irregular pulsations ($T \sim 1-15$ sec) composing the microstructure of several forms of macroscopic disturbances of the magnetic field and showing a close correlation with aurora; and (b) pulsations of the "pearl" type ($T \sim 1-4$ sec), distinguished by their regular form and showing a correlation with cosmic-ray intensity bursts in the stratosphere. The main features of magnetic-storm microstructure, as well as microstructure of SSC, are given. The importance of the occurrence during magnetic storms of "pulsations with diminishing periods" and correlation studies with high atmosphere phenomena is stressed. The dependence on local time of the fine structure of SSC is described. Contrary to some theoretical expectations the time difference between the first movements due to SSC was found to be very small; the movements may even have been simultaneous. For the Argus III explosion the onset time of oscillation was found to be within 1 sec.

FINE STRUCTURE OF MAGNETIC STORMS IN RESPECT OF MICROPULSATIONS ($T < 20$ SEC)

Phys. Abstr. 17219/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II, Pgs 63-70, January 1962.

V.A. Troitskaya, L.A. Alperovich, M.V. Melnikova, G.A. Bulatova

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). Summarises the results of the sub-division of 30 magnetic storms observed in the Arctic,

Antarctic, and in the middle latitudes of the Northern hemisphere, into the classes of continuous pulsations, pulsations irregular in form with different degrees of superposition of pulsations of small periods, bursts and solar whistles.

THE CONNECTION BETWEEN SHORT PERIOD OSCILLATIONS OF THE EARTH'S ELECTRO-MAGNETIC FIELD AND AURORAE

Phys. Abstr. 19235/1962; Izv. Akad. Nauk SSR, Ser. geofiz. 1962, No. 2, Pgs 262-70. In Russian. English trans. in: Bull. Acad. Sci. USSR, Geophys. Ser. (USA), No. 2, Pgs 180-5, (February 1962, published May 1962). V.A. Troitskaya, L.V. Al, Perovich, N.V. Georgio

Short period oscillations (SPO) of the earth's electromagnetic field associated with aurorae were investigated. It is shown that the correlation with the intensity of aurorae is greatest for certain types of SPO with a period of a few seconds.

PART B, SOLAR GEOPHYSICAL DATA

CRPL-F 206, Part B. Published Monthly
U.S. Department of Commerce, National Bureau of Standards, C.R.P.L.,
Boulder, Colorado.

No abstract

THE CORRELATION BETWEEN EARTH CURRENTS AT GODHAVN AND MAGNETIC DISTURBANCES
Technical Note No. 1, Contract AF 61(514)-1309, 13th July 1958. Ionosphere
Laboratory, Royal Technical University of Denmark, Report No. 5.
Eigel Ungstrum, Arne R. Pedersen

No abstract

THE CORRELATION BETWEEN EARTH CURRENTS AT GODHAVN AND MAGNETIC DISTURBANCES
Technical Note No. 1, Contract AF 61(052)-298, 1st June 1962; Ionosphere
Laboratory, Royal Technical University of Denmark, Report No. 10.
Eigel Ungstrum, Bent Møller Petersen

No abstract

GEOPHYSICAL EFFECTS ASSOCIATED WITH THE HIGH-ALTITUDE NUCLEAR EXPLOSION
Phys. Abstr. 16412/1960; J. Geomagn. Geoelect (Japan), V. 11, No. 2,
Pgs 39-41, 1959.
H. Uyeda and Others

This is a summarized report on observations and investigations made

in Japan up to presenttime concerning the geophysical effects associated with the high-altitude nuclear explosions carried out over Johnston Island on 1st and 12th August 1958. The effects considered are the geomagnetic disturbances, v.l.f. atmospherics, the field strength of the l.f. waves, the ionosphere, and acoustic and seismic waves. The result of investigations of the associated phenomena indicates the mechanism of generation of each phenomenon to be very complicated and inter-associated. However, in view of the time that elapsed after the blast, there seem to exist three distinct periods. The typical examples are two stages of the magnetic disturbance (s.s.c. and the main phase), and the ionospheric disturbance which appeared several hours later and lasted more than ten hours.

RELATIONSHIP BETWEEN RADIO-PROPAGATION DISTURBANCE, GEOMAGNETIC ACTIVITY AND SOLAR NOISE

EE Abstr. 5342/1954; J. atmos. terrest. Phys. (GB), V. 3, Pgs 194-9, May 1953.

D. Van Sabben

For the years 1948-49-50, ionospheric disturbance figures of transatlantic radio communication (circuit New York-Amsterdam) were determined and compared with magnetic character figures. The general correspondence is clearly shown by a diagram, containing running graphs (with 3 hr steps) of both quantities. The maximum of radio disturbance showed a mean time lag of 7 hrs behind the maximum of magnetic disturbance. A second investigation concerned the flux of solar radio noise in relation to magnetic storms. There appeared to be a marked increase of flux on at least one of the 3 frequencies - 80, 175 and 200 Mc at some time during the 5 days preceding the storm, except when the storm was of the recurrence type.

MORPHOLOGY OF MAGNETIC STORMS

Phys. Abstr. 13071/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-I, Pgs 61-9, January 1962.

E.H. Vestine

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.
I. Earth Storm (see Abstr. 9939 of 1962). The geomagnetic field frequently has superposed upon it magnetic fluctuations which undergo world-wide changes in pattern and intensity with time. The morphology of storms is concerned with these transitions in form of the field with time. The geomagnetic-field patterns of disturbance, almost always present in some degree, were measured until recently only at the earth's surface, but there now appear fleeting indications of the form of the disturbance field and its associated charged particles in nearby space from observations by various space probes

and earth satellites. The present article is intended to provide a summary of the better known and well established features of the morphology of storms. A magnetic storm often has a sudden beginning, known as a sudden commencement, which has a world-wide field pattern related to the position of the sun. The onset is sudden to about one minute or less the world over, and the field changes tend to involve an increase in the northward horizontal intensity H of some tens of gammas above normal. The onset is usually greatest in polar regions. There is often magnification of the initial increase by a factor two or so on the sunward side of the earth along the magnetic equator; In low latitudes, the initial change in H , usually positive, may be maintained and even increased over an hour or so to form an initial phase of the storm. The value of H then decreases and reaches a minimum (below the normal value) 15 to 20 hours after the sudden commencement. The value of H then returns to normal over a period of some days. The polar disturbance field during bays tends to rotate westward with time at a rate of order 5° - 10° of longitude per hour at, or just north of, the auroral zone. Outside the zones current-patterns appear to drift eastward. There is also evidence of a slow drift to the east of the eastward-directed electrojet at the auroral zone.

MAGNETIC EFFECT (OF EARTH STORMS)

Phys. Abstr. 3518/1963; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II, Pgs 616-618, January 1962.
E.H. Vestine

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). A summary is given of current ideas concerning the explanation of the magnetic effects of earth storms, considering separately the reverse impulse, sudden commencement, initial and main phases. Theories of the polar electrojets, polar noise, and of the micropulsations are also mentioned.

STRUCTURE OF THE EARTH'S NATURAL ELECTROMAGNETIC FIELD IN THE FREQUENCY RANGE OF 0.5 - 100 C/S

Phys. Abstr. 9121/1963; Izv. Akad. Nauk SSR, Ser. Geofiz., 1962, No. 10, Pgs 1368-74. In Russian. English trans in: Bull, Acad. Sci. USSR, geophys. Ser (USA), No. 10, Pgs 852-5; October 1962, published January 1963.

N.P. Vladimirov, N.G. Kleimenova

Investigations were conducted by the Institute of Physics of the Earth under various geological and geophysical conditions, from 1959 - 1961.

THE FREQUENCY DEPENDENCE OF SOLAR-FLARE EFFECTS IN THE LONGEST-WAVE RANGE

EE Abstr. 1849/1960; Arch. elekt. Ubertragung, (Germany), V. 13, No. 10, Pgs 443-8, October 1959.
H. Volland

Measurements of the field strength of signals from the transmitter GBR (16 kc) GBZ (19.6 kc) and GIY 20 (51.95 kc) at the Heinrich Hertz Institute, Berlin - Charlottenburg, show positive and also negative field-strength anomalies which are dependent on frequency, time of day and season of year. These anomalies are explained as being due to interference effects between the ground wave and the space wave reflected from the ionosphere, it being assumed that the height of the reflecting layer decreases during a solar flare. The mean apparent reflection-layer height for 16 kc signals is from 69 to 76 km, according to the time of year. During the existence of a solar flare it may decrease to 12 km. A similar explanation can be given of the change of the frequency spectra of atmospherics during a solar flare.

ON THE RELATION BETWEEN TELLURIC CURRENTS AND THE EARTH'S MAGNETIC FIELD
Geophysics (USA), V. 19, Pgs 281-289, April 1954.

J.R. Wait

The validity of Cagniard's analysis of the behaviour of telluric earth currents is questioned in view of the fact that the harmonic components of the electric field and the magnetic field tangential to the ground are only proportional to one another if the fields are sufficiently slowly varying over the surface of the ground. His result is extended to include the effects of a layered ground with both conductivity and susceptibility variations. Finally the corresponding transient problem is solved for a two-layer horizontally stratified earth.

THEORY OF MAGNETO-TELLURIC FIELDS

Phys. Abstr. 1477/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 5, Pgs 509-41, September-October 1962.

J.R. Wait

This paper is a review of the present state of knowledge of magneto-telluric fields. The subject has to do with the combined analyses of the geomagnetic and the telluric (earth-current) fields on the surface of the earth. Usually, the objective of such investigations is to obtain information about the earth's crustal layers. However, for a sensible use of the method it is desirable to understand something about the source of the fields. In this paper, the various suggestions for the source mechanism are discussed. Then a fairly detailed review of previous work on the theory of the magneto-telluric interpretation is given. Included are a number of three-layer interpretation curves. The influence of earth curvature in magneto-telluric theory is treated in a mathematical appendix which is, in itself, a self-contained derivation of the various formulae.

COMMENTS ON PAPER BY W.D. WESTFALL "PREDICTION OF VLF DIURNAL PHASE CHANGES AND SOLAR FLARE EFFECT"

J.R. Wait,

See Section I, Page 116.

GEOMAGNETIC ACTIVITY FOLLOWING LARGE SOLAR FLARES

J. Atmospheric. Terrest. Phys. 14, Pgs 287-295, June 1959.

C.W. Warwick, R.T. Hansen

No abstract

HYDROMAGNETIC EMISSIONS, X-RAY BURSTS AND ELECTRON BUNCHES.

II. THEORETICAL INTERPRETATION

Phys. Abstr. 24062/1962; J. geophys. Res. (USA), Vol. 67, No. 9, 3335-43, August 1962.

R.C. Wentworth, L.R. Tepley

The existence of bunches of monoenergetic electrons oscillations back and forth along field lines in the magnetosphere has been suggested by a number of workers to explain various geophysical phenomena. The simultaneous occurrence of X-Ray and hydro-magnetic emission bursts (regular oscillatory micropulsations at frequencies in the range 1-2 c/s) immediately after sudden commencements and during magnetically disturbed periods, as discussed in Part I (see Abstr. 24061 of 1962), raises the possibility that HM emissions could be generated by such electron bunches. A model is presented that considers certain aspects of the motion of geomagnetically trapped electrons relevant to the production of HM emissions by electron bunches. A new result is the calculation of electron motion in a dipole field confined to the interior of a sphere (as a first approximation to the solar wind cavity). The model calculations are applied to experimental results discussed in Part I, and it is shown that the electrons responsible for the X-ray burst after the sudden commencement of 27th June 1960 could have produced the HM emission burst at that time, and that the maximum observed HM emission frequency as a function of geomagnetic latitude is consistent with the calculated value. Hydromagnetic emissions during magnetically quiet times are characterized by a fine structure containing over-lapping bands of rapidly increasing frequency. This is tentatively interpreted as indicating rapid acceleration of electron bunches; hence, if the model is correct, HM emissions will provide a powerful tool for studying the acceleration mechanism for electrons in the magnetosphere.

PREDICTION OF VLF DIURNAL PHASE CHANGES AND SOLAR FLARE EFFECTS

W.D. Westfall

See Section I, Page 125.

OSCILLATIONS OF THE EARTH'S OUTER ATMOSPHERE AND MICROPULSATIONS
Phys. Abstr. 15261/1962; Geophys. J. (GB), Vol. 6, No. 3, Pgs 360-
76, April 1962.

K.O. Westphal, J.A. Jacobs

In recent years many workers have considered hydromagnetic oscillations of the Earth's outer atmosphere as a possible cause of geomagnetic micropulsations. Almost all of them use the equations derived by Dungey (1954) for calculating the eigenperiods of the system. Because of the complexity of the equations for coupling terms, which in spherical polar co-ordinates contain $\partial/\partial\phi$, are usually neglected. For this reason the equations of small hydro-magnetic oscillations are here derived in cylindrical co-ordinates with the main magnetic field lying in the plane perpendicular to the axis of the cylinder. Since the structure of the equations in this system is somewhat simpler than in spherical polar co-ordinates, it is possible to obtain the eigenperiods of toroidal oscillations as a function of co-latitude without making any approximations. Using an electronic computer it is possible to extend the calculations to the case of a non-uniform plasma density distribution, as used by Dessler (Abstr. 6527 of 1958) in his studies on the geomagnetic field. In the past most workers have assumed the Earth's field to be a geocentric dipole. As a result of recent studies, however, it appears that the geomagnetic field does not extend as far into outer space as was assumed but that to a first approximation it is confined to a cavity (Dungey 1954, Parker (Abstr. 7637 of 1958)). For this reason the equation toroidal oscillations is applied to a compressed dipole field. Assuming both a constant and a variable plasma density distribution the eigenperiods of the deformed magnetic lines of force are obtained.

CANADIAN NATIONAL REPORT ON GEOMAGNETISM

Dominion Observatory, rept. 25th July-6th August 1960.

K. Whitham

No abstract

AUDIO-FREQUENCY FLUCTUATIONS OF THE GEOMAGNETIC FIELD

U.S. Naval Ordnance Lab., White Oak, Maryland, NAVORD Rept. No. 4009,
102 p., illus., 1957.

J.B. Wilcox, E. Maple

Measurements of the spectrum of the naturally occurring fluctuations of magnetic field have been made at three stations in North America covering a latitude range of 41° . The audio-frequency range from 40 to 16,000 cps was covered in ten octave frequency bands. About three months of data, which are chiefly quasi-peak noise levels together with some measurements which approximate average-meter readings, were taken over a period of about a year (1951-1952).

PROVISIONAL GEOMAGNETIC FLUCTUATION SPECTRA

A graph compiled from data reported in NAVORD rept. No. 4009.
J.B. Wilcox, E. Maple

No abstract

AUDIO-FREQUENCY FLUCTUATIONS IN THE GEOMAGNETIC FIELD

J. geophys. Res. (USA), V. 65, No. 10, Pgs 3261-71, October 1960.
J.B. Wilcox, E. Maple

Audio-frequency geomagnetic fluctuation spectra are reported for three North-American stations covering a latitude range of 41° . Recording stations were located at Panama City, Florida; White Oak, Maryland; and Point Barrow, Alaska. Fluctuation intensities throughout the frequency range 70 to 16,000 cps were observed to decrease with increasing latitude. Between 100 and 1000 cps, fluctuation amplitudes were inversely proportional to about the $3/2$ power of frequency, the spectral slopes becoming somewhat steeper with increasing latitude. Between 1500 and 8000 cps, amplitudes decreased more rapidly with latitude than did those at other frequencies, and a spectral minimum was evident in this frequency range at Point Barrow. The vertical fluctuation component was smaller and decreased more rapidly with latitude than did the horizontal components. It is concluded that thunderstorm activity is the major source of the fluctuations throughout the audio-frequency range, with the magnetic atmospheric being generated chiefly in the lower latitudes and propagated poleward. The relationship of the observed fluctuations to thunderstorm distribution is discussed. There is considerable agreement with the results of others, although a few discrepancies are apparent.

CORRELATION BETWEEN SPORADIC E IONIZATION AND THE STRENGTH OF THE HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FIELD

Phys. Abstr. 21678/1966; Austral. J. Phys., Vol. 15, No. 2, Pgs 235-41; June 1962.
J.R. Wilkie, R.W.E. McNicol

By analysis of geomagnetic and ionospheric data recorded at Brisbane it was found that the horizontal component of the earth's magnetic field is decreased in strength by a few gammas during the appearance on ionograms of short-duration echoes, normally interpreted as coming from isolated patches of E_s ionization.

AUDIO-FREQUENCY MAGNETIC FLUCTUATIONS

Nature (GB), V. 161, No. 4101, 5th June 1948.
H.F. Willis

Measurements of the horizontal magnetic field from 5 to 1000 c/s at a site remote from man-made noise show a decrease with frequency roughly inversely as the power $3/2$. This noise showed no directionality in the horizontal plane and its source is not defined.

GEOMAGNETIC DISTURBANCE AND VELOCITY OF SLOW-DRIFT SOLAR RADIO BURSTS
Letter; Nature 184, Supp. 19, 1471-1472, November 1959.
M.B. Wood, C.S. Warwick

No abstract

LONG PERIOD FLUCTUATIONS OF THE GEOMAGNETIC FIELD
J. Roy. Naval Sci. Serv., V. 15, No. 4, July 1960.
C.S. Wright

No abstract

SOME CHARACTERS OF GEOMAGNETIC PULSATION PT AND ACCOMPANIED OSCILLATION
SPT
J. Geomagn. Geoelect. (Japan), V. X, No. 3, 1959.
K. Yanagihara

Many authors approved that geomagnetic pulsations are roughly classified into two or three groups. The Committee on Rapid Magnetic Variation and Earth-Current IAGA, adopted the symbol pt, pc and pg as these groups. It is difficult to strictly define a group except pg which means giant pulsation, but the group pt is considered to be the same as the night pulsations of G. Angenheister, Scholte and Veldkamp, and K. Yanagihara. In this paper some characters of pt are considered especially with respect to the associated shorter period oscillation spt, here named.

GEOMAGNETIC MICROPULSATIONS WITH PERIODS FROM 0.03 TO 10 SECONDS IN THE
AURORAL ZONES WITH SPECIAL REFERENCE TO CONJUGATE-POINT STUDIES
J. geophys. Res. (USA), Vol. 68, No. 11, 3383-97, 1st June 1963:
Phys. Abstr. 25957/1963.
K. Yanagihara

Conspicuous micropulsations in the auroral zones with periods from 0.03 to 10 seconds were studied using data obtained by the Pacific Naval Laboratory and Stanford University during January 1961. For periods less than 0.3 second bursts of oscillations frequently occurred superimposed on the background level of e.l.f. noise. These bursts are considered to be of extra-atmospheric origin because of their conjugate relationships. For periods between 0.3 and 10 seconds four typical classes are defined: (1) Burstlike micropulsations, with quite a wide range of frequencies, which appear at the onset of a polar storm or bay (noise burst). (2) Pearl, beating-type micropulsations, occurring intermittently so that they form separate bunches (PP). (3) Continuous micropulsations, typically found in the forenoon, with periods from 0.3 to 3 seconds (CPsp). (4) Continuous micropulsations, typically found in the afternoon, with periods from 3 to

10 seconds (CP1p). Not every polar storm or bay is accompanied by noise bursts. Noise bursts are found only at the onset of polar storms or bays occurring around or before local midnight. Separate bunches of pearl, beating-type micropulsations are attributed to a bouncing agent whose bouncing period of a few minutes can be determined from the time lag of their occurrences in conjugate areas. If the agent repeatedly excites micropulsations, they are continuous, although sometimes a correlation analysis between conjugate points indicates a bouncing period similar to that of PP. Possible physical mechanisms are suggested for these four classes of micropulsations.

OBSERVED RELATIONS BETWEEN THE CHANGES IN GEOMAGNETISM AND TELLURIC CURRENTS

Phys. Abstr. 7000/1963; Publ. Inst. Roy. Meteorol. Belgique B, No. 35, 42 pp. (1962). In English and French.
I. Yokoyama

A brief description of a study made at Dourbes in Belgium. It was found that variations in telluric potential have a predominant direction (6 degrees east of north at Dourbes) in contrast to geomagnetic variations which do not show directionality. The anomalous behaviour of short period ΔZ variations is also discussed and is suggested to be due to the anisotropy of earth-conductivity.

PART V

PART V

ATMOSPHERICS, WHISTLERS, LIGHTNING

LOW FREQUENCY NOISE DISTURBANCE

Proc. Amer. Acad. Arts Sci., V. 79, Pg 266, 1951.

J. Aarons

No abstract

AUDIO FREQUENCY ATMOSPHERICS 10-900 CYCLES PER SECOND

Paper presented at IRE-URSI Symposium, Washington, D.C., 30th April, 1st - 3rd May 1956.

J. Aarons

The audio frequency electromagnetic spectrum in the range 10-900 cps was surveyed over a two-month period, Summer 1955. A loop and vertical antenna were alternately switched to a narrow band analyzer (2 to 6 cps). The site chosen, Mescalero, New Mexico, was relatively free of man-made interference but local storms were recorded.

Results indicate the energy in the band is centered in the region 40-120 cps. Heavy attenuation of signals in the region 450-900 cps takes place during the day. Sunset raises the signal level of this high frequency portion of the spectrum to that of the lower frequency range. Large numbers of pulses are also seen during the night. The peak intensity level at all frequencies occurs around local midnight. Local storms have a spectrum similar to daytime levels.

The data indicates that the night-time levels at all frequencies come from great distances. The daytime energy is concentrated in the 40-120 cycle band and this portion of the band appears to come from distant atmospherics but the 450-900 cycle energy is relatively local in origin.

During one period of several hours a large increase of narrow band energy was seen at 33 cycles per second. The possibilities of this being radiation at the gyro frequency of the sodium ion is discussed.

SUDDEN ABSORPTION OF ATMOSPHERICS DUE TO INCREASE IN COSMIC RAY INTENSITY.

Phys. Abstr. 1811/1957; Nature (GB), V. 178, Pgs 277-8, 4th August 1956.

J. Aarons, W.R. Barron

Atmospheric noise studies on 49 kc at Fourth Cliff, Mass., indicated a sudden drop in signal level some 10 mins after the solar flare of 23rd February 1956 (2244 L.T.) which is considered to have been produced by the cosmic-ray increase (noted a few minutes later) rather than any ultra-violet effect.

LOW FREQUENCY ELECTROMAGNETIC RADIATION 10-900 CYCLES PER SECOND
J. geophys. Res. (USA), V. 61, No. 4, December 1956.
J. Aarons

During the period of 10th July - 15th September 1955, detection of electromagnetic signals in the frequency range 10 to 900 cycles per second was undertaken. Loop and a vertical antenna were used in a site remote from man-made interference. The spectrum was analyzed with a narrow bandwidth (2 to 6 cycles per second) amplifier. Indicated diurnal patterns show a maximum around local midnight. The peak in the band lies in the region 40 to 200 cycles per second. During one period of several hours, a large increase in narrow band energy was near 33 cycles per second. The possibilities of this being radiation at the gyrofrequency of the sodium ion is discussed.

ON VLF EMISSIONS IN THE EXOSPHERE

EE Abstr. 7750/1963; IRE Trans Antennas and Propagation (USA), Vol. AP-10, No. 6, 785-7, November 1962.
S. Adachi, Y. Mushiake

A brief theoretical analysis of the gain of the selective travelling-wave amplification mechanism postulated by Gallet and Helliwell in order to explain the phenomena of vlf emission in the exosphere. Numerical examples of the gain are given.

STRUCTURE OF ATMOSPHERIC RADIO NOISE

Phys. Abstr. 3470/1963; J. sci. industr. Res. (India), Vol. 21D, No. 7, 203-20, July 1962.
S.V.C. Aiya

The problem is discussed with special reference to its utility for improving the existing noise data. Available information is examined. The results of lightning discharge investigations and the characteristics of the different modes of propagation analysed and utilized to deduce theoretically the structure of the noise. The actual structure as experimentally realized on land masses lying below 23° N is described and discussed. Criteria are developed for studies of both short-term and long-term amplitude and time characteristics of the noise and for the manner in which numerical data of the observed characteristics should be provided. The need for improving the existing thunderstorm data and the manner in which it could be realized are discussed. Conclusions of general interest which emerge from the analysis are: (a) the distribution of any physical parameter associated with a lightning flash is log-normal; and (b) for all the effects arising directly from the same physical parameter, the standard deviation is also the same.

A STUDY OF THE AUDIO-FREQUENCY PHENOMENON KNOWN AS "DAWN CHORUS"

G. McK.Allcock

See Section IV, page 278.

SOLAR ACTIVITY AND WHISTLER DISPERSION

G. McK.Allcock

See Section IV, page 278.

GEOMAGNETIC ACTIVITY AND THE RECEPTION OF WHISTLERS IN POLAR REGIONS

G. McK.Allcock

See Section IV, page 278.

PROPAGATION OF WHISTLERS TO POLAR LATITUDES

Nature, Vol. 188, Pgs 732-733, 26th November 1960.

G. McK.Allcock

A statistically significant association was found between the occurrence of whistlers at Scott Base, Antarctica, and at stations in New Zealand. Detailed consideration of the dispersion characteristics of a coincident whistler which occurred on 7th April 1959, together with meteorological data strongly suggests that the source on this occasion was a local thunderstorm area in the middle of the Tasman Sea. Sonagrams of short whistlers recorded simultaneously in the USA also suggest that this whistler was a true middle-latitude one, with propagation paths terminating in middle latitudes. This supports Martin's theory that polar whistlers originate in lower latitudes and are propagated to polar regions by reflection between the earth and the lower ionosphere.

WHISTLER AND OTHER VERY LOW FREQUENCY PHENOMENA ASSOCIATED WITH THE HIGH-ALTITUDE

Phys. Abstr. 16229/1963; J. geophys. Res. (USA), Vol. 68, No. 3, Pgs 735-9, 1st February 1963.

G.M. Allcock, C.K. Branigan, J.C. Mountjoy, R.A. Helliwell

"Artificial Radiation Belt" Symposium Paper, Greenbelt (Maryland) 1962 (see Abstr. 13807 of 1963). The vlf phenomena observed near Wellington, New Zealand, after the nuclear explosion observed near Wellington, New Zealand, after the nuclear explosion of 9th July 1962, include the occurrence of an explosion-excited whistler, evidence of high ionospheric absorption around New Zealand, and a remarkably transient effect on the propagation of vlf radio waves near the explosion area. A reduction in electron content of the exosphere may also have occurred.

LIGHTNING AND THE PROPAGATION OF AUDIO FREQUENCY ELECTROMAGNETIC WAVES
Ya L. Al'pert
See Section I, Page 2.

INVESTIGATION OF THE PROPAGATION OF LONG AND VERY LONG RADIO WAVES BY
THE ANALYSIS OF ATMOSPHERIC WAVEFORMS
Radiotekh. Elektron (USSR), Vol. 1, No. 3, Pgs 293-308 (March 1956).
Translation available from Morris D. Friedman, Inc. Needham Heights, Mass.,
in Monograph A-131.
Ya L. Al'pert, S.V. Borodina

A description is given of a method which permits results on the properties of low frequency electromagnetic wave propagation to be obtained in terms of the results of a complete harmonic analysis of the photo-oscillogram of a single atmospheric excited by storm discharges. Described briefly are the experimental apparatus and certain measurements. The general characteristics of the shape of the atmospheric and the results of analyzing one kind are given. It is shown that the results obtained on the dependence of the relative amplitude of the field and of the mean velocity on the frequency and range are in generally good agreement with the results of the theoretical computations.

MEASUREMENTS OF THE SPECTRUM OF RADIO NOISE FROM 50 to 100 CYCLES PER SECOND
Phys. Abstr. 12712/1960; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 4, Pgs 415-18, July-August 1960.
M. Balsler, C.A. Wagner

Experimental spectra of radio noise in the band of about 50 to 100 cps were obtained by means of digital processing. Due to the long integration times which were used, the statistical uncertainty in the estimates of power was reduced to about 30% (0.13 dB). It was hoped in this way to observe maximums in the spectrum due to excitation of higher resonant modes of the earth-ionosphere cavity (for the accuracy of these data, such peaks should be observed in the Q cavity were 10 or greater at these frequencies). No statistically significant evidence of these cavity effects was found.

OBSERVATIONS OF EARTH-IONOSPHERE CAVITY RESONANCES
Nature (GB), V. 188, No. 4751, 19th November 1960.
M. Balsler, C.A. Wagner

No abstract

DIURNAL POWER VARIATIONS OF THE EARTH-IONOSPHERE CAVITY MODES AND THEIR RELATIONSHIP TO WORLDWIDE THUNDERSTORM ACTIVITY

Phys. Abstr. 9715/1962; J. geophys. Res. (USA), V. 67, No. 2, Pgs 619-25, February 1962.

M. Balser, C.A. Wagner

Measurements of e.l.f. radio-noise power in the lowest modes of the earth-ionosphere cavity were taken throughout 12 days during February 1961. The mean diurnal variation of the power in the first mode corresponds very closely to the mean worldwide thunderstorm activity expected for that month. Differences in the behaviour of different modes can be explained on the basis of the differing geometrical configuration of the modes. Direct comparison with weather records reveal some correlation between day-to-day variations in noise power and thunderstorm activity. Finally, the measured powers are converted to absolute field strengths by use of a calibrated test signal.

VERY LOW FREQUENCY NOISE POWER FROM THE LIGHTNING DISCHARGE

J. Franklin Inst., Vol. 258, No. 3, Pgs 187-203, September 1954.

J.S. Barlow, G.W. Frey, J.B. Newman

Following a summary of present knowledge of the lightning discharge mechanism, the expression of Bruce and Golde for the destruction of the cloud image dipole by the discharge has been derived phenomenologically. The radiation power spectrum of a lightning discharge has been calculated for two cases, considering the radiation to arise from (a) the destruction of the cloud-image dipole, and (b) the channel as a linear antenna.

The power spectrum of the waveform of a distant daytime atmospheric (daytime "tweek") characterized by a decrease in both amplitude and instantaneous frequency with time, has been obtained, assuming exponential decay of a sinusoidal waveform whose frequency is that of the power-weighted mean frequency. This waveform power spectrum, the transformed results of the (b) analysis above (using available experimentally determined propagation data for very low frequencies), and one of Bowe's spectra of distant daytime atmospherics have been compared. There is reasonable agreement of the transformed discharge spectrum with the observed "tweek" spectra, despite the approximations of the calculations, the variations among individual discharges, and the interpolation and extrapolation of the propagation data. These results indicate a peak in the power spectra of distant daytime atmospherics at about 10 kc in agreement with other "tweek" workers.

While the Bruce and Golde expression seems adequate for radiation analysis, a question has been raised concerning its use, except in special cases, for the near field analysis.

WHISTLERS AND MAGNETIC ACTIVITY

Phys. Abstr. 17144/1962; Canad. J. Phys. Vol. 40, No. 6, Pgs 775-781, June 1962.

R.E. Barrington, W.E. Thompson

The relationship between whistlers and magnetic activity was studied using planetary K indices and a whistler occurrence index. This index W_K , is the percentage of observing periods with a given K_p value during which at least one whistler was recorded. Data from eight whistler stations which were operated during the IGY were used. In almost all cases, the value of W_K was found to increase with K_p up to K_p values of 1.3 and then decrease as K_p is further increased. The decrease of W_K with increasing K_p is shown to be due in part to masking of whistlers by very low-frequency emissions, but this does not account for the whole effect. No diurnal variations of the relationship of W_K to K_p was detected, but a small seasonal change was observed. The formation and destruction of ducts or columns of enhanced ionization in the outer ionosphere are suggested as possible mechanisms for explaining some of the observed effects.

OBSERVATION OF ATMOSPHERICS GEOMAGNETISM : AERONAMIYA

Vol. 1, No. 3, Pgs 379-386 (1961). In Russian.

V.B. Belyanskiy, and Others.

For observations of atmospherics carried out by the Institute of Terrestrial Magnetism, Ionosphere, and Propagation of Radio Waves, Academy of Sciences, USSR, from December 1959 to August 1960, a special device with a passband of 3-8000 cps was constructed to register tails of atmospherics; (1) atmospherics which had one or two half-periods and (2) atmospherics with tails having a larger number of half-periods. Of the 2962 atmospherics with tails observed, 90.9% had either one or two half-periods with a duration of 3 msec. Signals of the first group were observed during the entire 24-hour period while those of the second group occurred most frequently at night. Increase in distance to the signal source resulted in an increase in the duration of signals in the first group and a reduction in the relative number of signals in the second group.

LOW FREQUENCY RADIO NOISE OF THE EARTH'S MAGNETIC FIELD

Compt. rend. (Paris), Vol. 242, No. 21, Pgs 2534-2535 (23rd May 1956).

In French.

R. Benoit

Tests carried out at Béni-Abbès confirmed that the noise was not continuous but consisted of very brief uninterrupted impulses of wide spectral range evidently produced by atmospherics. A filter was used to eliminate frequencies above 1000 c/s and an amplification of 10^4 was employed. An example is given of the registrations obtained at minute

intervals. Little is evident in the band 10-100 c/s. The tests lasted over a period of 10 days. It is concluded that either a period of exceptional calm existed during the tests or, the noise is a little less uniquely caused by impulses due to atmospherics, or both cases exist. The results confirm the theory developed by Grenet.

PROPAGATION OF VERY-LOW FREQUENCIES IN THE EARTH-IONOSPHERE SYSTEM

R. Benoit, A. Hourri
See Section I, Page 11.

NIGHT-TIME EFFECTS OF SUDDEN IONOSPHERIC DISTURBANCES ON LONG WAVES

EE Abstr. 4380/1963; C.R. Acad. Sci. (France), Vol. 255, No. 22, 3028-30, (26th November 1962). In French.
M. Bertrand

A study of recordings of atmospherics on long wavelengths (27 kc/s) obtained during the IGY shows that the sudden enhancement produced by an s.i.d. is observed not only in the sun-lit hemisphere but also sometimes during the night.

AMPLITUDE AND PHASE SPECTRUM OF RADIO-ATMOSPHERICS

J. Atmos. Terrest. Phys. (GB), Vol. 25, No. 8, 445-50, August 1963.
Phys. Abstr. 25891/1962
H. Bhattacharya

From the experimentally observed waveforms of atmospherics the amplitude-frequency and the phase-frequency distributions were obtained using the method of Fourier-integral transformation. These amplitude and phase distributions were also obtained by considering the return stroke current expression. A comparison of the amplitude maxima in both these cases suggested that discharges having sharper current pulse widths were more predominant.

ANALYSIS OF THE SHAPE OF ATMOSPHERICS

Naucho-Issledovatel'-skii Institut Zemnogo Magnetizma, Ionsfery i Rasprostraneniya Radiovoln, Trudy (USSR), Vol. 17, No. 27, Pgs 3-36, (1960). Translation AD-262422.
S.V. Borodina

It is shown how the propagation velocity of audio frequency electromagnetic waves and the effective conductivity of the lower part of the ionosphere at these frequencies can be determined on the basis of studying the phase characteristics of atmospherics by using a method proposed by Y. Al'pert (Uspekhi Fiz. Nauk 60; 370, 1956). Results of the analysis of atmospherics whose sources are 500 to 3300 km from the

observation point are presented. The behaviour of the function $B(\omega, r)$, which characterizes the properties of the medium and expresses the frequency dependence of the signal amplitude for various ranges, is obtained from these data and from data on the source of atmospherics. The experimental curves of the relative values of $B(\omega, r)$ and also other data on the amplitude of the field are compared with the theoretical results of Ya. L. Al'pert. The results of an analysis of the phase spectra of atmospherics and the results obtained on the phase velocities of electromagnetic waves in the 2- to 20-kc band are analyzed in detail. A comparison of the experimental curve of the frequency dependence of the phase velocity with the theoretical curve yields good agreement for $f \gg 3$ kc and noticeable divergence for $f < 3$ kc. The question of determining the effective parameters of the lower part of the ionosphere responsible for the propagation of very long electromagnetic waves is also considered.

THE WAVEFORM OF ATMOSPHERICS AND THE PROPAGATION OF VLF RADIO WAVES
Phil. Mag. Vol. 42, No. 325, Pgs 121-138 (February 1951).
P.W.A. Bowe

The responses of narrow-band receivers to individual radio atmospherics have been observed in order to describe the propagation of radio waves of frequency 2 kc/s to 10 kc/s over the surface of the earth. It has been found that the atmospherics from a fixed distance are sufficiently uniform to enable the relative attenuations of different frequencies to be deduced. The study reveals that waves of frequency below about 8 kc/s are heavily attenuated during the day-time but are propagated freely at night. The attenuation is greater during a sudden ionospheric disturbance.

These results confirm and extend those obtained recently by Gardner. They can be explained in outline on a theory recently proposed by Budden.

A STUDY OF INDIVIDUAL RADIO ATMOSPHERICS RECEIVED SIMULTANEOUSLY AT TWO PLACES
EE Abstr. 5062/1953; Phil. Mag. (GB), V. 44, Pgs 833-40, August 1953.
P.W.A. Bowe

Abstr. 1993/1951 described a method of studying the propagation of radio waves of frequency 2-10 kc over the surface of the earth, by observing the responses of narrow-band receivers to individual radio atmospherics. The present paper describes an extension of these observations in which the same method was used simultaneously at two places, Cambridge and Aberdeen, 550 km apart. The narrow band receivers at both places were tuned to frequencies 7.5, 5.0, 3.5 and 0.6 km. By

comparing the responses at the two places, the attenuation factors for each frequency could be found. The sources of the atmospherics were located by the "Sferic" direction finding system of the Meteorological Office, supplemented by a direction finder at Cambridge. Most of the observations were made at about noon. The results are presented as tables giving the propagation factor for 1000 km path, for the four frequencies studied. It was found that waves of frequency 0.6 kc are less attenuated than those of 3.5 kc. The results for 7.5 and 5.0 indicate that the attenuation is less in winter than in summer.

TRAVELLING WAVE AMPLIFICATIONS OF WHISTLERS

Better in J. Geophys. Research, Vol. 65, No. 11, Pgs 3840-3842,
November 1960.
N.M. Brice

Travelling wave amplification has been postulated by Helliwell (1956) and by Gallet (1959) as a possible generation mechanism for audio-frequency ionosphere emissions. The present note discusses the application of the theory of the travelling wave tube (Chodorow and Susskind, 1960) to these frequencies with particular reference to whistlers and whistler echo trains.

USE OF "LOCAL MEAN AURORAL TIME" FOR VERY-LOW FREQUENCY EMISSIONS
Phys. Abstr. 4804/1964; Nature (GB), Vol. 198, 874, 1st June 1963.
N. Brice, E. Ungstrup

The connection between high and low latitude vlf emissions is discussed. A consistent picture of these emissions is obtained if the time of peak occurrence is measured in terms of local mean auroral time.

AN EXPLANATION OF TRIGGERED VERY-LOW-FREQUENCY EMISSIONS
EE Abstr. 2672/1964; J. Geophys. Res. (USA), Vol. 68, No. 15,
4626-8, 1st August 1963.
N.Brice

The proposed mechanism is that the relative phases of particles gyrating about the lines of force of the earth's field are adjusted by the triggering wave so that the particles can radiate coherently. More particles are influenced by the induced radiation, and the process becomes self-sustaining.

COMMENTS ON A PAPER H. UNZ "ON THE ORIGIN OF 'VERY LOW FREQUENCY EMISSIONS'"
Phys. Abstr. 13730/1963; J. Atmos. Terrest. Phys. (USA), Vol. 25, No. 3,
185. March 1963.
R.M. Brice, R.L. Smith

Points out that the relations, explaining the origin of very-low-frequency emissions, derived by Unz (Abstr. 21656/1962) are incorrect, including the case applicable to a single stream. The reasons of alleged errors are given.

ELECTRIC FIELD CHANGES AND THE DESIGN OF LIGHTNING STROKE COUNTERS
Paper presented at 41st annual meeting of the American Geophysical Union,
Washington DC, 27-30 April 1960; Abstract in J. Geophys. Research, Vol.
65, No. 8, Pgs 2477-2478, August 1960. M. Brock, N. Kitagawa.

Examples of electric-field and field-change records of lightning discharges are discussed in relation to the design of lightning-stroke counters. Correlations between stroke counts and visual observations of nocturnal lightning were found to be very poor for a stroke counter which operates on the abrupt-field-change principle. The abrupt field changes of both signs which accompany all lightning discharges make it virtually impossible to discriminate between cloud-to-ground and cloud-to-cloud lightning with stroke counters of the conventional type. A reliable total count for nocturnal lightning of both types can be obtained with a photo-multiplier tube. A photo-multiplier tube operated in coincidence with an electric-field-change meter can be utilized to discriminate against sferics. Conversely, if the photo-multiplier and field-change meter are operated in anti-coincidence, the system will accept only sferics which originate outside the area of visible lightning discharges.

VERY-LOW-FREQUENCY NOISE AT BRISBANE
EE Abstr. 14878/1962; Nature (GB), Vol. 194, Pgs 962, 9th June 1962.
H.E. Brown, G.G. Cairns

The existence of noise burst coincident with magnetic disturbances is reported. The frequency of the observations lies in the 5 kc/s region. The maximum noise signal was $0.05 \mu \text{V} \cdot \text{sec} \cdot \text{m}^{-1}$, the 6 dB bandwidth being 800 c/s. Three disturbances are reported.

THE PROPAGATION OF A RADIO-ATMOSPHERIC
K.G. Budden
See Section I, Page 20.

THE PROPAGATION OF A RADIO ATMOSPHERIC. II.
Phys. Abstr. 1788/1953; Phil. Mag. (GB), V. 43, Pgs 1179-1200,
November 1952.
K.G. Budden

In Part I (Abstr. 2863/1951) an outline of the theory was given for the case when the top surface of the waveguide was the boundary of a homogeneous ionized medium, and the earth's magnetic field was neglected. The present paper gives the full mathematical theory, and shows how the characteristics of the waveguide modes may be determined in the most general case, provided that the reflecting properties of the earth and the ionosphere are known as functions of the angle of incidence, which is, in general, complex. It is found that the waveguide modes are of two types, which are described as "quasi-transverse magnetic" and "quasi-transverse electric". Allowance can be made for the curvature of the earth. A particular case is then discussed, in which the surface of the earth is assumed to be perfectly conducting, and the ionosphere is assumed to be a homogeneous ionized medium, with the steady magnetic field of the earth superimposed. The results of numerical calculations are given, for a few special cases, in the form of curves. These show (1) the attenuation in the various modes as a function of frequency, (2) the polarization characteristics of the wave in typical modes, and (3) the amplitudes of the waves which are excited in typical modes by a vertical electric dipole source.

ON THE SOURCES OF ATMOSPHERICS
Phys. Abstr. 1298/1953; Joint Commission on Radio-Meteorology, 41-4,
1951.
R. Bureau

Continuous recording of atmospherics on 27.5 kc allows the principal sources of storms of large range to be grouped and mapped on a world-wide scale. From a single station near Paris the principal sources have been located in tropical Africa, S. America, Central America, Antilles, and southern U.S.A.

ATMOSPHERIC NOISE, A REVIEW OF THE LITERATURE
EE Abstr. 1031/1963; AWA Tech. Rev. (Australia), Vol. 12, No. 2,
Pgs 63-5, 1962.
A.K. Carbrera

A review of recent advances in the field of atmospheric noise has been made. Atmospheric noise is the sum of a large number of components radiated from "stepped leaders" and "return strokes" in lightning discharges. The average level and fine structure of the noise waveform depends on the time of day, season, location, frequency and bandwidth. In general, the waveform of the noise field is much

more impulsive than random noise, particularly when the frequency is low, the received band is wide, or the location is tropical. As a result of statistical analysis of noise waveforms, various mathematical models of atmospheric noise have been developed.

A NOTE ON WHISTLERS OBSERVED ABOVE THE IONOSPHERE

J. Geophys. Research, Vol. 66, No. 9, Pgs 2677-2680, September 1961.
J.C. Cain, I.R. Shapiro, J.D. Stolarik, J.P. Heppner

The sensing coil of the proton precession magnetometer carried on the Vanguard III satellite also served as an antenna for detecting audio-frequency electromagnetic waves. A preliminary analysis is given for about 100 whistlers observed September 18th through December 12th 1959, at low latitudes over the altitude range 510 to 3750 km. About 90% of the whistler occurrences are between 6 pm and 6 am local time indicating a low nighttime absorption by the ionosphere. The intensity of the H component of the wave is estimated to be between 0.01 and 0.5 gamma, with that of a few signals exceeding 1 gamma.

WHISTLER SIGNALS OBSERVED WITH THE VANGUARD III SATELLITE

Phys. Abstr. 17145/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II, Pgs 84-8, January 1962.
J.C. Cain, I.R. Shapiro, J.D. Stolarik, J.P. Heppner

Cosmic Ray and Earth Storm Conference, Kyoto, 1961 II. Joint Sessions (see Abstr. 9940 of 1962). In addition to other experiments, the proton precessional magnetometer in the Vanguard III (1959 eta) satellite was used to detect audio-frequency electromagnetic waves. The results bring up to date an earlier preliminary analysis, though exact statistical tests have not yet been completed. Comparisons indicate that the number of whistlers occurring in unit time as observed by the satellite is at least comparable to the number per unit time observed at the earth's surface in middle latitudes, and certainly much greater than the number observed at the ground in low latitudes. 83% of the whistlers occurred between 6 p.m. and 6 a.m. local time. They showed less dispersion than is observed in whistlers received on the earth's surface. The majority of the dispersion values follow a pattern in which the dispersion increases with distance along the field line from the earth's surface. Comparisons between observed and theoretical dispersions are given, and the agreement is such that it is hoped to obtain average electron densities above F2. Precise data are not available on signal amplitude but approximate estimates are made. The authors also suggest that whistlers may be of importance in the acceleration and diffusion of electrons in the inner radiation belt.

DEFINITION AND MEASUREMENT OF THE MEAN FIELD OF ATMOSPHERICS OF IMPULSIVE TYPE

EE Abstr. 3489/1961; CR Acad. Sci. (France), V. 251, No. 17, Pgs 1756-8, October 24, 1960.

F. Carbenay

Considering that atmospherics generally exhibit a pulse character, an expression is derived for the mean effect on a receiver, having suitable amplification and linear detection, in terms of the equivalent effect of an electromagnetic field having the frequency to which the receiver is tuned.

IDENTIFICATION OF WHISTLER SOURCES ON VISUAL RECORDS AND A METHOD OF ROUTINE WHISTLER ANALYSIS

Technical Report 5, Contract AF.18(603)-126, Electronics Laboratories, Stanford University, Stanford, California (15th March 1959). AFOSR-TN-60-315.

D.L. Carpenter

This report discusses two of the problems that arise in whistler analysis: (1) the identification of the "causative sferic" associated with a whistler, and (2) routine analysis of whistlers based on visual frequency-versus-time records (Sonograms).

The introduction presents a brief discussion of the nature of whistlers and the type of record used in their analysis.

Section II covers the principal methods of identifying "causative sferics" on whistler records. One technique presented in some detail involves measuring the delay between successive echoes of an echo train and then using this measured delay to predict the time of the "causative sferic".

Section III outlines the method of routine analysis currently in use at Stanford. For each whistler component measurements are made of: (1) the time delay, at 5.0 kc, from the causative sferic, (2) upper and lower cutoff frequencies, (3) dispersion (using an overlay). In addition, the overall width of the whistler is measured. The data sheet and scaling table currently in use are illustrated, as are two sample analyses of whistlers.

Finally, an abbreviated form of the routine analysis is presented for application to whistlers for which (alas) the causative sferics cannot be identified.

WHISTLER MEASUREMENTS OF ELECTRON DENSITY AND MAGNETIC FIELD STRENGTH
IN REMOTE MAGNETOSPHERE

Phys. Abstr. 2210/1964; J. Geophys. Res. (USA), Vol. 68, No.12 , 3727-30,
15th June 1963.

D.L. Carpenter

During recent studies at Byrd station in the Antarctic, some whistlers were recorded which were propagated via high-latitude field lines, as well as the more usual middle-latitude type. Their characteristics and the information which may be deduced from them are discussed. The lowest value of noise frequency observed was 800 c/s.

AUDIO-FREQUENCY SPECTRUM OF ATMOSPHERICS

EE Abstr. 775/1954; Nature (GB), V. 172, Pgs 495-6, 12th September 1953.
F.W. Chapman, W.D. Matthews

Some results obtained from the simultaneous recording of the relative amplitudes of the different frequency components in the spectrum of atmospherics are given. The frequency of the largest component in the "slow tail" of the waveform decreases with increasing distance from the source, whereas for the higher frequency oscillatory portion the opposite effect occurs. A brief comparison is made with the results of other workers.

ON THE WAVEFORM AND AUDIO-FREQUENCY SPECTRUM OF ATMOSPHERICS

Paper presented at Symposium on Very Low Frequency Waves and Atmospherics, The Electro-Physical Institute of Technische Hochschule, München, Germany, 3rd October 1955.

F.W. Chapman

The work discussed relates to the radiation field of lightning discharges known as atmospherics and the information that can be derived from a study of the variation of the waveform with distance of propagation (1) the spectrum of the propagated disturbances (2) from such observations the laws of propagation of audio-frequency radio waves can be studied, or conversely, information on the spectrum of the primary disturbances radiated at the source may be deduced and the nature of the lightning discharge current calculated.

RELATIONS BETWEEN THE CHARACTER OF ATMOSPHERICS AND THEIR PLACE OF ORIGIN

J. Chapman, E.T. Pierce
See Section I, Page 27.

WAVE TYPES, FREQUENCY SPECTRA, AND PROPAGATION OF ATMOSPHERICS
L'Onde Electrique (Paris), Vol. 37, No. 362, Pgs 523-525 (1957).
In French.

J. Chapman, E.T. Pierce

From a statistical analysis of the relation between wave forms and frequencies of sferics recorded at Cambridge, England, curves of wave type frequency correlation are deduced. Results of propagation measurement over 18 Mc are consistent with the wave-guide mode of propagation advanced by Budden (1951).

THE WAVEFORMS OF ATMOSPHERICS AND THE PROPAGATION OF VERY LOW FREQUENCY RADIO WAVES

J. Atmos. Terrest. Phys. Vol. 11, Nos. 3/4, Pgs 223-236 (1957).

J. Chapman

Experimental observations upon atmospherics by several techniques are described. It is shown, in particular, that the results obtained for waveforms and for frequency spectra can be interrelated. The frequency spectrum of the electromagnetic disturbance at the source - the lightning discharge - is considered, and evidence is presented indicating appreciable differences, in this respect, between individual flashes. The interpretation of the results, on the basis of waveguide theory applied to the space between the earth and the lower ionosphere, is considered; this approach is entirely successful qualitatively, but quantitatively the agreement is less satisfactory.

WAVEFORMS CONSISTING OF UNUSUALLY LONG TRAINS OF OSCILLATIONS

Paper presented at IRE-URSI Symposium, 19th - 21st October 1959, San Diego, California.

C.J. Chilton

Waveforms consisting of unusually long trains of oscillations have been transcribed from magnetic tape recordings made by the Automatic Whistler Recorders of the IGY Whistlers-West Programme. These waveforms are characterized by a VLF head having a spectral peak in 5-15 kc region and a duration of 1 to 2 msec. Following the head, unusually long trains of oscillations are frequently seen attaining durations of 40 msec or more and consisting of 100 or more individual cycles. This long train is characterized by build-up and decay times of a few milliseconds and a decrease in frequency content with increasing time approaching a frequency of approximately 2 kc. The character of these atmospherics is reminiscent of unusually long tweeks or unusually short whistlers; however, difficulties arise in attempting to characterize them. They are rare, which suggests the possibility of being associated with a unique discharge and/or propagating mechanism.

A STUDY OF SUDDEN ENHANCEMENT OF ATMOSPHERICS ON 27 KC/S BAND
Phys. Abstr. 9046/1963; Indian J. Meteorol. Geophys. Vol. 13, No. 3,
Pgs 387-95, July 1962.
M.W. Chiplonkar, R.N. Karekar

Reports a study of sudden enhancement of atmospherics (SEA) on 27 kc/s at a station in low latitudes carried out during 1958-59, which is thought to be of importance for the world-morphology of SEA. It is found that SEA shows maximum association with magnetic crochet. The chance of occurrence of SEA are practically the same for most of the day hours. The rise-time and decay-time of SEA have an average ratio of about 1:4, with a total duration of about 40 mins. The rise-times cluster around two distinct values of 5 mins and 15 mins. The total duration of SEA is seen to increase with its amplitude whereas the rise-time does not increase with amplitude. It is observed that the SEAs with rise-times greater than about 13 mins. are more frequent in the forenoon than in the afternoon.

THE SUNRISE AND SUNSET EFFECTS ON THE LEVEL OF ATMOSPHERICS ACTIVITY ON THE 27 KC/S BAND
EE Abstr. 4370/1963; J. Atmos. Terrest. (Phys (GB), Vol. 25, No. 1,
Pgs 23-24, January 1963.
M.W; Chiplonkar, R.N. Karekar

The sunrise and sunset effects on the level of atmospherics on 27 kc/s were studied for the IGY and the IGC periods at a tropical station. The two effects are not observed to be symmetrical. The latest limit of the beginning and the earliest limit of the end of the sunrise fall occur about 10 mins. after ground sunrise at the station. A simple explanation is offered for this, which also explains the other limits of the start and the end of the sunrise fall. In the case of the sunset rise the start is seen to take place almost always after ground sunset. In summer frequently a dip in activity is observed near ground sunset. Both these are responsible for the asymmetry. On the average the fall from the day side obeys a cosine law up to the minimum, after which there is a steep rise for one hour, followed by a sudden change in the slope to a low value.

IONOSPHERIC PROPAGATION OF ATMOSPHERICS
EE Abstr. 1274/1964; Indian J. Meteorol. Geophys. Vol. 14, No. 3,
Pgs 343-52, July 1963.
M.W. Chiplonkar, M.S. Hattiangadi

Numerous waveforms of atmospherics in the frequency region 50 c/s to 300 kc/s have been observed during the period April 1957 to December 1958. A large number of these show a multi-hop propagation and the results of measurements of these waveforms are analysed and presented.

The statistical distribution of distances has been interpreted qualitatively with the help of a Holingworth interference pattern of field strength. When heights of the reflecting layers are plotted against the corresponding source distances, it is seen that the height increases rapidly at first and then gradually reaches a limiting value around 95 km. However, other evidence shows that there exist two reflecting layers, one at about 60 km and the other at about 90 km. The reflection coefficient of the ionosphere varied from 0.4 to 0.9 or more. Occasionally even smaller values down to 0.25 were also observed. The reflection coefficient is higher in winter than in summer.

THE AFTERNOON HUMP IN THE DIURNAL VARIATION OF ATMOSPHERICS ACTIVITY ON 27 KC/S.

EE Abstr. 15899/1963; Indian J. pure appl. Phys. Vol. 1, No. 7, Pgs 256-9, July 1963.
M.W. Chiplonkar, R.N. Karekar

The phenomena of "afternoon hump" and "sunset dip" observed in the diurnal variation of atmospherics activity on 27 kc/s are discussed with reference to the data obtained at Poona during 1958-59. Two basic variations are considered: (a) the diurnal variation of winter months and (b) the afternoon hump of summer months. Any type of observed diurnal variation can be explained by them either individually or by their superposition. The processes by which these basic variations may be produced are also discussed. It is concluded that though the diurnal and seasonal variations of thunderstorm activity and their geographic distribution play an important part in the production of the afternoon hump, the late occurrence of sunset rise in winter and presence of sunset dip in summer suggest that the role of the ionosphere is of no less importance.

RECORDING ATMOSPHERIC RADIO NOISE

C. Clarke
See Section III, Page 216.

ATMOSPHERIC RADIO-NOISE STUDIES BASED ON AMPLITUDE-PROBABILITY MEASUREMENTS AT SLOUGH, ENGLAND, DURING THE INTERNATIONAL GEOPHYSICAL YEAR

EE Abstr. 13550/1962; Proc. Instn. Elect. Engrs (GB), Paper 3908E, publ. September 1962 (Vol. 109B, 393-404).
C. Clarke

Measurements of the amplitude-probability distributions of atmospheric noise in a power bandwidth of 370 c/s, made at the Radio Research Station, Slough, England, during the International Geophysical Year, are presented for frequencies of 24 kc/s, 135 kc/s, 11 Mc/s and 20 Mc/s. The diurnal and

seasonal variations of the noise power and average value of the noise envelope are derived, and a comparison is made between the measured noise power and predictions prepared under the auspices of the International Radio Consultative Committee (CCIR). The distributions are normalized to the r.m.s. level and summarized in representative curves. The variations of these composite distributions are expressed in statistical terms, with particular reference to the r.m.s. to average ratio and the overall dynamic range.

CHOICE OF A PARAMETER CHARACTERIZING RADIO WHISTLERS

Ann. Geophys. (France), Vol. 16, No. 1, Pgs 128-129, 1960. In French.
Y. Corcuff

D, the dispersion of the whistlers, which is proportional to the path-lengths of the energy, has been taken as their character-number. However, analysis of the long whistlers leads to considering the dispersion as frequency dependent. The specification of zero and 4 kc/s as reference frequencies seems specially interesting. The methods which may be used to determine the dispersion of any whistler in both cases are described and discussed.

WHISTLER DISPERSION DURING MAGNETIC STORMS - NOCTURNAL, ANNUAL AND SEMI-ANNUAL VARIATIONS IN QUIET PERIODS

EE Abstr. 5403/1963; Ann. Geophys. (France), Vol. 18, No. 4, Pgs 334-40, 1962; In French.
Y. Corcuff

Some results are given from an analysis of the whistlers recorded at Poitiers during IGY. It is confirmed that the parameter D_0 decreases at a time between 18 and 24 hours after the beginning of a magnetic storm; the mean ratio of the values before and after the disturbance is of the order of 2. This phenomenon may be due to discrete paths of propagation shifting towards the equator and to the decreasing electronic content of the exosphere. During quiet periods, the amplitude of night variation of D_0 undergoes an annual variation with a minimum at the June solstice. This could result from an annual variation of diurnal ionization in the upper atmosphere. Finally, a semi-annual variation of D_0 , with April-May and October-November maxima, is made conspicuous at 00 UT.

VARIATION OF OCCURRENCE OF WHISTLERS AND IONOSPHERIC NOISES AT THE MOMENT OF SUNRISE IN THE IONOSPHERE

EE Abstr. 15894/1963; Ann. Geophys. (France), Vol. 19, No. 3, Pgs 244-8, 1963. In French.
Y. Corcuff, F. Fisson

More often, the activity of whistlers ceases, in the morning, as soon

as the sun rises to the altitude of the F-region above the conjugate point of the receiver. In contrast, the activity of the chorus is connected with the sunrise at the receiver, when it occurs before 06 LMT, a time which seems a function of the geomagnetic latitude of the station. Absorption through the D region may explain these results, deduced from the data obtained at Poitiers, from 1958-1962.

CORRELATION BETWEEN THE VERY LOW FREQUENCY EMISSIONS AND THE MAGNETIC AND COSMIC RAY STORMS

Phys. Abstr. 21658/1962; J. Phys. Soc. Japan, Vol. 17, Suppl. A-II, Pgs 76-8, January 1962.
Y. Corcuff, J.P. Legrand

Cosmic Ray and Earth Storm Conference, Kyoto, 1961.

II. Joint Sessions (see Abstr. 9940 of 1962). The occurrence of vlf emissions at Poitiers, the intensity of cosmic-ray variations, and the variations in the earth's magnetic field are compared for the fifteen days before and after the day J_0 of the beginning of cosmic-ray storms observed at Limeil (51° N geomagnetic). The maximum magnetic activity was found to coincide with J_0 , and the maximum vlf reception with $J_0 + 1$, the day of maximum amplitude of the cosmic-ray storm. Hiss was received during the main phase of the magnetic storms, the beginning and maximum of occurrence being at about 9 and 18 hours respectively after the SC. The authors conclude that their results support the vlf emission theory of Gallet and Helliwell (Abstr. 13974 of 1959).

EXPERIMENTS ON WHISTLERS AND ASSOCIATED ATMOSPHERICS

Paper presented at IRE-URSI Symposium, Washington DC, 30th April, 1st - 3rd May 1956.
J.H. Crary, R.A. Helliwell

Some recent results of experiments on whistlers and associated atmospheric are described. Stanford whistlers are correlated with impulsive atmospheric recorded on the U.S.S. Atka while she was near Stanford's geomagnetic conjugate point. Six apparent correlations were obtained on 27th December 1954, of which only one was expected on the basis of chance alone. Applying the Eckersley dispersion law the time of origin of each whistler was calculated. The difference between these times and the actual times of occurrence of the corresponding tweeks on the Atka average 0.07 second with a standard deviation of 0.24 second. Since the average delay of whistlers was about one second, it is concluded that these whistlers were in fact produced by lightning discharges in the southern hemisphere, thus giving support to Storey's theory of the whistler path.

The observation of "short" whistlers with frequency components extending up to at least 25 kilocycles is reported. The results show the practicability of conducting experiments on the whistler mode of propagation using signals from vlf stations or other man made generators.

STANFORD-SEATTLE WHISTLER OBSERVATIONS

J. Geophys. Research, Vol. 61, No. 1, Pgs 35-44, March 1956. Similar material was published as Scientific Report No. 10, Contract AF 19(604)-795, Stanford University, Stanford, California, May 1956.
J.H. Crary, R.A. Helliwell, R.F. Chase.

Simultaneous observations of times of occurrence of whistlers were made at Seattle, Washington, and Stanford, California, two hours every week from October 1951 to October 1952. Times were measured to an accuracy of about ± 1 second. The objective was to determine the percentage of whistlers received at either station which were coincident at both. The analysis showed that approximately 22 per cent were observed simultaneously at both stations.

This result is examined in relation to possible theories of whistler origin and propagation, and is shown to support the Storey-Eckersley theory.

MEASUREMENT AND INTERPRETATION OF THE POLARIZATION AND ANGLE OF ARRIVAL OF WHISTLERS

Prepublication papers NBS-IRE PGAP Symposium on Propagation of VLF Waves, Boulder, Colorado, 23rd-25th January 1957, Vol. II, Paper 21.
J.H. Crary

The measurement of the polarization and direction of arrival of whistler signals using the crossed-loop and vertical antenna system at Stanford is discussed. These characteristics are readily measurable if the unknown polarization is not linear.

Two-channel recordings show that the polarization and direction of arrival are not constant during a whistler. The polarization is generally elliptical with varying axis ratio and direction of rotation.

The calculation of the polarization below the ionosphere and the predicted antenna response is discussed. The lossless case is considered first, when the wave is a simple, infinite plane wave.

THE EFFECT OF THE EARTH-IONOSPHERE WAVEGUIDE ON WHISTLERS

Tech. Rept. 9, Contract AF18(603)-126, Electronics Laboratories, Stanford University, Stanford, California. (17th July 1961). AFOSR-1092.
AD-262 348.
J.H. Crary

A whistler is a natural audio-frequency electromagnetic signal which results from the dispersion of broad-band energy radiated by lightning discharges. Whistlers travel along discrete paths aligned with the earth's magnetic field. Such a path takes the energy several thousand kilometres

out into space, and back to earth in the opposite hemisphere. The space between the earth and the lower edge of the ionosphere acts as a waveguide. The whistler then propagates in the earth-ionosphere waveguide to the receiver. Thus it should be possible to explain certain properties of whistlers in terms of the properties of the waveguide. It should also be possible to locate the point at which the energy enters the waveguide (the exit point) by direction-finding (d-f) measurements at spaced stations.

The boundaries of the guide are assumed to be sharply bounded homogeneous media. The earth is described by a complex dielectric constant. The ionosphere is described by the approximation of the magneto-ionic theory, assuming a vertical, static, magnetic field. The coupling introduced between the two polarization components of the wave by the magnetic field in the ionosphere is included.

Curves (parametric in frequency, distance, and waveguide parameters) of the response of a vertical monopole and of crossed loops are shown. The ratio of the crossed-loop voltages and the null-bearing errors are determined for comparison with experimental data.

Qualitative agreement is found between the calculated and the previously unexplained experimental data on crossed-loop voltage ratios.

GEOMETRICAL OPTICS CONVERGENCE COEFFICIENT FOR THE WHISTLER CASE
Radio Science Journal of Research, NBS/USNC-URSI, Vol. 68D, No. 2,
February 1964, Pgs 211-214.
J.H. Crary

In a previous report (Crary, 1962) the field strength, direction of arrival, and apparent polarization of whistler signals was calculated by the use of ray theory (or geometrical optics). The convergence coefficient is a factor in the ray theory equations which expresses the net convergence or divergence of the rays caused by reflection from the curved earth and ionosphere.

Intuitive reasoning led to the assumption of unity for this coefficient in the whistler case, where there are an equal number of reflections from the concave ionosphere and convex earth. This is contrasted with the convergence coefficient for the case of ground-to-ground transmission; this coefficient contains singularities at critical distances.

The derivation and evaluation of the expression for the coefficient for the whistler case confirms the accuracy of the assumption of unity; this greatly simplifies whistler calculations.

WORLDWIDE RADIO NOISE LEVELS EXPECTED IN THE FREQUENCY BAND 10 KILOCYCLES
TO 100 MEGACYCLES

NBS Circular 557, 25th August 1955, 30 cents.

W.Q. Crichlow, D.F. Smith, R.N. Morton, W.R. Corliss.

No abstract

NOISE INVESTIGATION AT VLF BY THE NATIONAL BUREAU OF STANDARDS

EE Abstr. 5215/1957; Proc. Inst. Radio Engrs (USA), V. 45, No. 6,
Pgs 778-82, June 1957.

W.Q. Crichlow

The principal objective of the Radio Noise Section at the N.B.S. is the establishment of a regular service for predicting the levels and characteristics of radio noise. The various steps necessary to establish such a service are summarized. The characteristics of atmospheric noise vary with location, frequency, and time, and methods of dealing with these variations are discussed. Also discussed are new predictions of world-wide noise levels which have been prepared for the International Radio Consultative Committee (C.C.I.R.).

REPORT OF THE SUB-COMMISSION ON THE QUESTION: WHAT ARE THE MOST READILY
MEASURED CHARACTERISTICS OF TERRESTRIAL RADIO NOISE FROM WHICH THE INTER-
FERENCE TO DIFFERENT TYPES OF COMMUNICATIONS SYSTEMS CAN BE DETERMINED?

In Proc. of the XIIth Gen. Assembly, International Scientific Radio Union,
Boulder, Colorado, 22nd August - 5th September 1957, XI, Pt. 4, Pgs 9-47,
1957 (Document 254).

Prepared by W.Q. Crichlow

RECOMMENDATION NO. 1 AND ANNEX, MEASUREMENT OF ATMOSPHERIC NOISE

In Proc. of the XIIth Gen. Assembly, International Scientific Radio Union,
Boulder, Colorado, 22nd August - 5th September 1957, XI, Pt. 4, Pgs 99,
102-106, 1957. URSI (Int. Sci. Radio Union). Inform. Bull No. 105,
10-11, 13-18, September-October 1957.

Prepared by W.Q. Crichlow, Chairman, G. Foldes, F.J. Hewitt, F. Horner,
H. Shinkawa, A.W. Sullivan

RADIO NOISE OF TERRESTRIAL ORIGIN

Report of U.S. Commission 4, URSI. J. Research (D. Radio Propagation),
Nat. Bur. Standards 64D, Pgs 637-654, November-December 1960.

W.Q. Crichlow, editor.

AMPLITUDE-PROBABILITY DISTRIBUTION FOR ATMOSPHERIC RADIO NOISE
EE Abstr. 1656/1961; Nat. Bur. Stand. (USA), Monogr. No. 23, Pgs 1-22,
1960.
W.Q. Crichlow, and Others

Families of amplitude-probability distribution curves are presented in a form such that by using three statistical parameters of atmospheric radio noise, the corresponding amplitude-probability distribution may be readily chosen. Typical values of these parameters are given.

DETERMINATION OF THE AMPLITUDE-PROBABILITY DISTRIBUTION OF ATMOSPHERIC RADIO NOISE FROM STATISTICAL MOMENTS
EE Abstr. 3775/1960; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 1, Pgs 49-56, January-February 1960.
W.Q. Crichlow, and Others

During the I.G.Y., the National Bureau of Standards established a network of atmospheric noise recording stations throughout the world. The ARN-2 noise recorder at these stations measured three statistical moments of the noise: average power, average voltage, and average logarithm of the voltage. An empirically derived graphical method of obtaining an amplitude-probability distribution from these three moments, and its development, is presented. Possible errors, and their magnitude are discussed.

PROPERTIES OF ATMOSPHERIC NOISE AT VARIOUS RECEIVING LOCATIONS
EE Abstr. 6102/1962; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 6, Pgs 640-1, November-December 1960.
W.Q. Crichlow

URSI National Committee Report, London, 1960 (see Abstr. 2183/1962). The integrated noise level on 8 frequencies between 13 kc and 20 Mc was determined during the International Geophysical Year at 16 recording stations throughout the world. Published information is quoted on the amplitude-probability distribution and on methods for deriving the complete distribution from statistical moments measured by a standard noise meter.

MEASUREMENT OF THE ARRIVAL ANGLE OF "WHISTLERS"
J. Geophys. Research, Vol. 60, Pgs 364-365; September 1955.
D.D. Crombie

It is suggested that Storey's theory on the origin of whistling atmospherics could be treated by determining their arrival angle by a phase-measurement method based on that of Ross et al., using a pair of antennas spaced 15km apart along the direction of the horizontal component of the geomagnetic field.

A STUDY OF WHISTLING ATMOSPHERICS. III. OBSERVATIONS AT CLOSELY SPACED STATIONS

Phys. Abstr. 13681/1963; Austral. J. Phys. Vol. 15, No. 4, Pgs 470-81, December 1962.

J. Crouchley, K.J. Duff.

For Part II see Abstr. 10309 of 1961. Whistling atmospheric were recorded simultaneously at four stations with separations of about 150 km during the winter of 1960. Individual whistlers showed the same dispersions at all stations but significant differences in strength were sometimes observed. These features and the diffuseness of the whistlers are consistent with the idea of energy emerging from the ionosphere through localized regions of size of the order of 100 km or less. A method was developed of obtaining amplitude-frequency profiles. These were sometimes fairly flat but the less diffuse whistlers tended to show abrupt (up to 100 dB (kc/s)⁻¹) changes of amplitude of up to more than 20 dB for frequency ranges of about half a kilocycle per second. Such changes, were, on occasions, dissimilar at the four stations.

THE NATURE OF LIGHTNING DISCHARGES WHICH INITIATE WHISTLERS

Recent Advances in Atmospheric Electricity, Pgs 619-623 (Pergamon Press, London, 1958)

H.W. Curtis

The basic theory of whistler generation and propagation is outlined; magnetic tape recordings of these naturally occurring audio-frequency electromagnetic wave supplement this presentation. The known facts about those few discharges which produce whistlers are presented, and a contrast is then made between the few whistler-producing and the many non-whistler-producing discharges which occur in nature.

This presentation is intended to point out the many questions not yet answered concerning the nature of whistler initiating discharge.

EFFECT OF LIGHTNING DISCHARGES ON MAGNETOGRAPHS

A.K. Daas

See Section IV, Page 288.

INTEGRATED FIELD INTENSITY OF ATMOSPHERICS IN RELATION TO LOCAL THUNDERSTORMS

J. atmos. terrest. Phys. (GB), Vol. 25, No. 5, Pgs 306-8, May 1963.

Phys. Abstr. 23597/1963

M.K. Das Gupta, A.K. Sen

In the majority of cases, the starting time of the steady rise of the integrated field intensity of atmospheric (i.f.i.a.) recorded at Calcutta on 30 kc/s, precedes the reported time of a so-called nor'wester onset, or any other thundersquall onset, by 1 to 12 hours. The normal value of i.f.i.a. is attained within 5 hours of the reported time of the end of the thundersquall.

THE OBSERVATION OF VERY LOW FREQUENCY ELECTROMAGNETIC SIGNALS OF
NATURAL ORIGIN

O.E. Deal

See Section III, Page 218.

THE DIRECTION OF ARRIVAL AND POLARIZATION OF WHISTLER ATMOSPHERICS
EE Abstr. 4318/1957; CR Acad. Sci. (France), V. 244, No. 6, Pgs
797-9, 4th February 1957.

J. Delloue

The direction of arrival is determined from measurements of the phase difference between the signals produced by the whistlers in two pairs of identical aerials located at the ends of two perpendicular base lines, one of which coincides as nearly as possible with the mean-magnetic N-S direction. The polarization "in projection" is given by two vertical frame coils at right angles, located at the central station, and the polarization in the plane of the wave is deduced when the direction of arrival is known. Details are given of the equipment. Within the limits of accuracy set by the continuous background of atmospherics, the results obtained show that the apparent direction of arrival of whistlers is always near that of the local terrestrial magnetic field, as predicted by the magneto-ionic theory, the angle between the two directions rarely exceeding 25° . The apparent direction of arrival varies within the duration of a whistler, there being a certain latitude in the direction which may be due to the juxtaposition of elementary whistlers arriving by neighbouring paths of different lengths. On some nights when notable whistlers were rare, occasionally a rapid succession of several whistlers was observed, all having the same polarization and phase characteristics. This is considered due to the sudden and very localized appearance in the very high atmosphere of zones of ionization. The results relative to the polarization of the whistlers will be published later.

THE DETERMINATION OF THE DIRECTION OF ARRIVAL AND THE POLARIZATION OF
WHISTLERS, PART I, EXPERIMENTAL DEVICES

J. Phys. Radium (Paris), Vol. 21, No. 6, Pgs 514-526, June 1960. In
French.

J. Delloue

This article starts with a brief account of the characteristic features of the various electromagnetic perturbations of natural origin, and more particularly of those affecting the very low frequencies band. The author specifies the present state of knowledge on whistlers; he lays out the Storey-Eckersley theory which is based on magneto-ionic theory to account for whistling atmospherics and suggests a peculiar mode of propagation of very low frequency electromagnetic waves along the lines of force of the earth's magnetic field through the feebly ionized regions of the outer atmosphere. As a check to the foregoing theory, he tries to

determine the directions of arrival of whistlers which should make a rather small angle with the direction of the magnetic field, and their polarization which is related through a magneto-ionic formula to that angle. The article then goes on by giving an account of the measurement techniques and of some aspects of the problem and their influence on the apparatus design. It also describes the various parts of the equipment and the successive modifications to the whole of measurements as required in the course of the experiences. Difficult interpretation of diagrams observed on measuring oscillographs, both for the determination of the directions of arrival and for the polarization is then discussed. A simple method of representing the characteristics of a whistler is proposed.

EMERGENCE OF WHISTLERS FROM THE IONOSPHERE

EE Abstr.1242/1964; C.R. Acad. Sci. (France), Vol. 257, No. 6, Pgs 1327-31, 5th August 1963. In French.
J. Delloue, M. Garnier

The form of the wave front of certain pure whistlers can be interpreted if it is allowed that the electromagnetic energy emerges from the ionosphere at the level of the D region in a zone of small extent comparable to a point source. This result suggests that in certain cases, there is guidance by columns of ionized gas extending through the entire depth of the normal ionosphere.

THE POLARIZATION OF WHISTLERS IN RELATION TO THEIR DIRECTION OF ARRIVAL

Phys. Abstr. 4773/1964; C.R. Acad. Sci. (France), Vol. 257, Pgs 1131-4, 29th July 1963. In French.

J. Delloue, M. Garnier, F. Glangeaud, P. Bildstein

Most of the whistlers had directions of arrival near the vertical or the direction of the magnetic field. The polarization is circular for directions near vertical, becoming elliptical when the direction is more oblique, and linear for directions of arrival near the horizontal. The components of a complex whistler generally have different directions of arrival and polarization.

WHISTLING ATMOSPHERICS

NRL Report 4825, U.S. Naval Research Laboratory, Washington DC, 14th September 1956.

H.E. Dinger

Since 1953 NRL has been observing and recording audio-frequency atmospherics and their correlation with other geophysical phenomena. Beginning in April 1955, the diurnal variation in both whistler activity and the occurrence of "dawn chorus" has been determined. Whistler coincidence at several locations has been recorded in an attempt to prove LRO Storey's

theory on the mode of propagation of these atmospherics. Many whistlers of unusual character have been spectro-analyzed for the purpose of extending present theory to cover the general case. Plans have been formulated for synoptic observations at a number of selected locations during the International Geophysical Year.

OBSERVED TIME AND DIRECTIONAL VARIATIONS IN SFERIC ACTIVITY

Abstract in Symposium on Radiation from Lightning Discharges, Programme of Joint URSI-IRE Meeting, Washington, DC., 4th-7th May 1959, Pg 44.

R.H. Doherty

Recently the National Bureau of Standards has made measurements of the number of sferics per second (sferic rate) that exceed a present level. These sferic rates show temporal variations attributed to thunderstorm activity mainly within the U.S. Particularly, diurnal effects in the summer relate to the rise and decay of late afternoon and early evening thunderstorms. Diurnal effects are compared to day-to-day effects for the same periods of time. Seasonal effects are also covered to the extent possible with limited data.

Sferic densities (sferics per degree per second) are plotted on polar paper using a logarithmic scale to show the full range of amplitudes. The effect of seasonal and geographical changes upon the sferic densities is considered. Linear plots are utilized to show typical daily thunderstorm variations. Sferics observed in a narrow sector are interpreted to represent only one or two thunderstorms. The cumulative distributions of the rate vs. amplitude observed in a narrow sector are distinctly different from the corresponding omni-directional distributions. Amplitude distributions of sferics occurring in a narrow beam are discussed with respect to individual storms.

"WHISTLER MODE" ECHOES REMOTE FROM THE CONJUGATE POINT

Phys. Abstr. 7697/1959; Nature (GB), V. 183, Pgs 385-6, 7th February 1959.

R.L. Dowden, G.T. Goldstone

Reception of v.l.f. radio pulses (17.4 kc) at Hobart after a delay ~ 0.2 sec following transmission from Tokyo is interpreted as "whistler mode" propagation to somewhere near the geomagnetic conjugate point to Tokyo (around Darwin) followed by earth-ionosphere waveguide propagation to Hobart. Calculations using Storey's equation suggest an electron density $\sim 2 \times 10^4 \text{ cm}^{-3}$ at 1400 km. This experiment demonstrates that it is not necessarily safe to assume that short whistlers originate near one's conjugate point.

LOW FREQUENCY (100 KC) RADIO NOISE FROM THE AURORA

Phys. Abstr. 4815/1960; Nature (GB), V. 184, No. 803, 12th September 1959.
R.L. Dowden

Observations of radio noise on a range of frequencies from 4.6 to 180 kc covering the band between normal "hiss" (audio frequencies) and "cosmic noise" at Hobart have revealed at least one occasion on which "hiss" occurred at frequencies up to 180 kc. This suggests that radio noise at such frequencies which is usually attributed to cosmic sources might be hiss of terrestrial origin, generated in the upper atmosphere by auroral particles.

THEORY OF GENERATION OF EXOSPHERIC VERY-LOW-FREQUENCY NOISE (HISS)

Phys. Abstr. 19248/1962; J. geophys. Res. (USA), Vol. 67, No. 6,
Pgs 2223-30, June 1962.
R.L. Dowden

The travelling wave tube amplification process proposed by Gallet and Helliwell (1959) is considered in greater detail. Account is taken of the spiral motion of particles travelling in the magnetic field, the interaction distance for which amplification at any one frequency can occur, and the slowing down of the stream particles by the wave-amplification process. It is shown that narrow band bursts of hiss can be generated by weak electron streams of even very broad velocity and pitch distribution. The centre frequency of such a band is characteristic of the terminating latitude of the line of force of generation. Stronger streams produce an overload effect giving rise to wide and very wide bands. Narrow bands can be produced at other frequencies by streams of narrow velocity and pitch distribution.

VERY-LOW-FREQUENCY DISCRETE EMISSIONS RECEIVED AT CONJUGATE POINTS

Phys. Abstr. 21657/1962; Nature (GB), Vol. 195, 64, 64-5, (7th July 1962).
R.L. Dowden, R.A. Helliwell

It is suggested that multiple noise bursts observed at conjugate points at 5 kc/s could be explained in terms of a bunch of spiralling electrons moving from hemisphere to hemisphere. Such a cloud would emit the radiation backwards and would only be observed while travelling directly away from the observing station. The second author points out that such an effect can equally well be produced by whistler-mode echoes.

SIMULTANEOUS OCCURRENCE OF SUB-VISUAL AURORAE AND RADIO NOISE BURSTS
ON 4.6 KC

Phys. Abstr. 11661/1959; Nature (GB), V. 183, Pgs 1618-19, 6th June
1959.

R.A. Duncan, G.R. Ellis

A 6300 A airglow scanning photometer has recorded transient increases in intensity presumably due to sub-visual aurorae. These increases are often accompanied by an increase in radio noise at 4.6 kc. It is suggested that both phenomena are caused by the entry into the atmosphere of proton or electron streams.

THE VLF RADIO EMISSIONS FROM THE EARTH'S OUTER ATMOSPHERE

EE Abstract 1236/1964; Proc. Instn. Radio Engrs. Australia, Vol. 24,
No. 2, Pgs 204-7, February 1963.

G.R.A. Ellis

Electromagnetic waves in the frequency band from 2-20 kc/s are generated by streams of electrons travelling through the distant outer atmosphere of the earth. They may be recorded with very simple equipment and provide information about the disturbances which occur in these regions following particle outbursts from the sun. The properties of these vlf emissions are described and details of suitable receivers are given.

SPACED OBSERVATIONS OF RADIO NOISE FROM THE OUTER ATMOSPHERE

G.R.A. Ellis, D.G. Cartwright, J.R.V. Groves

See Section IV, Page 293.

LOCATION OF INITIAL SPHERICS OF LONG WHISTLERS

Zhur. Meteorol., Vol.13, Pgs 193-194, July-August 1959. In Russian.

G. Entzian, C. Popp

Sources of atmospheric spherics were located by a USSR research vessel in the vicinity of Ireland in December 1958, and coincidences with long whistlers were observed. One of the records is analyzed.

A 27 KC SUDDEN ENHANCEMENT OF ATMOSPHERICS ANOMALY

W.A. Feibelman

See Section IV, Page 371.

ANALYZERS FOR ATMOSPHERICS

G. Francini

See Section III, Page 221.

REPORT ON SOME OBSERVATIONS ON ATMOSPHERIC ELECTRICITY
Geophysical Research Papers No. 42, U.S. Air Force, Cambridge Research
Centre, Pgs 135-139, November 1955.
J. Fuchs

The audio-frequency phenomena of "whistlers" or "sifflements", which can be heard in long wires as a musical tone descending in frequency from several kilocycles to nearly zero cycles within an interval of about 1 sec., was observed at the Sonnblick Observatory (elevation 10,200 ft) continuously over a six-year period. It shows a daily and a yearly fluctuation (Trabert; Conrad). Studies of potential-gradient measurements made during times of disturbed weather have shown distinct characteristics associated with the passage of different types of meteorological fronts. The form of the potential-gradient curve as a function of time during the passage of cold fronts is quite unique and easy to distinguish from that during the passage of warm fronts (Seper). Observations of the kind of atmospherics called "grinders" and "clicks" have shown that the former, probably resulting from glow discharges, exist only during the earlier phases of the development of a thunderstorm, while the latter, resulting from normal lightning flashes, predominate during the storm's main phase and thereafter. Continuous observations of grinders and clicks are therefore a valuable source of information about the electrical state of weather situations and also give indications about the dynamic processes involved.

EFFECT OF RECEIVER BANDWIDTH ON THE AMPLITUDE DISTRIBUTION OF VLF
ATMOSPHERIC NOISE

F.F. Fulton, Jr.

See Section III, Page 223.

ON THE THEORY OF AMPLITUDE DISTRIBUTION OF IMPULSIVE RANDOM NOISE

K. Furutsu, T. Ishida

See Section III, Page 223.

TERRESTRIAL EXTREMELY LOW FREQUENCY NOISE SPECTRUM IN THE PRESENCE OF
EXPONENTIAL IONOSPHERIC CONDUCTIVITY PROFILES

J. Galejs

See Section I, Page 41.

ORIGIN OF "VERY-LOW-FREQUENCY EMISSIONS"

R.M. Gallet, R.A. Helliwell

See Section I, Page 43.

A SYSTEMATIC CLASSIFICATION OF NUMERICAL VLF NOISES OTHER THAN WHISTLERS

Paper presented at IRE-URSI Symposium, Washington, D.C., 22nd-25th May 1957.

R.M. Gallet, D.L. Jones

Starting at the beginning of 1956 an intensive programme of observations of whistlers and other types of vlf noises, so-called hiss, dawn chorus, etc., was undertaken by the writers, with the help of J. Watts who is responsible for very valuable achievements in the recording technique and the securing of spectrograms. A very high sensitivity was achieved by using the one-mile loop antenna built for vlf sweep frequency ionospheric soundings by Watts. Since the beginning of 1957, simultaneous observations at Anchorage, Alaska, are available.

The magnetic tape recordings are taken at 35 minutes past every hour. A collection of about 10,000 spectrograms is now available and expands continuously. Besides the whistlers, a large number of other types of vlf noises have been recognised and systematically studied.

Their occurrence is essentially related to periods of geomagnetic activity, according to a progressive pattern of shape variations. A number of "families" have been established by criteria of reproducibility of forms of spectrograms and progressive transitions around a general property such as the risers, the hooks, quasi-horizontal tones, tails, etc. Besides the shape the degree of sharpness or fuzziness is also important, going to the extreme case of the hiss, which appears as a solid band of noise on the spectrograms, continuous in time sometimes for hours. Many phenomenological properties have been established for the extra-terrestrial beams and bunches of ionized particles which seem to be responsible for their production.

An atlas of spectrograms of these vlf noises is in publication, and is intended to serve as a guide for IGY observations. The presentation of these data is relevant to a companion paper (see preceding abstract) related to the theory of these noises.

A THEORY OF THE PRODUCTION OF VLF NOISE (SO-CALLED DAWN CHORUS)
BY TRAVELLING WAVE AMPLIFICATION IN THE EXOSPHERE OF THE EARTH
Prepublication Papers NBS IRE PGAP Symposium on Propagation of VLF
Waves, Boulder, Colorado, 23rd-25th January 1957, Vol. II, Paper 20.
R.M. Gallet, R.A. Helliwell

VLF hiss is frequently observed in auroral regions. It is the purpose of this paper to suggest a mechanism for the generation of hiss and constant tones based on selective travelling wave amplification of noise energy arriving from the sun or elsewhere and to suggest its extension to the dawn chorus.

NUMERICAL COMPUTATIONS FROM THE THEORY OF VLF NOISE EMISSIONS AND THEIR
COMPARISON WITH OBSERVATIONS

Paper presented at IRE-URSI Symposium, Washington DC, 22nd-25th May 1957.
R.M. Gallet, A. Hessing

A theory for explaining the very low frequency emissions other than whistlers (so-called hiss, dawn chorus, hooks, etc.) was presented by Gallet and Helliwell in a recent communication. This theory now has been developed in detail with the purpose of obtaining numerically the predicted spectra (frequency vs time) and to compare them with the observations presented in the preceding communication.

A programme for the total time $t + T$ vs. frequency f has been developed on the electronic computer IBM650. The computations have been made with different models of the distribution of electronic density outside the earth. Computed curves and observed spectrograms will be shown and compared. A short discussion of the best models of the exosphere and of the velocity v from these results will be given.

PROPAGATION AND PRODUCTION OF ELECTROMAGNETIC WAVES IN A PLASMA

Nuovo Cimento, Supplement 13, No. 1, Pg 234, 1959.
R.M. Gallet

A very brief discussion on the non-thermal radiation in a plasma is given. Examples are: (1) radio bursts from the planet Jupiter, (2) solar bursts, (3) galactic radio emission, (4) aurorae. The author then goes on to say that the theory of a propagation in a plasma explains the phenomenon of "whistlers" and "very low frequency emission". Whistlers, which are now well known, are described as a train of waves in the kilocycle range which propagate along the earth's magnetic field with high dispersion and low velocity; vlf emissions are said to result from the mass motion of ionized clouds in the outer atmosphere at 2 or 3 earth's radii. The author then suggests that, using the whistler mode, the electron density and electron temperature of a dense plasma could be measured with micro-waves whose frequency is lower than both the plasma and the gyrofrequency.

VLF EMISSIONS

In U.S.A. Nat. Com. of the Int. Scientific Radio Union. Report to the National Academy of Sciences-National Research Council on the 13th General Assembly, 5th-15th September 1960, London UK, Pgs 255-257. Washington, National Academy of Sciences, 1961.
R.M. Gallet

A NOTE ON WHISTLER PROPAGATION IN REGIONS OF VERY LOW ELECTRON DENSITY
EE Abstr. 3827/1959; J. Geophys. Res. (USA), V. 63, No. 4, Pgs 862-5,
December 1958.

O.K. Garriott

As wave-frequency approaches the plasma frequency, the refractive index passes through a pole resulting in a maximum group velocity at some frequency below the plasma frequency, and thus suggesting another possible mechanism for the formation of noise whistlers. Digital computations based on an assumed ionospheric model as described, which indicate that although two noise frequencies are possible only one may be observable.

GUIDING OF WHISTLERS BY THE MAGNETIC FIELD

Planetary Space Sci., Vol. 5, Pgs 274-282, August 1961. In French.
R. Gendrin

A mechanism is proposed which explains the wideband noise observed during whistler reception. A particle moving with velocity $cf_H/2f_0$, where f_H is gyrofrequency and f_0 is the plasma frequency, causes a wave to be propagated along the earth's magnetic field; all frequency components of the wave travel with the same velocity.

INVESTIGATION OF ATMOSPHERIC RADIO NOISE

Final Report, Contract AF 19(604)-876, the University of Florida,
Gainesville, Florida, 15th November 1957. AD-133 768.
T.S. George

A statistical study was made of atmospheric noise characteristics for further understanding of the nature of atmospheric noise and for evaluation of its effect on communication systems. A probability distribution was measured under varying noise conditions to enable the calculation of such parameters as average power. A good approximation to the distribution of noise and envelope was afforded for the logarithmic normal curve. The average noise envelope varied directly as a power of the bandwidth where the power was about 0.34 as compared to 0.5 for pure fluctuation noise.

The rise time of very-low-frequency pulses such as are propagated by lightning strokes was studied in terms of the length of the propagation path. Only ground wave propagation was considered. An analysis of peak amplitude indicated that at considerable ranges the log-normal law was followed closely. At close ranges the log-normal was not a good approximation. Specialised measuring devices were designed and constructed. These devices included a meteoric signal analyzer and two models of lightning stroke recorders.

This Final Report was preceded by 16 Scientific Reports, mostly by A.W. Sullivan. These are available from ASTIA.

PROPAGATION OF WHISTLING ATMOSPHERICS IN THE UPPER ATMOSPHERE

Radiofizika, No. 5-6, Pgs 49-59, 1958, In Russian.

B.N.Gershman

The disturbances covered by the term "whistlers" lie in the frequency range 0.4 to 20 kc/c and originate in lightning flashes. They reach a height of 15 to 20,000 km. Their propagation characteristics are determined by the magnitude and, particularly, the direction of the earth's magnetic field. One table.

PROPAGATION AND GENERATION OF LOW-FREQUENCY ELECTROMAGNETIC WAVES IN THE UPPER ATMOSPHERE

Uspekhi Fiz. Nauk (USSR), Vol.72, No. 2, Pgs 235-271, October 1960.

Translation in: Soviet Phys. Uspekhi, Vol. 3, No. 15, Pgs 743-764, March-April 1961.

B.N. Gershman, V.A. Ugarov

This summarizes both experimental and theoretical knowledge on whistlers and VLF emissions. The use of low frequency radio waves to provide information on the upper atmosphere (such as electron concentration, magnetic field, velocity of solar corpuscular streams, etc.) is also discussed, and the review ends with a consideration of some unsolved problems.

MEASUREMENT OF ATMOSPHERIC NOISE

B.B. Ghosh, S.N. Mitra

See Section III, Page 227.

ATMOSPHERIC NOISE LEVELS FROM 0.6 TO 10 KILOCYCLES PER SECOND

J. geophys. Res. (USA), V. 66, No. 6, Pgs 1745-49, June 1961.

L.H. Ginsberg, D.J. Blatner

A comprehensive series of observations on atmospheric noise in California and Florida for frequencies below 10 kc is described and analyzed. The diurnal variation for N-S loop orientation is a minimum in the interval 0400-1200 L.T. at both sites and minimum noise levels are found to occur between 3 and 5 kc. The latter result is in agreement with the theory of Wait (2886/1957).

ATMOSPHERICS ON 20 KC AT THE TIME OF LOCAL AURORAE

Phys. Abstr. 21394/1960; Nature (GB), V. 187, Pgs 225-6, 16th July 1960.

E. Gherzi

On 30 occasions when bright aurorae were seen at Montreal, Canada, violent bursts of atmosphericics were recorded simultaneously on a fre-

quency of 20 kc. These latter are explained by the presence of ionized strips of the lower stratosphere, or upper troposphere. The patchy ionization is caused by the entry of auroral particles at these levels, and it is sufficiently intense to enhance the degree of reflection of distant atmospherics.

SFERICS MONITORING SYSTEM

E.G. Goddard

See Section III, Page 229.

THE OBSERVATION OF SHORT PERIOD FLUCTUATIONS IN THE GEOMAGNETIC FIELD

P.A. Goldberg

See Section III, Page 229.

MAGNETO-IONIC DUCT PROPAGATION TIME (WHISTLER MODE) VS GEOMAGNETIC LATITUDE AT 4 KC

EE Abstr. 14879/1962; Proc. Inst. Radio Engrs. (USA), Vol. 50, No. 8, 1852, August 1962.

C.V. Greenman

The path length of a whistler mode signal from origin to conjugate point increases with geomagnetic latitude. However, because the group velocity varies with height, the time of propagation need not increase steadily with latitude. It is shown that for one model of the ionosphere the calculated time delay curve for 4 Mc/s signal has a subsidiary maximum at a latitude of 20° and a minimum at 35° .

AUDIO-FREQUENCY ELECTROMAGNETIC RADIATION IN THE AURORAL ZONE

J. Geophys. Research, Vol. 65, No. 9, Pgs 2749-2758, September 1960.

G. Gustafsson, A. Egeland, J. Aarons

During three one-month periods, continuous spectograms of the electromagnetic energy in the spectral region between 10 cps and 10 kc/sec were recorded in Kiruna, Sweden.

The records were examined from the viewpoint of background energy. Throughout the entire frequency band studied, there is a low daytime signal level and a night-time maximum. The ratio of the maximum to minimum amplitude varies as a function of frequency (the higher maximum to-minimum ratio occurs at the lower frequency range of 20 to 200 cps) and with the season of the year. It is concluded that the daytime ionosphere absorbs the energy throughout the entire spectrum studied. It was found that, although strong deviations of the signal level from the normal were often associated with geomagnetic disturbances, there was a general lack of correlation between magnetic index and low-frequency noise, except in the 10- to 45-cps frequency range.

The origin of the background signals is probably twofold, atmospherics from great distances as well as magnetic and exospheric fluctuations contributing to the lower band.

On eleven occasions, electromagnetic radiation associated with micropulsations of the earth's magnetic field was detected. Two frequency bands were identified; one centred at 750 cps, which is the gyro frequency for protons at an altitude of 100 km above Kiruna; and the other ranging between 1.8 and 4.5 kc/s, which has been identified as hiss. On all but one of the occasions when emissions were detected the 750 cps signals were quite stable in frequency. During four of the longest periods when radiation was recorded, the low-frequency emissions were received between two phases of a magnetic storm; micropulsations were simultaneously evident on the Kiruna magnetograms.

RAPID GEOMAGNETIC FLUCTUATIONS

S. Haraldson

See Section III, Page 235.

A METHOD FOR THE DETERMINATION OF LOWER IONOSPHERE PROPERTIES BY MEANS OF FIELD MEASUREMENTS ON SPHERICS

J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 4, 463-78, July-August 1962.

Phys. Abstr. 15232/1962

F.B. Harris, Jr., R.L. Tanner

The propagation of audio-frequency and sub-audio-frequency waves between the earth and an ionosphere whose conductivity varies continuously with altitude is considered in detail. It is shown, on the basis of existing data on the ionosphere, that waves in this frequency range can be considered to be confined to a thin, but not sharply bounded, spherical shell about the earth. Greatly simplified radial wave equations in dimensionless form are derived incorporating this approximation. Solutions of these equations are given for two regions: where $\sigma/\omega\epsilon_0 \ll 1$ and, in the case of certain restricted types of conductivity profile for the high-altitude region where $\sigma/\omega\epsilon_0 \gg 1$. It is demonstrated that at frequencies about 50 c/s the propagation constant can be obtained from measurements of the horizontal components of electric and magnetic fields in individual atmospherics at airplane altitudes, while at lower frequencies the same information can be obtained through ground-based observation of cavity resonance effects in spheric noise. Existing data on these cavity resonances are used to calculate the complex propagation constant as a function of frequency from 6 to 34 c/s. The results, when extrapolated to higher frequencies, predict attenuation rates in excellent agreement with currently available data.

THE MEASUREMENT OF ATMOSPHERIC RADIO NOISE BY AN AURORAL COMPARISON
METHOD IN THE RANGE 15-500 KC

J. Harwood, B.N. Harden
See Section III, Page 235.

ATMOSPHERIC RADIO NOISE

J. Harwood, C. Nicolson
See Section III, Page 236.

ATMOSPHERIC RADIO NOISE AT FREQUENCIES BETWEEN 10 KC AND 30 KC

J. Harwood
See Section III, Page 236.

INITIAL RESULTS OF A NEW TECHNIQUE FOR INVESTIGATING SFERIC ACTIVITY

J. Research NBS, Vol. 65D, No. 2, Pgs 157-166, March-April 1961.
G. Hefley, R.H. Doherty, R.F. Linfield

A technique for the measurement of sferics on a massive scale has been developed. The technique pertains largely to spectral and directional measurements. Representative samples of data are presented and discussed. The data samples include:

- (1) Diurnal variations in sferic rates as a function of the 10.5, 40 and 100 kc/s component amplitudes.
- (2) Sferic rates as a function of triggering level.
- (3) Directional measurement of sferic rates.
- (4) Correlation of directional sferic rates with weather reports.
- (5) Sferic amplitude distributions at 10.5, 40, and 100 kc/s.
- (6) Comparison of the distribution of amplitudes of the sferics from two different storm areas.

Recommendations for future measurements are made.

SOME OBSERVATIONS OF THE GEOMAGNETIC FLUCTUATION SPECTRUM AT AUDIO
FREQUENCIES

J.R. Heirtzler
See Section III, Page 237.

THE WHISTLER - A NEW HIGH-LATITUDE PHENOMENON

J. Geophys. Research, Vol. 61, No. 1, Pgs 139-142, March 1956. Similar material was published in The Nose Whistler - a High Latitude Phenomenon. Scientific Rept. 11, Contract AF 19(604)-795, Radio Propagation Lab., Stanford University, Stanford, California (May 1956).
R.A. Helliwell, J.H. Crary, J.H. Pope, R.L. Smith

Whistlers exhibiting both falling and rising tones from a starting

("nose") frequency have been observed at College, Alaska. These often occur in trains with the nose frequently gradually descending in time. It is proposed that these whistlers originate from lightning-discharge impulses propagated along dispersive paths along lines of the earth's magnetic field, similar to conventional whistlers, the nose frequency corresponding to the frequency at which the energy is propagated with maximum velocity. The condition is realized for the longitudinal extraordinary mode for a frequency which is some fraction of the gyro frequency, and its magnitude shows that a substantial contribution to the total dispersion must occur near the top of the path where the gyro frequency is relatively low.

A NEW WHISTLER DISPERSION THEORY

Paper presented at IRE-URSI Symposium, Washington DC, 30th April, 1st - 3rd May 1956.

R.A. Helliwell, T.F. Bell, R.L. Smith

Expressions are derived for the group velocity and attenuation rate in the longitudinal extraordinary mode of propagation for frequencies below the gyro frequency. Detailed graphs of refractive index and the above quantities are shown. The theory predicts a maximum in the group velocity at a frequency less than or equal to one-fourth of the gyro-frequency. This behaviour is not exhibited by the Eckersley approximation, a special case of the theory. The region of validity of the graphs is discussed. Examples are given of their application to the study of whistlers and related low frequency phenomena.

LOW FREQUENCY PROPAGATION STUDIES - PART I: WHISTLERS AND RELATED PHENOMENA,

Final Report, Contract AF 19(604)-795, Radio Prop. Laboratory, Stanford University, Stanford, California (December 1956, revised 28th May 1958). AFCRC-TR-56-189. AD-110 184.

R.A. Helliwell

This report is divided into two parts. Part I is concerned mainly with whistlers and related low frequency signals which pass through the ionosphere. Part II covers certain studies of low-frequency propagation in which the signals are reflected from the ionosphere. (AD-110 185 - See Yabroff, I.W.).

COMPARISON OF WHISTLERS WITH MAGNETO-IONIC DUCT SIGNALS FROM STATION NSS,

Paper presented at IRE-URSI Symposium, Washington, DC, 23rd-26th April 1958.

R.A. Helliwell, E. Gehrels

The time delays of one-hop whistlers and echoes from NSS (near Washington DC) were measured at Cape Horn on 15.5 kc. They correlated closely, even though their day-to-day variations were large. The whistler variations could not, therefore, be attributed to changes in the location of the causative lightning flashes. At Washington DC there were 18 two-hop whistlers which were coincident at Cape Horn. Their dispersions were 30% greater, on the average, than twice those at Cape Horn. If the propagation path had been the same for the Cape Horn and Washington Whistlers, the dispersion ratio should have been exactly two.

These results are compared with NSS split-echo data and recent whistler data from the IGY programme. The study provides new evidence that magneto-ionic duct signals are often restricted to discrete paths. Two possible models for such paths are compared. They are based on (1) columns of field-aligned ionization extending into the outer ionosphere and (2) irregularities in the E or F2 layer.

Tape recordings of whistlers at Washington, D.C., were kindly supplied by H.E. Dinger of the Naval Research Laboratory.

SOME PROPERTIES OF LIGHTNING IMPULSES WHICH PRODUCE WHISTLERS

EE Abstr. 1797/1959; Proc. Inst. Radio Engrs (USA), V. 46, No. 10, Pgs 1760-2, October 1958.

R.A. Helliwell, A.G. Jean, W.L. Taylor

Gives conclusions drawn from the result of simultaneous observations of storms at Boulder and at Stanford. It is found that a characteristic waveform is often associated with the impulse that produces a whistler. It possesses an intense energy peak near 5 kc and occurs infrequently compared with other atmospherics. Whistler producing discharges are more frequent over sea than over land. The time of origin of a whistler should not be calculated from the Bakersley dispersion law.

WHISTLER THEORY OF ELF PROPAGATION

From Proceedings of the 1960 Conference on the Propagation of ELF Radio Waves, Nat. Bur. Stands. (USA), Boulder Labs, Technical Note. No. 1, 1960.

R.A. Helliwell

No abstract.

VERY LOW FREQUENCY OBSERVATIONS IN THE ANTARCTIC

Paper presented at 41st Annual Meeting, American Geophysical Union, Washington, D.C., 27th - 30th April 1960.

R.A. Helliwell, L.H. Martin, K. Marks

Many whistlers received at the Antarctic stations have dispersions characteristic of middle latitudes, suggesting propagation below the ionosphere from the lower-latitude exit point. Many complex and unusual phenomena occur with strong activity at very low frequencies, probably extending below 125 cps. Varying types of chorus and discrete emissions occur simultaneously in separate and distinct frequency bands. Data from Byrd Station shows that aurora is closely associated with one type of VLF hiss usually occurring about 4 kc/s and often extending to at least 16 kc/s the upper frequency limit of the recorder. Diurnal and seasonal behaviour of whistlers and other phenomena under the unique conditions of the Antarctic have been established. Whistlers are most prevalent in local winter, and chorus and other emissions are more prevalent in local summer.

ATMOSPHERIC WHISTLERS

Phys. Abstr. 7698/1959; Proc. Inst. Radio Engrs (USA), V, 47, No. 2, Pgs 200-8, February 1959.

R.A. Helliwell, M.G. Morgan

A general description is given. Their discovery, and the development and proof of a theory to explain them, are reviewed. The I.G.Y. synoptic programme is described and examples of results, both individual and statistical, are presented and discussed.

SUMMARY OF RESEARCH ON WHISTLERS AND RELATED PHENOMENA

EE Abstr. 6108/1962; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 6, Pgs 624-6, November-December 1960.

R.A. Helliwell, M.G. Morgan

URSI National Committee Report, London, 1960 (see Abstr. 2183/1962). This is a synopsis of research on whistlers and related phenomena carried out at Stanford University and at Dartmouth College (USA) since the XIIth General Assembly of URSI. The results from a number of stations located both in Northern and Southern Hemisphere are summarized and the daily and seasonal variations noted. Techniques for spectrographic analysis have been developed which in many cases enable unambiguous identification of the source of both long and short whistlers. Methods for identifying the causative spheric associated with whistlers are included. A new mechanism for accelerating charged particles in the outer ionosphere has been proposed using a circularly polarized swept-frequency v.l.f. transmitter to accelerate relativistic electrons trapped by the earth's magnetic field by propagating in the whistler mode. Such a mechanism

could be used to study the dynamic processes in the outer ionosphere as well as whistler-mode propagation. An experiment to measure the angle of arrival of whistlers and ionospherics by comparing the time of arrival at three stations mutually 100 km apart is in progress.

WHISTLERS WEST IGY-IGC SYNOPTIC PROGRAMME

Final Report, Nat. Science Foundation Grants, IGY 6.10/20 and G-8838, Electronic Laboratories, Stanford University, Stanford, California. 20th March 1961; AD-254 279.
R.A. Helliwell, D.L. Carpenter

The operation and first results from the Whistlers-West project, directed by Stanford University during IGY-IGC, are described. Tape recordings of whistlers and VLF ionospheric noise (VLF emissions) were taken at 10 western-hemisphere stations operating from 1st July 1957 through 31st December 1959. The methods for handling tapes and performing auroral analyses are described. New methods for analyzing the spectra of whistlers are introduced, including techniques for locating whistler sources and for measuring whistler dispersion.

Among the recommendations are proposals for further synoptic work, satellite and rocket measurements, direction finding, extension of observations to frequencies above and below those used during IGY-IGC, correlation with auroral phenomena, and use of VLF stations for whistler-mode studies. A bibliography is included.

WHISTLER-TRIGGERED PERIODIC VERY-LOW FREQUENCY EMISSIONS

EE Abstr. 1273/1964; J. Geophys. Res. (USA), Vol. 68, No. 19, 5387-95, 1st October 1963.
R.A. Helliwell

From new experimental data on the relationship between whistlers and periodic v.l.f. emissions (v.l.f. ionospheric noise) it is found that both the dispersive and non-dispersive types of periodic noise are of common origin. In the cases examined, a sequence of emissions is indicated or "triggered", by a whistler, and the period between emissions is the same as the whistler-mode echoing period at some frequency within the range of the emission. To explain these results it is proposed that the generation, or triggering, of the emissions is controlled by packets of electromagnetic waves echoing in the whistler mode. In this triggering hypothesis it is supposed that the wave packets act to organize temporarily the particles in existing streams of charge so that their radiation is coherent. The resultant temporary increase in total radiation is seen on the ground as a short burst of noise. An earlier explanation of non-dispersive periodic noise based on a postulated small bunch of particles that oscillates between its mirror points in the earth's magnetic field is found to be incompatible with the data.

ATMOSPHERIC WAVEFORMS WITH VERY LOW-FREQUENCY COMPONENTS BELOW 1 KC
KNOWN AS SLOW TAILS

F. Hepburn

See Section III, Page 237.

ATMOSPHERICS WITH LONG TRAINS OF PULSES

Phys. Abstr. 10360/1954; Phil. Mag. (GB), V. 45, Pgs 917-32, September 1954.

F. Hepburn, E.T. Pierce

The waveforms of atmospherics having long-continued trains of pulses, and the systematic modifications associated with time of recording, storm distance and the presence of a l.f. component, are described. Their interpretation is discussed and the results of analysis assuming the simple ionospheric reflection mechanism are presented. Estimates of reflection height and storm distance show the applicability of the theory to the temporal parameters of the waveforms, and the origins of two groups of atmospherics having calculated ranges of 4500 and 7000 km are considered. The variation of pulse amplitude with reflection order is shown to lead to the postulation of horizontal radiating elements in the channel during the later stages of the return stroke, although difficulties arise in reconciling this concept with magnitude and orientation of the horizontal elements.

ATMOSPHERICS WITH VERY LOW-FREQUENCY COMPONENTS

EE Abstr. 5100/1953; Nature (GB), V. 171, Pgs 837-8, 9th May 1953.

F. Hepburn, E.T. Pierce

Observations of the l.f. "slow-tail" component in the waveform of atmospherics shows that, on the average, both the time occupied by the first quarter-period of the tail and the time interval between the start of the main oscillatory section of the atmospheric and the commencement of the tail increase in a linear manner with the distance of origin of the atmospheric; the rate of increase being significantly different by day and by night. Assuming a waveguide model for the propagation (perfectly conducting earth, ionosphere of conductivity σ , at height h) estimates are made as follows: $\sigma = 5 \times 10^3$ e.s.u. (day), 11×10^3 e.s.u. (night); $h = 65$ km (day), 90 km (night).

WAVE-GUIDE INTERPRETATION OF ATMOSPHERIC WAVEFORMS

J. Atmos. Terrest. Phys. Vol. 10, No. 3, Pgs 121-135, March 1957.

F. Hepburn

The precise current variation in the lightning discharge channel and the propagation characteristics of the transmission path for the low-

frequency radio waves generated provide possible explanations of the finer details of recorded electric-field change waveforms and some of the observed anomalies in the application of the pulse-reflection theory to "atmospherics". A graphical construction for the prediction of waveforms, given the source conditions indicate how the change in shape can be explained in terms of source effects and the mode response of an imperfectly conducting infinite parallel-plane waveguide, whose known propagation characteristics give a qualitative explanation of the diversity of waveforms recorded. The dependence upon range and time of day provides experimental confirmation of Budden's waveguide approach. One type of waveform, observed during day and night, indicates a directional variation of the propagation factor transcending the diurnal variation over a certain region.

CLASSIFICATION OF ATMOSPHERIC WAVEFORMS

Phys. Abstr. 2075/1958; J. atmos. terrest. Phys. (GB), V. 12, No. 1, Pgs 1-7, 1958.

F. Hepburn

The desirability and requirements of a systematic classification of atmospheric waveforms (electromagnetic disturbances resulting from the generation and subsequent propagation of radio waves from lightning discharges) are discussed. An observational scheme is suggested and interpreted in terms of known properties of the discharges and propagation mechanisms. This data is reviewed to clarify application of the scheme to individual waveforms. The relationship of the classification to previous inadequate groupings is indicated.

INTERPRETATION OF SMOOTH TYPE ATMOSPHERIC WAVEFORMS

J. Atmos. Terrest. Phys., Vol. 14, Pgs 262-272, 1959.

F. Hepburn

Following a brief survey of the conflicting opinions in this field and general remarks on pulse reflection and waveguide interpretations of atmospheric waveforms, the analyses of smooth type waveforms of varying degrees of irregularity are considered. Since observation suggests such irregularities are a source phenomenon, the implications of various discharge currents in the lightning channel are discussed in terms of waveguide propagation on the first-order mode and are seen to explain regular and pseudo regular waveforms. The simple reflection theory is also extended to more complicated source conditions to give analagous conclusions. Obviously irregular waveforms are tentatively ascribed to discharges of pulsating character.

Amplitude analysis of the waveform oscillation is shown to give the waveform spectrum very simply so that observations of a statistical

nature can yield both the average spectrum at the source and the relative attenuation coefficients for the respective frequencies which are propagated.

A review of previous work in the light of the present paper is thought to resolve the apparent discrepancies.

APPARATUS FOR THE STATISTICAL STUDY OF ATMOSPHERICS IN THE VERY LONG WAVE REGION

Phys. Abstr. 23600/1963; Z. angew. Phys. (Germany), Vol. 16, No. 1, Pgs 40-4, July 1963. In German.
G. Heydt, H. Volland

The apparatus counts atmospherics in eleven frequency bands between 5 and 50 kc/s. Magnetic tape recording enables the amplitude distribution to be found by repeated playbacks with different input thresholds. A mathematical analysis of the instrumental errors is given.

ELECTROMAGNETIC RADIATION FROM LIGHTNING STROKES

J. Franklin Inst. (USA), V. 263, No. 2, Pgs 107-20, February 1957.
E.L. Hill

A theory is given of the spectral distribution and the absolute amount of low frequency electromagnetic radiation emitted from a vertical lightning stroke from **cloud-to-ground**. The calculation depends on an assumed physical mechanism for the flow of charge on the discharge channel, but the model corresponds closely to the empirical observations of Scholand, Pierce and others. The radiated energy has a maximum intensity at about 11 kc and a total width at half-maximum of 12 kc. The predicted radiation in the megacycle region agrees reasonably well with that reported by Chandrashekhar Aiya (Abstr. 5371B of 1955); Proc. Inst. Radio Engrs (USA), V. 43, Pgs 966-74, 1955), although the present theory was developed primarily for the low frequency region. The total energy radiated in one leader and return stroke is estimated to be about 220,000 joules.

VERY LOW-FREQUENCY RADIATION FROM LIGHTNING STROKES

EE Abstr. 5213/1957; Proc. Inst. Radio Engrs, (USA), V. 45, No. 6, Pgs 775-7, June 1951.
E.L. Hill

A theory of the generation of low-frequency electromagnetic radiation by cloud-ground lightning strokes is presented. Only the effect of the return stroke is considered. The predicted form of the radiated pulse from the return stroke is a single cycle with a field variation which varies linearly with time. The spectral distribution of the radiated energy is found to be centred at about 11 kc with a total width a half-maximum of 12 kc. The total energy radiated in one leader and return stroke is estimated at 22×10^4 J. Some qualitative considerations on the emission of radiation at extremely low frequencies are given.

THE PRODUCTION OF WHISTLERS BY LIGHTNING

Abstract: Symposium on Radiation from Lightning Discharges. Programme of Joint URSI-IRE Meeting, Washington DC, 4th-7th May 1959, Pg 43.
E.L. Hill

The evidence on the production of whistlers by lightning suggests that conditions over a whole storm area are involved, rather than the properties of individual lightning strokes. This may imply the existence of some type of local ionospheric control by storms having particular characteristics. Possible conditions are, (1) very high altitudes for the upper electrical charge distribution, leading to extended general electrical fields, (2) correlation between successive ground strokes, (3) exceptional electric activity in cloud-cloud strokes perhaps correlated with cloud-ground strokes.

THE PRODUCTION OF WHISTLERS BY LIGHTNING

EE Abstr. 3123/1960; Proc. Inst. Radio Engrs, (USA), Vol.48, No. 1, Pgs 117-19, January 1960.
E.L. Hill

The correlation between lightning strokes and whistlers is briefly discussed, and it is suggested that conditions in the equalizing layer, above the storm area and below the ionosphere, play an important part in the production of whistlers.

LIGHTNING STROKES AS SOURCES OF WHISTLERS

Abstract: Symposium on ELF Propagation and Wave Forms, Programme of Joint IRE-URSI Meeting, Washington DC, 2nd-5th May 1960, Pg 101.
E.L. Hill

The production of whistlers by lightning discharges appear to involve some mechanism of coupling between a storm area and the lower ionosphere. A rough physical model for such a mechanism, dependent on the presence of negative ions in the atmosphere, is suggested. The intense electric fields associated with a thunderstorm may produce a transient pulse of electrons from the negative ions which, in turn, simulates the presence of electrical ducts leading into the lower ionosphere. In this way a storm area may be able to produce a type of local ionospheric control. The association of this mechanism with meteorological factors is not clear.

HEAVY-ION EFFECTS IN AUDIO-FREQUENCY RADIO PROPAGATION

J. Atmos. Terrest. Phys., Vol. 11, No. 1, Pgs 36-42, 1957.
C.O. Hines

The usual theory of whistler propagation, in which the effects of electrons alone are considered, leads to the conclusion that whistler ray directions cannot differ markedly from the direction of the geomagnetic field. When the effects of heavy ions are considered, however, it is found that all directions of propagation are possible at audio frequencies, and that the dispersion of frequencies takes place in opposite senses for longitudinal and transverse propagation. These theoretical results may suggest new possibilities for the detection of heavy ions and for the interpretation of some types of audio-frequency observations.

LOW AUDIO-FREQUENCY ELECTROMAGNETIC SIGNALS OF NATURAL ORIGIN

Nature, Vol. 177, Pgs 536-537, 17th March 1956.

R.E. Holzer, O.E. Deal

The mean diurnal variation is plotted of a natural signal within the frequency range 25-130 c/s. A typical difference is shown to exist between the signals received in winter and summer. It is suggested that these signals are due to atmospherics produced in different parts of the world and that the world's entire thunderstorm activity might be recorded by a very few low-frequency stations.

LOW AUDIO FREQUENCY NATURAL ELECTROMAGNETIC SIGNALS

Proc. Symposium on Propagation of VLF Radio Waves, Boulder, Colorado, 23rd - 25th January 1957, Vol. III, Paper 45.

R.E. Holzer, O.E. Deal, S. Ruttenberg

Some time ago a study of low-frequency signals below 1000 cycles was started with a view to gathering evidence concerning their physical cause. Now data are presented to support the hypothesis that signals in the 30- to 130-cps band are produced by world-wide thunderstorm activity and to indicate extensions of the low-frequency studies now in progress.

WORLD THUNDERSTORM ACTIVITY AND EXTREMELY LOW-FREQUENCY SFERICS

Pgs 599-602, Recent Advances in Atmospheric Electricity - Pergamon Press, NY, 1958.

R.E. Holzer

During a series of measurements directed toward determining the physical cause of natural electromagnetic signals in the low audio-frequency range. Holzer and Deal found that the mean signal amplitude in the frequency band from 30 to 120 c/s exhibited a simple, systematic diurnal oscillation at a station in the Borrego Desert of Southern California. In the cooler months of the year when the nearest large thunderstorm centre was more than 60 degrees from the observing station, the diurnal oscillation was similar in relative amplitude and phase to that of the atmospheric electric air-earth current observed over the oceans. However, the approximate proportionality between the air-earth density and the mean electromagnetic signal amplitude was somewhat surprising in view of the large differences in the distances of the thunderstorms from the observing stations.

At higher frequencies the phase of the diurnal oscillation of the electromagnetic signal amplitude reversed and became consistent with sferics observations in the kilocycle range where the night-time signals are strong and the daytime signals weak.

The present paper is an attempt to find an approximate quantitative explanation of the observations.

SOME WAVEFORMS OF ATMOSPHERICS AND THEIR USE IN THE LOCATION OF THUNDERSTORMS

Phys. Abstr. 10132/1955; J. atmos. terrest. Phys. (GB), V. 7, No. 1-2, Pgs 1-13, August 1955.
F. Horner, C. Clarke

Illustrations are given of the main types of waveforms which have been recorded in southern England, using equipment previously described. Particular emphasis is given to echo-type waveforms comprising a series of echoes arriving by different modes of reflection between the earth and the ionosphere. The frequency of occurrence of suitable types of waveform is derived from an analysis of routine recordings over a period of one year. It is concluded that waveform analysis would be of some value for thunderstorm location as an adjunct to a network of cathode-ray direction finders, but that the reliability and convenience of the technique are not yet sufficient for use as the sole method of estimating distance.

AN INVESTIGATION OF ATMOSPHERIC RADIO NOISE AT VERY LOW FREQUENCIES

Proc. IEE (London), Vol. 103, Pgs 743-751, 1956.
F. Horner, J. Harwood

A description is given of a technique for investigating the characteristics of atmospheric noise, and of the type of information obtained at very low frequency. The results quoted are typical of those which have been obtained in southern England during a long period of recording, but a discussion of the statistics of all the data is not included.

A detailed description of the noise is given in terms of the amplitude distribution of the peaks in the envelope and the amplitude probability distribution of the envelope itself. Either of these distributions can be expressed empirically in terms of two parameters, and can be inter-related at the higher voltage levels where the impulses have consistent shape determined by the characteristics of the receiver. At one location the amplitude of the noise may vary between wide limits with time, frequency and band-widths, but the parameters which can be used to describe the noise structure are comparatively invariant.

RADIO NOISE FROM LIGHTNING DISCHARGES

Phys. Abstr. 3614/1958; Nature (GB), V. 181, Pgs 688-90, 8th March 1958.
F. Horner, C. Clarke

Examples are given of atmospheric wave-forms recently recorded in the high-frequency band (11 Mc), and also simultaneous recordings of atmospheric noise at 11 Mc and 6 kc. The bursts of noise in the h.f. band are often in the form of pairs of pulses with duration up to 300 msec, and they cannot be ascribed to the short duration stepped-leader type of lightning discharge.

POLARIZATION OF ATMOSPHERICS

Nature, Vol. 181, No. 4624, Pgs 1678-1679, 14th June 1958

F. Horner

A complex type of trace was obtained with a twin-channel cathode-ray direction finder. This paper contains assumptions and deductions on the polarization of the echoes that were received after varying numbers of reflections between earth and ionosphere. It is concluded that the trace can be produced by a vertical discharge to the ground, and not by a horizontal discharge channel.

NARROW BAND ATMOSPHERICS FROM TWO LOCAL THUNDERSTORMS

J. Atmos. Terrest. Phys., Vol. 21, No. 1, Pgs 13-25, April 1961.

F. Horner

Atmospherics from two local storms at known distance have been recorded on magnetic tape. The frequencies of reception were 11 Mc/s for one storm and both 6 kc/s and 11 Mc/s for the other. The power bandwidths were in the range 200-300 c/s. Values of duration, peak amplitude, mean field strength and mean power flux have been deduced from the records, and estimates of the radiated power have been derived.

The waveforms of the atmospherics are partly explicable in terms of known characteristics of lightning discharges, but there are many features, particularly at 11 Mc/s, for which an adequate quantitative explanation is lacking. The results conflict with some theories of the origin of high frequency atmospheric noise which have been advanced in recent years.

THE RELATIONSHIP BETWEEN ATMOSPHERIC RADIO NOISE AND LIGHTNING

Phys. Abstr. 1988/1960; J. atmos. terrest. Phys. (USA), V. 13, No. 1-2, Pgs 140-54, 1958.

F. Horner

Examination of atmospherics in a bandwidth of 300 cps at 10 kc from storms of known location in Europe has shown that in median amplitude, amplitude range and frequency of occurrence, they corresponded with what would be expected from lightning discharges to ground. Other experiments in Australia showed that atmospherics from tropical storms had overall durations similar to those of lightning discharges, and consisted of a series of pulses. High frequency atmospherics had similar durations to those recorded at very low frequencies, but were more continuous. The start and finish of h.f. atmospherics tended to coincide with large v.l.f. pulses. The atmospherics were much longer than would have been expected if stepped leader discharges had been the main source.

ON THE FINE STRUCTURE OF ATMOSPHERICS FROM NEAR ORIGINS
Proc. Research Inst. Atmospheric, Nagoya Univ. (Japan), Vol. 2,
Pg 25, January 1954.
H. Ishikawa, M. Takagi

In the previous paper the authors classified the atmospheric wave-forms from near origins into three fundamental types, i.e. main discharge type, leader discharge type and partial discharge type. It has been studied further in this paper, the fine structure of the leader discharge type wave forms from cumulonimbus which has grown up to a stage just before a thunder-cloud, the wave-forms from cloud to earth discharges, and the main discharge type waveforms in calm days.

STUDIES ON RECORDING APPARATA FOR THUNDERSTORM OBSERVATIONS - PART V.
RESULTS OF TEST THUNDERSTORM OBSERVATION IN SUMMER
Bull Research Inst. Atmospheric, Nagoya Univ. (Japan), Vol. 5, No. 2,
1955. In Japanese.
H. Ishikawa, T. Kamada, M. Takagi

The thunderstorm activity observation was carried out in summer 1954 with the apparata, i.e. atmospheric waveform recorder, electro-static field meter, atmospheric mean intensity meter, lightning frequency recorder and Boy's camera. The following results have been obtained from the investigation of the records.

Any variation in the frequency distribution curve of lightning counters can be made to correspond to some thunderstorm activity in the range of 100 km or more from the station.

The peak occurrence time of frequency curve coincides with each other in our three methods of lightning frequency recording, in which the main amplifier of the apparata were tuned at 28 kc, 100 kc, 8.15 Mc respectively.

The height of the peak in lightning frequency curve can be used as a rough estimation of the storm activity.

Effective ranges of our electro-static field meter has been estimated to be of the order of 30 km around the station.

ON THE FINE STRUCTURE OF ATMOSPHERICS NEAR THEIR ORIGINS
Proc. Research Inst. Atmospheric, Nagoya Univ. (Japan), Vol. 3,
Pgs 29-42, 1956.
H. Ishikawa, M. Takagi

The pulsive leader type wave-form of cloud discharge has been studied in the present paper. It has been shown that large amplitude pulses on the leader type wave-form of cloud discharge compose a random series of pulses, and hence the discharge processes, each of which emits a large pulse, occur nearly at random. This result has led the present authors to the conclusion that the minute discharge processes which occur in the course of a cloud discharge and emit their respective large pulses do not correspond to each of the step streamers composing the whole of the α type stepped leader of violent cloud discharge.

THE "DAWN CHORUS" IN RADIO OBSERVATIONS
Phys. Abstr. 465/1958; Nature (GB), V. 180, Pg 716, 5th October 1957.
G.A. Isted, G. Millington

The term "dawn chorus" was adopted by the late K.W. Tremellen on account of the similarity in sound of this "whistler" phenomenon to the dawn chorus of the birds; he was well aware that the phenomenon was not confined to the dawn. Pope's suggestion that it should be called simply "chorus" obscures the origin and purpose of the term and it is suggested that "dawn chorus" should be retained, with a reference, if necessary, to its true significance in relation to the characteristic sound of the phenomenon.

THE MEASUREMENT OF WORLD-WIDE THUNDERSTORM ACTIVITY AT A SINGLE LOCALITY
Phys. Abstr. 2714/1958; Marconi Rev. (GB), V. 20, Pgs 130-2, 1957.
G.A. Isted

Confirmation of the author's suggestion (Abstr. 6646/1955) that measurements of the diurnal variation of world-wide thunderstorm activity can be made by counting the electrical impulse disturbances observed in the kc band at a single station (Great Baddow) is obtained from similar measurements in the 25-130 cps band by Holzer and Deal in California (Abstr. 5567/1956) for the same period. The diurnal variations plotted against Universal Time show striking agreement, and appear to confirm that such measurements reflect the variation of the vertical electric field over the earth, which is believed to be maintained by the world-wide thunderstorm activity.

LOCAL LIGHTNING FLASH COUNTER WITHIN 20 KM

Proc. Research Inst. Atmospherics, Nagoya University, (Japan),
Vol. 3, Pgs 69-74, 1956.
K. Ito, T. Kato, A. Iwai

Last summer, direct comparisons among eleven lightning flash counters of various types concerning the receiving frequency ranges and gains were made at Maebashi.

The results obtained are discussed and compared with the data of visual and aural observations of meteorological observatories.

Sufficient data on observation to restrict the counting radius within 20 km, as recommended by CCIR have not yet been obtained, but some results suggest that instruments available for a suitable frequency range and gain, especially a wide band of frequencies in the VLF range, can be used to restrict the counting radius within 20 km.

LOCAL LIGHTNING FLASH COUNTER WITHIN 20 KM

Bull. Research Inst. Atmospherics, Nagoya Univ., Vol. 5, No. 2, 1955;
in Japanese.
A. Iwai, K. Ito, T. Kato

In recent years, several devices designed for counting local lightning flashes have been proposed, but available performance data are insufficient to compare the merits of these devices.

Last summer, direct comparisons concerning the receiving frequency ranges and gains were made at Maebashi among eleven devices of various types designed for the lightning flash counters. The results obtained are discussed, together with the data of visual or aural observations of meteorological stations.

Sufficient data on restricting the counting radii within 20 km, recommended in CCIR, were not yet obtained, but several results suggested that instruments responding to a suitable frequency range and gain, especially a wide band of frequencies in the VLF range, could be possible to restrict the useful range within 20 km.

ON AN INVESTIGATION OF WHISTLING ATMOSPHERICS IN JAPAN

Proc. Research Inst. Atmospherics, Nagoya Univ. Japan, Vol. 4,
Pgs 29-47, December 1956.
A. Iwai, J. Otsu

As part of the Study Programme of IGY, we have prepared an observation of whistling atmospheric. Since January 1956, continuous observations of whistlers have been made at Toyokawa (geomagnetic latitude 24.5°). Simultaneous observations at Toyokawa and Wakkanai (geomagnetic latitude 35.3°) were made for one month beginning 13th July 1956. The results

obtained in the analysis of the dispersion of whistlers were essentially similar to those reported by Storey. But at Toyokawa, long whistlers, whistler trains and whistler pairs have not been observed, only short whistlers being observed. The greater part of the observed whistlers occurred in winter; in other seasons it was scarcely possible to detect them. At Wakkanai, long whistlers and whistlers and whistler pairs have been observed this summer, but whistler trains have not been observed during this period.

ON AN INVESTIGATION OF THE FIELD INTENSITY OF WHISTLING ATMOSPHERICS
Proc. Research Inst. Atmospherics, Nagoya Univ., Japan, Vol. 5, Pgs 50-52, March 1958.

A. Iwai, J. Otsu

An apparatus is described and its wiring illustrated (diagrammatically) for creating a pseudo-whistling tone to compare with an actual whistler in order to gage the field intensity of the latter. The full intensity is calibrated in microvolts/meter and the record can be obtained in 1-2 sec. by a skillful operator. A "sona-gram" of the pseudo-whistling tone generator is illustrated and a typical example of data obtained at Toyokawa on 12th February 1957 tabulated (an unusually frequent series of whistlers). These occurred about sunset on several days in February 1957. It is concluded that the frequency and full intensity of whistlers varies greatly with geomagnetic latitude, etc.

ON THE CHARACTERISTIC PHENOMENA FOR SHORT WHISTLERS OBSERVED AT TOYOKAWA IN WINTER
Proc. Research Inst. Atmospherics, Nagoya Univ., Japan, Vol. 5, Pgs 53-63, March 1958.

A. Iwai, J. Otsu

About 84% of short whistlers observed at Toyokawa on winter nights were recognised by analysis to be preceded by tweek type atmospherics, which made it possible to measure distances between the observation station and the sources of short whistlers. And at Toyokawa in winter, dispersions of short whistlers were found to decrease regularly towards midnight. A variation of electron density in the outer ionosphere is calculated from this variation of dispersions.

WHISTLER AND VLF-EMISSIONS FROM SALTHOLM, DENMARK, 1960-1961.
TN 1, Contract AF61(052)-652, March 1963, Ionosphere Lab., Royal Technical Univ. of Denmark, Report No. 15.
I.M. Jackerott, Jørgen Taagholt, E. Ungstrup

No abstract.

OBSERVATIONS OF WHISTLERS AND VLF-EMISSIONS AT GODHAVN AND NARSSARS-SUAQ, GREENLAND AND AT TROMSØ, NORWAY, IN 1962
Tech. Final Report, Contract AF61(05)-652, February 1964.
Ionosphere Lab., Royal Technical University of Denmark, Report No. 18.
I.M. Jackerott, T. Stockflet-Jørgensen, Jørgen Taagholt

No abstract

IONOSPHERIC REFLECTION COEFFICIENTS AT VLF FROM SFERICS MEASUREMENT
A.G. Jean, L.J. Lange, J.R. Wait
See Section I, Page 55.

VLF PHASE CHARACTERISTICS DEDUCED FROM ATMOSPHERIC WAVE FORMS
A.G. Jean, W.L. Taylor, J.R. Wait
See Section I, Page 55.

POLARIZATION OF SFERICS
Prepublication Papers NBS-IRE PGAP, Symposium on Propagation of VLF
Waves, Boulder, Colorado, 23rd-25th January 1957, Vol. III, Paper 32.
A.G. Jean, L.J. Lange, J.R. Wait

Four quantities are required to characterize the incident wave: azimuth α , elevation angle θ , and electric field components E'' and E^{\perp} parallel to the plane of incidence and perpendicular to the plane of incidence, respectively.

At Boulder, the sferics recording installation consists of a vertical antenna and two crossed-loop antennas. The azimuth is determined from the ground-wave portion of the sferic as observed at Boulder and Stanford using broad-band direction-finding equipment.

The analyses are made using the waveforms as recorded by the three antennas. The elevation angle, θ is calculated.

The polarization, P, of the downcoming wave is given by the expression:

$$P = \frac{E^{\perp}}{E''}$$

Using the method outlined above, the polarization of sferics recorded at different ranges from the source is calculated.

RADIO-FREQUENCY RADIATION FROM LIGHTNING DISCHARGES

EE Abstr. 6103/1962; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 6, Pgs 638-9, November-December 1960.

A.G. Jean

URSI National Committee Report, London, 1960, (see Abstr. 2183-1962). Modern work is surveyed on the radiation produced by different types of vertical and inclined lightning discharges within the range from several thousand Mc to the extra-low frequency region. Experimental and theoretical investigations on the nature of the atmospheric wave form and on the radiation spectrum are considered.

THE INFLUENCE OF CONDUCTIVITY INHOMOGENEITIES UPON AUDIO-FREQUENCY MAGNETIC FIELDS

Phys. Abstr. 16230/1963; Geophys. (USA), Vol. 28, No. 2, Pgs 201-21, April 1963.

T.R. Jewell, S.H. Ward

Audio-frequency magnetic fields originate mainly from a world-wide distribution of energy sources associated with thunderstorms. This energy is propagated over great circle routes within an earth-ionosphere waveguide, and in passage is attenuated to varying degrees dependent upon the reflective properties of the waveguide. Various investigators have shown that the intensity and direction of the observed electromagnetic waves exhibit characteristic diurnal variations as a function of frequency, time of year, and geographical location. The results of this study demonstrate that the diurnal variations, particularly with regard to direction, are affected by the presence of a large, linear conductivity inhomogeneity in the vicinity of the recording site. Preliminary investigations were carried out near a mineralized fault zone roughly approximating a planar surface of unknown conductivity. No apparent effects upon the intensity or direction of 140 or 590 c/s fields were observed. Subsequent experiments adjacent to a large, elongated, pyritized rhyolite formation which contained several massive sulphide ore bodies of high relative conductivity demonstrated quite well the effect of the conductivity inhomogeneity upon the 140 c/s magnetic fields. The diurnal variations of magnetic field azimuth and intensity were relatively unaffected by the conducting body and agree reasonably well with the results of other investigators. In addition, they show a good correlation with the estimated diurnal of energy sources. The differences between the diurnal variations at different locations relative to the conductivity inhomogeneity are reconciled by adopting a theoretical model based upon the known geology. The diurnal behaviour of the horizontal field direction at positions relative to the model which correspond to actual recording locations are then calculated and compared with the observed curves. Apparently, the character of the diurnal variation of the 140 c/s magnetic field azimuth is affected by the relative position of the recording site to the conductivity inhomogeneity; the geometry and propagation constant associated with the conductor or conductors; and the relative variation of the primary field direction about the mean axis of conductivity.

GROUND-CONDUCTIVITY DETERMINATIONS AT LOW FREQUENCIES BY AN ANALYSIS
OF SFERIC SIGNATURES OF THUNDERSTORMS

J. Geophys. Research 66, Pgs 3233-3244, October 1961.
J.R. Jöhler, C.M. Lilley

No abstract

AN ATLAS OF WHISTLERS AND VLF EMISSIONS - A SURVEY OF VLF SPECTRA FROM
BOULDER, COLORADO.

January 1963, NBS Technical Note No. 166, PB 181454, \$2.25.
D.L. Jones, R.M. Gallet, J.M. Watts, D.N. Frazer

No abstract

THE SFERIC CHARACTERISTICS OF THUNDERSTORMS

Paper presented at IRE-URSI Symp. Washington, DC, 30th April, 1st - 3rd
May, 1956.
H.L. Jones

In order to obtain a more precise location of a given thunderstorm centre it is considered necessary to substantially increase the present knowledge of the sferic nature of thunderstorms. Consequently, the research programme for the tornado season of 1956 at the Oklahoma A. and M. Tornado Laboratory has been designed to provide a substantial increase in the recorded data for all types of thunderstorms, including those that may contain tornadoes.

The number of strokes per second coming from a thunderstorm centre varies over a wide range from one second to another. The data from a number of storms of various types are correlated in an attempt to demonstrate that individual storm centres do exist, although each storm centre may be a part of an overall group. Comparisons are made between the data obtained from moving film and the data as recorded by the automatic stroke counter.

THE IDENTIFICATION OF LIGHTNING DISCHARGES BY SFERIC CHARACTERISTICS

Recent Advances in Atmospheric Electricity, Pgs 543-556, Pergamon Press,
New York, 1958.
H.L. Jones

Discovery of a new type of atmospheric by Jones & Hess in 1950 made possible the development of the present sferic-radar system for the tracking and identification of severe thunderstorm cells which sometimes develop into tornadoes. The development of the 150 kc static direction finder at the Tornado Laboratory of Oklahoma State University has resulted

in the identification of the "tornado oscillator" or "inner cloud discharge" that is characteristic of severe storms common to the Great Plains Area.

The sferics network of the Air Weather Service initiated and directed by Lt. Col. E.J. Fawbush, was equipped with three AW/GRD 1-A direction finders operating on a band in the neighbourhood of 10 kc. This network was first operated in the spring of 1954, and covered parts of Texas, Oklahoma, Arkansas, and Kansas. As a result of the operations of this network during the tornado season of 1954, a significant discovery was made.

As the intensity of a thunderstorm increased, the number of sferics per second from the thunderstorm increased to reach a peak value some 30 to 90 mins before the formation of a tornado. Following the maximum value, the rate of sferic arrival decreased to a relatively small value just prior to tornado time.

QUASI-STATIC ELECTRIC FIELD STUDIES OF THUNDERSTORMS

Paper presented at Joint Symposium on Sferics and Thunderstorm Electricity, U.S. Nat. Committee of the Int. Scientific Radio Union, Commission IV, American Geophysical Union, and the American Meteorological Society, Washington, D.C., 30th April 1960.
H.L. Jones, F.J. Boudreaux, W.D. Woodruff

During the severe storm season of 1959, studies were made of the quasi-static electric fields of thunderstorms as these structures passed in the vicinity of the Atmospheric Laboratory. Recordings were made of both the rapid and the slow variations of the electric field, and these variations were correlated with the waveforms and the 10- and 150-kc/s directional pulses. The studies were made in order to obtain a better understanding of the rapid field variations peculiar to cloud-to-cloud, cloud-to-ground, and intra-cloud discharges. The techniques developed this year are expected to lead to additional information on the tornado oscillator that is peculiar to thunderstorm structures during the tornado and pre-tornado stages of development. Unfortunately, there were no tornado oscillators in the vicinity of the Atmospheric Laboratory during the severe storm season of 1959.

DIRECT OBSERVATION OF CORRELATION BETWEEN AURORAE AND HISS IN GREENLAND

Nature (GB), Vol. 194, Pgs 462-3, 5th May 1962.

Phys. Abstr. 17193/1962.

T.S. Jørgensen, E. Ungstrup

Observations during January and February 1961 at Godhavn established clear correlation between the strength of 8 kc/s hiss and variations of the intensity of light in, and the activity of, aurorae, from second to second and minute to minute, irrespective of the zenith angle of the aurorae.

ENERGY CONVERSION MECHANISM IN A BOUNDED MAGNETIZED CURRENT-CARRYING PLASMA

Phys. Rev. Letters, Vol. 6, No. 7, Pgs 339-341, April 1961.
G.H. Joshi

A linear microscopic analysis is made of the phenomena of conversion of kinetic energy of a drifting plasma to electromagnetic energy and vice versa on account of the coupling of quasi-longitudinal space-charge waves and electromagnetic waves in a finite plasma. It is suggested that very low frequency whistler noise may be explained by this mechanism.

THE MEASUREMENT OF THE INTENSITY OF ATMOSPHERICS, PART I.

Proc. Research Inst. Atmospheric, Nagoya University, Japan, Vol. 2, Pgs 31-39, January 1954.
T. Kamada, J. Nakajima

In order to study the nature of atmospheric, the measurement of intensity of atmospheric over the range from 10 kc/s to 30 kc/s is now put into practice at the Research Institute of Atmospheric, Nagoya University. The integration method has been employed in measuring the atmospheric with narrow-band receivers. The band-width of the receivers was 500 c/s at 6 dB down point and the time of integration about one minute. Diurnal and seasonal variations of the level are shown by the data from February to November 1953. The well-known enhancement of atmospheric at 27 kc/s was observed during the outburst of solar radio waves on 22nd November 1952 and 15th October 1953.

STATISTICAL PROPERTIES OF THE SUDDEN ENCHANCEMENT OF ATMOSPHERICS IN VLF RANGE

Proc. Research Inst. Atmospheric, Nagoya University, Japan, Vol. 7, Pg 28, 1960.
T. Kamada, J. Nakajima

This report describes the statistical results obtained in five years from 1955 to 1959, about SEA which is caused by solar flare disturbances. The important matters resolve themselves into the following points:

- (1) The basic modes and types of SEA are determined from among the abnormal increases in the intensity of atmospheric.
- (2) In order to determine the abnormal increases in the intensity of atmospheric as SEA, it is necessary to observe three frequency components about 10, 20 and 30 kc/s simultaneously.
- (3) The results obtained have intensified the conception that to observe SEA is the most useful means for watching SF and SRO on the sun.

SUDDEN ENCHANCEMENT OF ATMOSPHERICS ON FREQUENCIES BETWEEN 10 AND 30 KC/S

EE Abstr. 15900/1963; J. Inst. Elect. Commun. Engrs, Japan, Vol. 54, No. 10, Pgs 1324-32, October 1962. In Japanese.
T. Kamada

During the occurrence of solar flares, abnormal increases in the intensity of atmospherics in the vlf range have been observed. The results of continuous recordings of the intensity of atmospherics at 10, 21 and 27 kc/s during the period 1955 to 1959 are shown graphically and discussed. Four basic types of s.e.a. (sudden enhancement of atmospherics), termed V, U, W and F types, depending on the shape of the intensity variations, were noted and seem to be related to the conditions of the D-region. The frequency range 12-18 kc/s appears to be unaffected by the sudden ionospheric disturbances during solar flares. Correlations between s.e.a., solar flare and solar radio outburst were demonstrated statistically as regards simultaneity of occurrence, flare magnitude, and outburst intensity, etc.

OBSERVATIONAL RESULTS OF "CUT-OFF FREQUENCY" OF FREQUENCY SPECTRUM OF THE ATMOSPHERIC IN THE VLF BAND

Review of Radio Research Laboratories, Vol. 7, No. 28, January 1961. In Japanese.

I. Kasuya, T. Obayashi, C. Ouchi, C. Nemoto.

A new sweeping frequency method of measuring the atmospherics in the VLF band propagated through the ionosphere was devised and continuous observations have been made since July 1958.

The notable lowest frequency from which the atmospherics are observable is shown around 3 kc/s and has temporal variations. These frequencies may be considered to correspond to the cut-off frequency of wave guide which formed by the wall of surface of the lower ionosphere and the earth.

The observational data on these frequencies were analyzed and the results are as follows:

- (1) As for the diurnal variation, the cut-off frequency is lower in the night than in the daytime. This may be explained in terms of the cut-off frequency f_c being inversely proportional to the height of the ionosphere.
- (2) As for the seasonal variation, the cut-off frequency is the highest in winter, descends at the equinoxes and is the lowest in summer. This may be due to the change in distance of the source of the atmospherics.
- (3) In the period of intense SID (sudden ionospheric disturbance) accompanied by the solar eruption, the height D layer descends to about 60 km, judging from the results of the sudden increase of the cut-off frequency.

ENERGY SPECTRUM OF ATMOSPHERICS AND ATTENUATION OF DIFFERENT LOW
FREQUENCIES WITH DISTANCE

S.R. Khastgir, R.S. Srivastava
See Section I, Page 63.

ABNORMAL POLARIZATION OF THE ATMOSPHERIC PULSES REFLECTED SUCCESSIVELY
FROM THE IONOSPHERE

Nature, Vol. 181, Pgs 404-405, 8th February 1958.
S.R. Khastgir

During the recording of atmospherics in India, many cases of elliptic patterns have been observed on the c.r.t. direction-finder. These showed continuously changing eccentricity and tilt-angle, and almost certainly represent abnormal polarization of the atmospheric pulses reflected successively from the ionosphere.

CLASSIFICATION OF THE WAVEFORMS OF ATMOSPHERICS

J. Inst. Telecommun. Engrs (India), Vol. 6, Pgs 260-265, October 1960.
S.R. Khastgir, R.S. Srivastava

This is a review with 28 references.

FLUXMETER STUDIES OF SLOW ELECTRIC FIELD-CHANGES DUE TO MOVING THUNDER
CLOUDS

Phys. Abstr. 21637/1962; Indian J. Phys. Vol. 36, No. 3, Pgs 137-50,
March 1962.

S.R. Khastgir, R.S. Srivastava

An electrostatic fluxmeter similar to the one developed by Malan and Schonland (1950) was constructed and used for the study of slow electric field changes due to nearby thunderclouds. The principle and the constructional details of the instrument are given. The fluxmeter experiments gave the following results: (i) the initial electric field due to thundercloud was more often negative than positive; (ii) there was a steady decrease of the negative field with time; sometimes the decrease was slow and showed minor variations; (iii) the negative field was sometimes found to increase to an optimum value which was followed by a continuous decrease; (iv) the positive field, in many cases, was found to increase attaining an optimum value after which it was found to decrease passing through zero to a negative value which after attaining an optimum value was found to decrease steadily with time. In many observations the electric field changes are shown to be due to the movement of a negative cloud or of a bi-polar cloud. The effect of the negative charge extending over a very wide region in the cloud has been evident in a number of observations. The minor abrupt changes have been attributed to changes in the charge distribution and to occasional local discharges within the thundercloud.

THE WAVE FORM OF ATMOSPHERICS IN DAYTIME

EE Abstr. 774/1954; J. Geomagn. Geoelect. (Japan), V. 1, Pgs 14-16, March 1949.

A. Kimpara

From oscillographic records of atmospheric, frequency distribution curves are derived showing that the frequency of the first oscillation in the highly damped oscillatory train produced by the return stroke of a lightning discharge to earth varies from ~ 3 to 15 kc with a pronounced max. at 7.5 kc and that the duration of the oscillatory train has a max. of $\sim 600 \mu$ sec although durations up to 3000 μ sec have been observed. Brief mention is made of other types of atmospheric.

THE WAVEFORMS OF ATMOSPHERICS. II.

EE Abstr. 2511/1959; Mem. Fac. Engng Nagoya Univ. (Japan), V. 9, No. 1, Pgs 1-18, May 1957.

A. Kimpara

A study of waveforms from 1940-56, especially from 1955-6, classified into two groups, one for daytime, the other at night. The daytime waveform consists of (1) stepped leader stroke, partial discharge within cloud, successive discharges among clouds, (2) return streamer, (3) multiple stroke, while the slow-tail and the reflection-echo type are generally found at night, relatively seldom in daytime. The night waveform consists of (4) stepped leader stroke, partial discharge within cloud, successive discharges among clouds, (5) return streamer, (6) slow tail, (7) reflection echo and (8) long train types. General features of waveforms, frequency characteristics and their dependence on distance are fully discussed with photographs.

ON FIELD INTENSITY RECORDING OF ATMOSPHERICS AT 27 KC/S IN ACCORDANCE WITH THE RECOMMENDATION OF WMO,

Proc. Research Inst. Atmospheric, Nagoya Univ. (Japan), Vol. 5, Pgs 21-29, March 1958.

A. Kimpara, Y. Kimura

In order to see if Recommendation 40 of working group of WMO in 1957 can be applied satisfactorily to the results obtained in Japan, the authors examined the records of intensity meters of atmospheric at 27 kc/s observed continuously in 1957 at Toyokawa station. They found fairly regular behaviours of sferics which can be reasonably explained by the distribution of sources with seasonal variations as well as by the principle of wave propagation. "A" (sunrise effect) is found generally 20 min. before sunrise, except in winter where it is found about 2 hours before sunrise. "B" (first minimum) and "C" (recovery effect) are often found more than once, and also found frequently in the evening. "D" (morning minimum) is found about 2 hours after sunrise, but sometimes not

clearly. "E" (afternoon maximum) is found about 2 hours before sunset and sometimes indicates flat maximum. "F" (late minimum) is found within a half-hour of sunset. "G" (night maximum) is not found in Toyokawa. After sunset the field intensity of spherics increases gradually and reaches night level about $2\frac{1}{2}$ hours after sunset, and keeps its level nearly constant till dawn when "A" is found. "G" should be called "sunset effect" in Japan. It is due to the difference of distribution of sources between Europe and Asia.

CORRELATION OF OCCURRENCE OF WHISTLERS WITH GEOMAGNETIC ACTIVITIES

Nature, Vol. 186, No. 4720, Pg 230, 16th April 1960.

A. Kimpara

The frequency of occurrence of whistlers has a seasonal variation upon which are superposed daily variations which reach a maximum on the second day after a geomagnetic disturbance.

ON SOME REMARKABLE CHARACTERISTICS OF WHISTLER ATMOSPHERICS

Phys. Abstr. 17146/1962; Rep. Ionospheric Space Res. Japan, Vol. 14, No. 2, Pgs 160-179, June 1960.

A. Kimpara

Describes some remarkable characteristics of whistlers observed in IGY and IGC at Toyokawa and at Wakkanai in Japan. The author found that the frequency of occurrence of whistlers has a definite seasonal variation due to thunderstorm activities and distributions of electron density and geomagnetic intensity in the exosphere. Correlation of the number of whistlers with geomagnetic activities, superimposed on this variation, is very close in periods of heavy geomagnetic disturbances or of abundant occurrence of whistlers: the correlation coefficient of the effective K-index and number of whistlers on the second day after geomagnetic disturbances is +0.60. The average dispersion of whistlers per month lags two months behind solar activities expressed by sunspot numbers. Characteristics of the dispersion of whistlers observed simultaneously at both stations are discussed in some detail. Diurnal and seasonal variations for the two years are also described.

SOME CHARACTERISTICS OF THE DISPERSION OF WHISTLERS

EE Abstr. 5404/1963; Rep. Ionosphere Space Res. Japan, Vol. 16, No. 1, 27-36, March 1962.

A. Kimpara

The author studied some of the characteristics of the dispersion (D) of whistlers for 4 years from the beginning of the IGY, and found that in diurnal variation D generally decreases from sunset to sunrise and there-

after increases. The tendency can be observed very clearly in winter but is less obvious in summer, and it becomes ambiguous with the decrease in solar activity. At Toyokawa D is at its minimum in winter and maximum in summer while at Wakkanai it is at its minimum in winter and summer and maximum in spring and autumn, which is contradictory to Helliwell's report (J. Res. Nat. Bur. Stand. (USA), Vol. 64D, No. 6, November-December 1960), and suggests a geomagnetic latitude dependence. As to solar activity, D correlates with the sunspot number with a time lag of 1 to 2 months. Investigating D individually, the author also found that on storm days the diurnal variation of D increased.

ON A CORRELATION BETWEEN RADIO WHISTLERS AND SOLAR ACTIVITY

Phys. Abstr. 15201/1962; C.R. Acad. Sci. (France), Vol. 254, No. 7, Pgs 1321-2, 12th February 1962. In French.
A. Kimpara

At low geomagnetic latitudes, the number of whistlers varies inversely with solar activity, probably due to the absorption of long waves in the ionosphere.

OCCURRENCE OF WHISTLERS AND SOLAR ACTIVITY

Phys. Abstr. 13682/1963; Rep. Ionosphere Space Res. Japan, Vol. 16, No. 1, Pgs 69-70, March 1963.
A. Kimpara

Examination of IGY whistler data shows that the occurrence of whistlers in Japan in winter correlates inversely with solar activity. The data for summer were too limited for any conclusions to be reached.

AMPLIFICATION OF THE VLF ELECTROMAGNETIC WAVE BY A PROTON BEAM THROUGH THE EXOSPHERE. AN ORIGIN OF THE VLF EMISSIONS

Phys. Abstr. 15264/1962; Rep. Ionosphere Space Res. Japan, Vol. 15, No. 2, Pgs 171-91, June 1961.
I. Kimura

The mechanism of the t.w.t. (travelling wave tube) - like amplification of vlf electromagnetic waves by an electron beam in the exosphere is first re-examined. The computation shows than an electron beam with identical velocity with the phase velocity of a v.l.f. electromagnetic wave does not cause any amplitude growth of the electromagnetic wave. In place of the t.w.t. like mechanism, amplification due to the transverse interaction of the extraordinary mode of the electromagnetic wave with a cyclotron mode of a proton beam, is considered. By this mechanism, the condition of amplification is the same as that of the t.w.t. mechanism, and an amplitude gain of 4 dB per 100 km for a 3 kc/s wave is expected, provided that the proton

beam has the density of 10^7m^{-3} . The phenomena of the vlf emissions may be explained by the above mechanism if the input (or seed) for amplification is a powerful atmospheric noise pervading the exosphere, which comes from the vicinity of the earth's surface and penetrates the ionospheric layer.

DIFFERENT TYPES OF MUSICAL ATMOSPHERICS AND THEIR RELATIONS TO LIGHTNING DISCHARGES

EE Abstr. 7765/1963; Ark. Geofys (Sweden), Vol. 4, Paper 5, Pgs 83-101, 1962.

E. Knudsen, H. Norinder

The recording method at a whistler observation station showed a correlation between lightning discharges and musical atmospheric produced by them. About 700 musical whistlers collected in 1958-61 were analysed. It was found that about 70% of the records were correlated with lightning discharges and about 30% were not. With these comparatively extended records as a basis it was possible to undertake a classification of different types. It was possible to start with fully adequate variational types. There were also introduced multiples and combinations of the fundamental types. The striking resemblance between correlated and non-correlated short-time variational types indicated that variational types that are not correlated must also emanate from lightning discharges. The combined variational types proved that the wave-packets emitted from the lightning discharges were modified in different ways as to their mode of propagation.

ATMOSPHERICS OF THE LOWEST FREQUENCIES

EE Abstr. 6769/1959; Z. angew. Phys. (Germany), V. 11, No. 7, Pgs 264-74, July 1959.

H.V. K8nig

Regarding the earth and the surrounding ionosphere as a sort of spherical cavity resonator, Schumann has calculated its natural resonance frequency to be about 10 cps. A detailed account is given of experiments to test whether the propagation of atmospheric, of such low frequencies, was consequently favoured. The special receiving equipment, which had a lower frequency limit of about 1 cps, is described and typical results are shown in diagrams. The recorded signals fall into two main groups. In the first group the signals have a sinusoidal oscillatory character with frequencies chiefly around 8-9 cps, the duration of the signals ranging from 0.2 sec to, in rare cases, 30 sec. Beat effects were noted and the signals frequently resembled a wave train. Effects of weather conditions and diurnal variations of signal strength are described, the night signals being considerably weaker. The signals of the second type are mostly of irregular form, their frequencies varying between about 2 and 6 cps. Such signals might last for an hour or more. Characteristic signals were recorded at sunrise. The origin

of the various types of received signal is discussed. The oscillatory signals of the first type, with frequencies near 9 cps, are considered as probably due to lightning flashes setting the earth-ionosphere resonator in oscillation at its fundamental frequency.

ATMOSPHERICS GERINGSTER FREQUENZEN

Z. angew. Phys. (Germany), V. 11, No. 7, July 1959.

H. V. König

No abstract

ULTRA-LOW FREQUENCY ATMOSPHERICS

EE Abstr. 1655/1961; Inst. Radio Engrs (USA), Internat. Convention Record, V. 8, Pt. 1, Pgs 128-33, 1960.

H.V. König

The earth and the ionosphere form a spherical-type resonant cavity. The natural frequency of this resonator was calculated by Schumann (Abstr. 7413A/1952; Z. Naturforsch (Germany), V. 7A, Pgs 250-1, March-April 1952) to be approximately 10 cps. In order to test this result, it was decided to determine experimentally whether or not there might actually exist in the atmosphere signals which could lie within this frequency range, and to investigate the effects of such signals on living organisms.

MESSUNG VON "ATMOSPHERICS" GERINGSTER FREQUENZEN IN BONN

Z. angew. Phys. (Germany), V. 13, No. 8, Pgs 364-367, August 1961.

H.V. König, E. Haine, C.H. Antoniadis

Atmospherics were recorded in the range 0.5 to 10 kc and the various types of record are shown and classified into five groups. The results are compared with similar measurements made on a single frequency (10 kc) at Munich.

REGISTRIERUNG BESONDERS NIEDERFREQUENTER ELEKTRISCHER SIGNALE WAHREND DER SONNENFINSTERNIS AM 15 FEBRUAR 1961

H. König, E. Haine

See Section IV, Page 310.

AN ATTEMPT TO OBSERVE WHISTLING ATMOSPHERICS NEAR THE MAGNETIC EQUATOR
Phys. Abstr. 5156/1955; Nature (GB), Vol. 175, Pgs 36-7, 1st January
1955.

J.R. Koster, L.R.O. Storey

No whistling atmosphericics have been observed at Achimota, Gold Coast (geomagnetic latitude 10°N) over a three-year period when other observations indicated that they were common in middle latitudes. This is in agreement with the Barkhausen-Eckersley theory of the production of whistlers.

THEORY OF TERRESTRIAL ATMOSPHERICS

Phys. Abstr. 24023/1962; Dokl. Akad. Nauk SSSR, Vol. 144, No. 2, Pgs 334-7, 11th May 1962. In Russian.

P.E. Krasnushkin

The propagation of atmosphericics is discussed in terms of idealized models. Mode theory is used to calculate field-strength versus time relationships at a distance from an impulsive source.

UNIVERSAL-TIME DIURNAL VARIATION OF THE THUNDERSTORM FREQUENCY

Phys. Abstr. 21632/1962; Z. Geophys. (Germany), Vol. 28, No. 2, Pgs 33-52; 1962; In German.

H.C. Krumm

According to the thunderstorm cards of the world published by the World Meteorological Organization and according to an intensive study of all published (local time) diurnal variations of thunderstorms. Whipple's (1929) publication on the mean (universal time) diurnal variation of the thunderstorm frequency was recalculated. Tables give the average number of thunderstorms which occur in any world-time interval of two hours. The calculation is made for the whole year and the four seasons. A separate calculation is presented for four quadrants, each including a continent or an ocean.

SOME RESULTS OF FIVE YEARS OF WHISTLER OBSERVATIONS FROM LABRADOR TO ANTARTICA

EE Abstr. 7721/1963; Proc. Inst. Elect. Electronics Engrs (USA), Vol. 51, No. 4, Pgs 554-68, April 1963.

T. Laaspere, M.G. Morgan, W.C. Johnson

Some interesting curves result when whistler data are averaged over a long period of time to smooth out random short-term variations in whistler generation and propagation. Local season is such a strong factor in determining the shape of the diurnal curves of observed whistler

activity that even in the case of the north-south "Whistlers East" chain of audio-frequency receiving stations, diurnal curves of the northern- and southern-hemisphere stations tend to be similar not during the same period of the year but during the same local season at the point of observation. A basic form of the diurnal curves appear to be one which is symmetrical about local midnight with a deep minimum at local noon and relatively high nighttime activity showing maxima at about 2000, 2400, and 0400 hours local time. Depending on local season and location of the station, one or more of these peaks may be absent or enhanced. It is concluded that the shape of the diurnal curves is determined largely by the conditions of whistler propagation rather than of generation. The curves presented should therefore be useful in predicting the behaviour of man-made signals propagation in the "whistler mode" through the ionosphere and the magnetosphere of the earth. Some difficulties are pointed out with the prevalent idea that the marked depression in the occurrence of whistler-mode signals in the daytime is primarily the result of absorption of these waves in passing through the D layer. On the other hand, caution is advised against neglecting ionospheric factors, other than D-region absorption, in deference to the role of field-aligned ducts of enhanced ionization in the magnetosphere. Finally, some results are presented which show that, in addition to a latitude variation of the dependence of whistler rate upon the K_p index of geomagnetic disturbance, there is, especially at the lower latitude stations, a seasonal variation of these curves as well. Of particular interest also is the observation that, at the higher latitude stations where the maximum whistler rate obtains at low values of K_p , the rate decreases almost linearly with greater values of K_p .

WAVE FORM, ENERGY AND REFLECTION BY THE IONOSPHERE, OF ATMOSPHERICS
Proc. Roy. Soc. (GB), V. 174, No. 957, 1st February 1940.
T.H. Laby, and Others

The waveform of the electromagnetic pulse radiated from a lightning flash, known as an atmospheric, has been studied. The atmospheric are received on a vertical aerial which is connected through an aperiodic amplifier to a cathode ray tube. From the simple theory and methods of reduction given in the paper, it is possible to determine the height of the reflecting ionized layer and the distance of the flash. When this is done, the height of the layer is found to be between 53 and 82 km. values in reasonable agreement with the lower limits of the E layer. The observations are consistent with the sky wave and the ground wave, having the same velocity to 0.7%. Oscillograms of typical atmospheric wave forms are shown, together with a possible interpretation of many of them. The assumption is made that the electrical discharge which radiates an atmospheric is a damped oscillation with a period determined by the instantaneous resistance, inductance and capacity. The relation between the distance of an atmospheric source and its field strength is found to be linear and figures are given for the peak power and the total energy radiated as found from representative examples.

FLUCTUATIONS IN THE VERTICAL ELECTRIC FIELD IN THE FREQUENCY RANGE 1
CYCLE PER SECOND TO 500 CYCLES PER SECOND
Recent Advances in Atmospheric Electricity, Pgs 603-607, Pergamon Press,
New York, 1958.
M.I. Large, T.W. Wormell

It has been shown by the work of Whitlock and Chalmers that the frequency range from 1 to 0.01 c/s in the spectrum of the variations in the vertical electric field near the earth's surface is associated with the motion and turbulent diffusion of the space-charge distribution in the lowest few tens of metres of the atmosphere in the immediate vicinity of the site of observation.

The range of frequencies immediately above this is of particular interest from many points of view. In it the main cause of the fluctuations changes over from a local one to distant lightning discharges, with the possibility of other effects playing an appreciable part. Owing to the transmission properties of electromagnetic waves in this region there is a possibility of using observations in it as an index of world-wide thunderstorm activity, a field which has been extensively explored by Holzer and Deal.

Most previous investigators of this range of frequencies have considered it necessary to make observations at special sites where noise of artificial origin is exceptionally low. The technique used in the investigation to be described in this paper uses sharply tuned receivers at a series of discrete frequencies. It is thus possible to avoid frequencies where artificial disturbance is obvious, in particular the fundamental and harmonics of the power frequency (50 c/s in England). One of the objects of the present work was to investigate the possibility of making such observations at an average site.

THE ATMOSPHERIC NOISE LEVEL IN THE LONGEST WAVE REGION AND ITS DIURNAL
AND ANNUAL VARIATIONS
Z. Meteorol., Vol. 10, No. 4, Pgs 110-121, April 1956. In German.
E.A. Lauter

Problems of the definition and measurement of the noise level are discussed from measurements of dependence on frequency, and statistics, of atmospherics. The dependence of the noise level on ionospheric conditions and on the frequency and position of centers of disturbance is shown from 3-year mean monthly diurnal variations on 14, 27 and 48 kHz. This shows that in winter the distribution conditions depend especially on the diurnal variation, but in summer on the approach of disturbance centers. Some remarks are added on geophysical peculiarities in the recording of atmospheric disturbances, such as interdiurnal variability, twilight effect and solar flare effect.

FACTORS OF ATMOSPHERIC DISTURBANCE LEVELS AND PARAMETERS FOR THEIR DESCRIPTION

EE Abstr. 1032/1963; Wiss. Z. Hochsch, Elektrotech, Ilmenau (Germany), Vol. 8, No. 1, Pgs 59-64; 1962. In German.
E.A. Lauter

Factors influencing atmospheric disturbance and methods of assessing it, are discussed. Some examples are given of diurnal and seasonal variations of 'impulse rates' observed at frequencies in the range 25-50 kc/s.

HYPERBOLIC DIRECTION FINDING WITH SPHERICS OF TRANSATLANTIC ORIGIN

E.A. Lewis, R.B. Harvey, J.E. Rasmussen
See Section I, Page 66.

GENERATED LIGHTNING ATMOSPHERIC RESEARCHES, Abstract.

Symposium on Atmospheric Radio Noise, Programme of Joint URSI-IRE Meeting, Washington, DC, 2nd-5th May 1960, Pg 77.
E.A. Lewis

Artificial lightning generators have been designed to generate simulated lightning atmospheric wave shapes, with helicopter supported antenna wires to simulate lightning channels. A one million volt artificial lightning generator installed in a sea-going schooner provides a mobile installation which can readily be moved to various geomagnetic locations to permit planned study of magnetic channeling effects of the "whistler" mode of propagation.

Pulse propagation experiments have been carried out in fair weather utilizing a supported wire about 10,000 ft high. Radiated 25 kilocycle frequency pulses, with peak powers of the order of 10 mega watts, have provided reproducible wave shapes received at various distances with good agreement with initial approximate calculations.

EXTREMELY LOW-FREQUENCY ELECTROMAGNETIC WAVES. I. . RECEPTION FROM LIGHTNING. II. PROPAGATION PROPERTIES

L. Liebermann
See Section I, Page 67.

ANOMALOUS PROPAGATION BELOW 500 c/s

Prepublication Papers NBS-IRE PGAP, Symposium on Propagation of VLF Waves, Boulder, Colorado, 23rd-25th January 1957, Vol. III, Paper 25.
L. Liebermann

Long range propagation below 500 c/s has been studied using lightning

as a natural transmitter. Two distinct propagation types are readily distinguished. Both commonly occur; both may be observed within the same hour, although not from the same locality simultaneously. The propagation type termed "normal" is explained by a modified wave guide theory in which one reflector is partly conducting. The propagation type termed "anomalous" has thus far not been explained. Many properties including attenuation, phase and group velocity of anomalous propagation have been determined. The travel distance of anomalous pulses can be deduced from one simple characteristic. Possible explanations are suggested for anomalous propagation.

A SPECTRAL ANALYZER OF VARIABLE-FREQUENCY SIGNALS

Phys. Abstr. 7543/1962; Pribory i. Tekh. Eksper. (USSR), No. 1, Pgs 96-8, January-February 1961.

Ya I. Likhter, S.M. Prozumenshchikov, Ya P. Sobolev

A general description is given of a harmonic analyzer of signals whose frequency varies at a rate of the order of 2×10^4 cps sec⁻¹. Provision is made for the instantaneous frequency to be shown as a function of time on the screen of an oscillograph. The device has been designed for the analysis of whistling atmospherics.

OBSERVATION OF SOME SPECTRAL COMPONENTS OF SFERICS

Abstract, Symposium on Radiation from Lightning Discharges, Programme of Joint URSI-IRE meeting, Washington, D.C., 4th-7th May 1959, Pgs 43-44.

R.F. Linfield

The electromagnetic energy radiated from a lightning discharge is extremely variable. This is evidenced in amplitude and phase variations among the various spectral components. Statistical quantities of sferics having specified characteristics have been measured using equipment developed by the National Bureau of Standards. One such characteristic which has been measured is the amplitude of the pulse formed by a band-pass filter. Pulses whose amplitude exceed a pre-set triggering level were automatically counted and recorded. Three separate filters were used with centre frequencies of 10 kc, 40 kc and 100 kc with bandwidths of 60 percent, 30 percent and 30 percent, respectively. Measurements were made at two geographical locations - Oregon and Colorado, and at two differing periods - summer and fall. The variations observed are attributed primarily to the seasonal change and not the geographical change.

The distribution of sferic rates as a function of triggering level and filter frequency are presented for both omnidirectional and narrow sector measurements.

DURATION AND SPACING OF SPHERIC PULSES

EE Abstr. 1059/1963; Proc. Inst. Radio Engrs. (USA), Vol. 50, No. 8,
Pgs 1841-2, August 1962.

R.F. Linfield, C.A. Samson

About 9000 waveforms of atmospherics recorded in Colorado and Kansas have been analysed. Curves show the distribution of duration between 50 and 500 ~~μ~~ s, the variation of the percentage sample interval occupied with rate, the rate as a function of triggering level, and the distribution of the intervals between atmospherics. In general the durations were longer by night than by day and for distant rather than near storms. With the occurrence of a tornado there was a shift towards shorter durations.

BOMB-EXCITED "WHISTLERS"

B.A. Lippmann

See Section IV, Page 312.

DAILY VARIATION IN THE NUMBER OF LIGHTNING DISCHARGES

Leningrad, Glavnaya geofizicheskaya observatoriya Voyeykova, Trudy,
No. 97, Pgs 39-42, 1960. In Russian.

B.F. Loch

The author describes the principles of operation of a vacuum tube lightning recorder and presents data obtained by the instrument over three seasons (1954-1956).

Based on a thyratron and tetrode tube, a simple battery-fed device requiring 50-100 a was built. A non-directional antenna was used. The maximum range of operation is 300 km.

Data collected on seasonal distribution of discharges showed increased activity in September 1954, and June-July 1956. The data for daily activity shows that the possibility of lightning striking between 0600 and 1200 hours is less than during other hours. The use of data on daily activity is useful, the author concludes, in estimating the possibility of lightning caused damage.

A THEORETICAL INVESTIGATION OF THE PROPAGATION PATH OF THE WHISTLING ATMOSPHERICS

K. Maeda, I. Kimura

See Section I, Page 68.

CALCULATION OF THE PROPAGATION PATH OF WHISTLING ATMOSPHERICS

K. Maeda, I. Kimura

See Section I, Page 69.

RADIATION FROM LIGHTNING DISCHARGES AND ITS RELATION TO THE DISCHARGE PROCESS

Recent Advances in Atmospheric Electricity, Pgs 557-563, (Pergamon Press, London, 1958).

D.J. Malan

Simultaneous recordings were made of electrostatic field changes and radiation at different frequencies of nearby discharges.

In the 1 Mc/s to 10 Mc/s the radiation is fairly continuous and of the same order of intensity throughout the duration of all types of discharges but has a maximum in the preliminary stages in the case of discharges to ground.

With decreasing frequency from 100 kc/s to 3 kc/s the radiation is increasingly confined to the return strokes of discharges to ground and to the small rapid components of cloud discharges, the latter, however, becoming comparatively very small at 3 kc/s.

In considering the spark channel as a radiating aerial, the observations support earlier theories about the nature of the various components of discharge and their relation to charge distribution.

DAYTIME STUDIES OF THE WAVEFORMS OF ATMOSPHERICS

Phys. Abstr. 13683/1963; Indian J. pure appl. Phys. Vol. 1, No. 2, Pgs 84-5, February 1963.

R. Manoranjan, H. Bhattacharya, S.R. Khastgir

The results of studies over Calcutta during the summers of 1961 and 1962 are reported. Most of the "predischarges" recorded were of the isolated type. Among the return stroke pulses recorded, the heavily damped oscillatory type was found to be more frequent than the N-type and the quasi-periodic type. There is adequate evidence of the return stroke pulses being followed by the c-field change. The peaky type and the smooth sinusoidal type of the ionospheric reflections were found to be less frequent during daytime than during night.

OBSERVATIONS OF "WHISTLERS" AND "CHORUS" AT THE SOUTH POLE

L.H. Martin

See Section IV, Page 317.

SOME RECENT MEASUREMENTS OF ATMOSPHERIC NOISE IN CANADA
Proc. Inst. Radio Engrs (USA), V. 45, Pg 782, June 1957
C.A. McKerrow

No abstract

SOME MEASUREMENTS OF ATMOSPHERIC NOISE LEVELS AT LOW AND VERY LOW
FREQUENCIES IN CANADA
Phys. Abstr. 16486/1960; J. geophys. Res. (USA), V. 65, No. 7,
Pgs 1911-26, July 1960.
C.A. McKerrow

Atmospheric noise levels at 11, 35 and 135 kc were recorded at Ottawa and Churchill for a period of 1 year beginning September 1958. A statistical analysis of the noise as a function of frequency, time of day, and season of the year has shown the following: (1) the same noise storms determine the noise levels received at both locations (since the beginning of the midday maxima occurs at the same time, whereas local time differs by 1 hour, and the departures of the daily median from the monthly median varies in a regular way and is the same at both locations); (2) the noise level decreases with increase of frequency more rapidly than predicted by CCIR (especially in winter when the noise storm centres are most distant); (3) the morning decrease in noise level varies in a regular way over the year, as expected from the sunrise time, between the receiver and the location of the most active storm centres; (4) the equipment measures both r.m.s. and the average noise levels. Only at the frequency during the winter season is a regular daily variation obtained.

CHARGE TRANSFER IN THE LIGHTNING STROKE AS DETERMINED BY THE MAGNETO-
GRAPH
Phys. Abstr. 17147/1962; J. Franklin Inst. (USA), Vol. 273, No. 5,
Pgs 375-82, May 1962.
A.D. Meese, W.H. Evans

Records of the Tuscon Magnetic Observatory were analysed for the summer period of 1960. Sixteen stroke responses were found for which location data were available. The magnetometer reacts to a lightning stroke as a ballistic instrument so that the maximum deflection is proportional to charge. The average charge transferred was found to be between 143 and 256 coulombs. This charge magnitude is in agreement with previous ballistic measurements, but much larger than the generally accepted value of 20-30 coulombs. The lack of sensitivity of other methods to the smaller persistent current in many strokes may account for the discrepancy.

RADIO PATROL OF SOLAR FLARES

J. Sci. & Industr. Research (India), Vol. 17A, No. 12, Pgs 74-80,
December 1958.

A.P. Mitra, K.A. Sarada, N.V.G. Sarma, M.N. Joshi

Ionospheric effects associated with solar flares have, in recent years, been successfully used to provide continuous radio patrol of solar flares at a number of observatories. There are several such effects: (a) sudden enhancement of intensity of atmospherics at VLF (SEA); (b) sudden increase in absorption of medium and short radio waves; and (c) sudden change in phase at VLF (SPA). Changes in absorption referred to under (b) have been measured by using terrestrial transmission and also by receiving radio-frequency radiation from our galaxy; the latter is known as sudden cosmic noise absorption (SCA).

At the Radio Propagation Unit of the National Physical Laboratory, methods (a) and (b) have been used during the IGY to study solar flares, using the following frequencies: (1) SEA at 27 and 100 kc/s, (2) SCA at 22.4 and 30 Mc/s and (3) f_{\min} by P'-f panoramic recorder sweeping over 1-25 Mc/s.

During the first year of the IGY, for which results are presented in this article, several outstanding flare effects were observed; in a few cases simultaneously at different frequencies. In this article we report the effects observed during the period July 1957 to August 1958, and also discuss some of the implications of these observations.

ATMOSPHERICS AND THEIR SIGNIFICANCE IN THE INVESTIGATIONS OF IONOSPHERE AND EXOSPHERE

EE Abstr. 8261/1962; Przegląd telekomun (Poland), 1961, No. 2, Pgs 39-47. In Polish.

J. Molski

A survey of the nature, origin and methods of investigation of atmospherics observed often in the range between a few hundred c/s to ~ 20 Mc/s, and a description of the related "whistlers" arising in the a.f. band. It is stressed that these natural sources may be useful in the investigation of the propagation of radio waves and in the observation of the properties of the respective media. The author also analyses various mechanisms of propagation, which explain the weak damping of electromagnetic waves. 15 references.

A PRELIMINARY METEOROLOGICAL STUDY OF THE ORIGIN OF WHISTLERS
J. Geophys. Research, Vol. 64, No. 7, Pgs 745-748, July 1959.
C.P. Mook

A possible unique source of whistling atmospherics is found to be the presence of large cyclonic disturbances at the geomagnetic conjugate point for the whistler receiving station. The possible role of these cyclonic disturbances in producing narrow magneto-ionic duct propagating conditions is also discussed.

SYMPOSIUM ON SFERICS AND THUNDERSTORM ELECTRICITY
Phys. Abstr. 16481/1960; J. geophys. Res. (USA), V. 65, No. 7, Pgs 1865-1966, 1960.
C.P. Mook

This symposium was held in San Diego, Cal., U.S.A. in October 1959. Abstracts of the first eleven papers are published below, and titles of the remaining papers which were given as short abstracts only, are as follows: The role of continuous discharges in cloud-to-ground lightning, N. Kitagawa, M. Brook and E.J. Workman (Pg 1965); thunderstorm electrical discharges interpreted by aircraft and related ball lightning and sferics phenomena, M.M. Newman (Pg 1966); Quasi-static electric field studies of thunderstorms, H.L. Jones, F.J. Bordeaux and W.D. Woodruff (Pg. 1966).

OBSERVATIONS OF WHISTLING ATMOSPHERICS AT GEOMAGNETIC CONJUGATE POINTS
Nature, Vol. 177, No. 4497, Pgs 29-31, 7th January 1956.
M.G. Morgan, G. McK. Allcock

Whistlers were observed to occur simultaneously at 55.1° and 50.2° geomagnetic latitude on the east coast of North America, but the stronger whistler did not always occur at the same station. Tape recordings of them were analyzed on a comb-filter type of sound spectograph. Typical examples are shown. Storey's form of the frequency-dependence formula given by Eckersley, $f = (D/t)^2$, fits the data for a dispersion $D - 200$ where t is measured from the initiating atmospheric. Further observations near geomagnetic conjugate points at about 50° geomagnetic latitude in the Aleutian Islands and New Zealand appear to confirm Storey's theory that the long dispersive paths needed by Eckersley to explain the generation of "whistlers" and "swishes" from atmospherics are along the geomagnetic flux lines between the northern and southern hemisphere.

ON THE DEPENDENCE OF WHISTLER DISPERSION UPON THE GEOMAGNETIC LATITUDE
OF THE GENERATING SPHERIC

Paper presented at IRE-URSI Symposium, Washington DC, 30th April,
1st-3rd May 1956.

M.G. Morgan, H.W. Curtis, H.E. Dinger, A.W. Sullivan

Spherics fixes obtained along the east coast of North America by the Air Weather Service of the U.S. Air Force are identified with individual whistlers observed at one or more locations. The dispersion of these whistlers is determined from spectrograms and compared with the geomagnetic latitude of the spherics.

WHISTLERS AND DAWN CHORUS

Annals International Geophysical Year 1957/1958, Vol. 3, Pgs 315-336 (1957).

M.G. Morgan

A detailed account of the available information on methods of measuring whistling atmospherics is given.

After a general description of the phenomena involved, the following topics are covered with a view toward standardization of measurement observations, equipment, etc. (1) IGY objectives; (2) equipment and observing techniques (general, antennae, cathode input, dynamic range, filters, antenna siting, oscillation, calibration, and recording technique); (3) data reading and presentation (general, spectrographs, wave form analysis); and (4) a minimum station. A series of appendices includes an analysis of tweeks, notes on the earth's magnetic field and on multiple whistlers, and sample tables of subjective data which were recorded as the result of various observations.

WHISTLER STUDIES AT DARTMOUTH COLLEGE, GEOPHYSICS AND THE IGY

Proc. Symposium at Opening of International Geophysical Year, Washington, DC, 28th-29th June 1957; Geophysical Monograph 2, American Geophysical Union of National Research Council, Publication 590 (1958).

M.G. Morgan

This paper describes the whistler research at Dartmouth College and recommendations for the IGY.

CORRELATION OF WHISTLERS AND LIGHTNING FLASHES BY DIRECT AURAL AND VISUAL OBSERVATION

Phys. Abstr. 8558/1958; Nature (GB), V. 182, Pgs 332-3, 2nd August 1958.

M.G. Morgan

A recent extended observation of the progress of a storm at Hanover, New Hampshire, U.S.A., suggests that, although lightning flashes can generate whistlers, the majority of the flashes do not.

WHISTLERS AND DAWN CHORUS AT UNIVERSITY OF ALASKA AND THEIR CORRELATION WITH SIMULTANEOUS DATA AT THE GEOMAGNETIC CONJUGATE WHISTLERS AND DAWN CHORUS AT KNOB HILL, QUEBEC.

To be submitted to J. Res. Nat. Bur. Stand. (USA), Section D, Radio Propagation.

M.G. Morgan, W.C. Johnson

No abstract

PATH COMBINATIONS IN WHISTLER ECHOES

Proc. IRE, Vol. 47, Pgs 328-329, (February 1959)

M.G. Morgan, H.W. Curtis, W.C. Johnson

The report is presented in the wake of Storey's confirmed deduction that "whistlers echo back and forth between the hemispheres". It is also an investigation that applies the concept of path combinations in echoes to one of the spectrograms published by Morgan and Allcock in the 7th January 1956 issue of Nature, Vol. 177, Pgs 30-31. The spectrogram discussed is one recorded on 11th November 1956 at Unalaska (50° geomag. lat.) in the Aleutian Islands. It shows dispersion curves that are 60 in the lower and 120 in the higher noise-frequency. Hence it is observed that the echo of a short whistler has thrice the dispersion of the initial one. The conclusion is reached that a second path that has twice the dispersion of the normal path must be present.

WHISTLERS

J. Atmos. Terrest. Phys. Vol. 15, Nos. 1/2, Pgs 54-57, September 1959.

M.G. Morgan

Whistler research in various parts of the world is briefly summarised.

WHISTLERS ALONG W 56° LONGITUDE ("WHISTLERS-EAST") DURING THE IGY AND IGC, 1959.

Abstract, Symposium on Whistlers, Programme of Joint URSI-IRE Meeting, Washington, D.C., 2nd-5th May 1960. Pg 114.

M.G. Morgan, W.C. Johnson

The incidence of whistlers at stations not reported upon at the 1959 Fall Meeting is presented, and a comparison made of average activity during the IGY and IGC for all stations whose data are available.

The location of meteorological storms during periods of whistler activity, and the diurnal and annual distribution of echo trains, have been investigated and are presented.

WHISTLERS EAST DURING THE IGY WHISTLERS

Paper presented at IRE-URSI Symposium, San Diego, California, 19th-21st October 1959.

M.G. Morgan, W.C. Johnson

Data gathered during the course of the IGY indicate that at Whistlers-East stations: (1) naturally occurring noise levels are higher in the Northern hemisphere than in the Southern; (2) whistlers are observed over a fairly widespread area; (3) stations in the Northern hemisphere receive mainly long whistlers, while those in the Southern receive mostly short whistlers, independent of local season; (4) at most antarctic stations, many short whistlers are followed by a burst of hiss after a time interval of one second; (5) most all antarctic whistlers (short) show a pronounced fine structure indicating four to ten coherent paths, while most Northern whistlers (long) do not exhibit this fine structure; (6) on many occasions echo trains are observed simultaneously at both Port Lockroy and Ellsworth, and can be observed at Dartmouth as well; (7) whistler activity seems to diminish north of $N55^\circ$ geomagnetic and south of $N50^\circ$ geomagnetic; (8) nose whistlers having nose frequencies less than 7 kc are fairly common, occurring usually during period of high ionospheric activity; (9) high whistler activity seems to occur in cycles of 10- or 11-day period; and (10) whistler activity peaks at all stations in June and July, both in Northern and Southern hemispheres.

THE DAWN CHORUS AND RELATED PHENOMENA ALONG $W65^\circ$ LONGITUDE ("WHISTLERS-EAST") DURING THE IGY AND IGC 1959

Abstract, Symposium on Whistlers, Programme Of Joint URSI-IRE Meeting, Washington, D.C., 2nd-5th May 1960, Pg 114.

M.G. Morgan, W.C. Johnson

The dawn chorus is found to have a broad maximum of activity at $N55-60^\circ$ geomagnetic latitude, falling off rapidly at higher and lower latitudes. Average activity during the IGY and IGC 1959 are found to be similar at stations for which data are available.

Examination of the data from stations at $N55^\circ$, 60° and 65° (350 miles separation) shows that dawn chorus may be quite local in appearance at times and wide-spread at others.

SUMMARY OF RESEARCH ON WHISTLERS AND RELATED PHENOMENA, DARTMOUTH COLLEGE, Report of U.S. Commission 4, URSI, J. Research NBS, Vol. 64D, No. 6, Pgs 644-646, November-December 1960.

M.G. Morgan

A meridional chain of observing stations, nominally along $W75^\circ$ was set up to make synoptic observations during the IGY from Thule to Florida, at Huancayo, and from Cape Horn to Antarctica. Fifteen stations were

involved, each a story unto itself. Co-operating, in order of latitude, were Danes, Canadians, Americans, Bermudians, Peruvians, Argentines, and Britons. Some results have been published by independent co-operating workers, as for example the Godhavn, Greenland, results by Ungstrup (1959), and the Washington results by Dinger (1960). Geographically comprehensive studies have been made at Dartmouth and will soon be presented for publication. The following conclusions are based on the subjective reduction of the magnetic tapes and subsequent statistical analysis.

THE VARIATION WITH DISTANCE IN THE RANGE 0-100 KM OF ATMOSPHERIC WAVE-FORMS

EE Abstr. 5099/1953; Phil. Mag. (GB), V. 44, Pgs 980-6, September 1953.
R.B. Morrison

The magnitude and waveform of atmospheric within 100 km of the source have been calculated on the basis of existing information on the lightning discharge. Particular attention is paid to the variation with distance of the waveform associated with the return stroke. This variation shows several characteristics of interest. A direct comparison is made between the theoretical results and the experimental observations made on near atmospheric waveforms.

ON THE OCCURRENCE OF ATMOSPHERIC WHISTLERS OVER CENTRAL EUROPE IN 1958

Studia Geophysica et Geodaetica, No. 3, Pgs 298-302, 1960.
J. Mrázek

The author describes the result of studies of whistlers made at the Průhonice ionospheric station (long. $14^{\circ} 33'$ E., lat. $40^{\circ} 59'$ N.) in 1958. Two simple antennas were used in the experiments. The first was a horizontal wire 70 m long set at a height of 10 m above the ground; and the second was a perpendicular rod 10 m long. The former arrangement set in an east-west direction proved most effective. A low frequency amplifier with minimum noise level and amplification of more than 80 db served as receiver. Frequencies lower than 500 cycles and more than 20 kilocycles were filtered out. A magnetophone with a tape velocity of 9 cm/sec recorded the signals. Results showed that the occurrence of whistlers over Central Europe follows the same pattern as over West Europe and that a definite daily period exists with a minimum during the day and a maximum at night. Yearly values show clearly that the minimum occurrence of whistlers is at the time of vernal and autumnal equinoxes. Concerning the relationship between the number of whistlers and geomagnetic activity, the author notes that an abnormal number of whistlers occurs shortly before the onset of a strong geomagnetic disturbance and that the number falls quickly thereafter. When whistler activity is unusually great in any given night, the author asserts, the chances of increased whistler activity the following night is also high.

MEASUREMENT OF RAPID MAGNETIC FIELD CHANGES IN LIGHTNING DISCHARGES
EE Abstr. 6764/1961; Elteknik (Sweden), V. 3, No. 7, Pgs 110-12,
September 1960.
D. Müller-Hillebrand

The pulses produced by a lightning discharge were first measured using a bifilar oscillograph and an open aerial by De Blois in 1914. Present-day measuring apparatus is required to reproduce magnetic pulses within a very wide frequency band up to 1 Mc. Changes in magnetic field generated in multiple flashes of microsecond duration occurring within about 0.5 sec have to be analysed. This places severe demands on a loop aerial with natural frequency of 5 Mc. An oscillograph is used with a time unit for the abscissa of 1000 μ sec in one direction and 60 μ sec on the return. A special camera has been designed with a revolving film of 120 m. Thunderstorm recordings are reproduced.

THE MAGNETIC FIELD OF THE LIGHTNING DISCHARGE
EE Abstr. 11410/1963; CEEGB Conf. on Gas Discharges and the Electricity Supply, Leatherhead, 1962. (see Abstr. 3511 of 1963) Pgs 89-111.
D. Müller-Hillebrand

In the first part of the paper the mathematical relations are given for the determination of the magnetic induction by the exact method due to Lundholm, and by the approximate dipole method, as well as the limits of error. A number of assumptions are made of the variations of the lightning current and velocity with time, and the magnetic induction is determined. In the second part of the paper experimental results are reported. Four examples of short-period magnetic field impulses are discussed, which show discharges in the cloud and to earth along already existing channels, and lightning discharges to earth with limited current feed. Although the measuring apparatus makes it possible to measure magnetic induction down to 2 μ G at a limiting frequency of 0.9 Mc/s it appears doubtful whether the Schomland process of a dart leader can be directly measured electro-magnetically. The example of a lightning stroke comprising three discharges and the relevant history is given. The relations between current, rate of change of current, velocity and height of the lightning stroke, all of which determine the magnetic induction, are explained by giving an example.

LIGHTNING COUNTERS. I. THE CHANGE IN ELECTRIC FIELD DUE TO LIGHTNING STROKES WITH REFERENCE TO ITS EFFECT ON LIGHTNING COUNTERS
Phys. Abstr. 16222/1963; Ark Geofys (Sweden), Vol. 4, Paper 10, Pgs 247-69, 1963.
D. Müller-Hillebrand.

If the change of the electric field with time is calculated in the conventional way from the current moment of a dipole, its derivative and

its time integral, an expression is obtained which is determined by the lightning current, the particular length of stroke, the speed of the stroke and the variation with time of the current. But for the closer study of the electric field the basis of a statistical treatment of data from measurements has to be used. Measurements in Sweden and in Tessin (Switzerland) gave in the case of earth strokes a wide agreement with the time variation of the field obtained by calculation. Inter alia oscillograms of multiple strokes are shown, in which 14 partial strokes within 635 msec and 7 partial strokes within 510 msec were measured at a distance of 5 km with sudden jumps in field of several 100 V/m. The first sudden jump in the field within 3 μ sec repeats with astonishing regularity, even in detail. The cloud strokes are divided into 3 groups: comparatively slow changes within 3 to 300 msec and more rapid changes within 50 μ sec to 500 μ sec and very rapid pulses within 10 or 20 μ sec. An analysis of 4761 oscillograms of the electric field during 24 thunderstorms at a distance up to about 20 km from the measuring position in Tessin gave 76.6% cloud flashes and 23.4% earth flashes, i.e. a numerical ratio 3.26. This number may vary to a considerable extent from one thunderstorm to another. Measured limits were 0.69 and 165, i.e. thunderstorms with a majority of earth flashes and thunderstorms with cloud flashes exclusively. In Uppsala in four thunderstorms 1.87 times more cloud flashes than earth flashes were measured. See also following abstract.

LIGHTNING COUNTERS. II. THE EFFECT OF CHANGES OF ELECTRIC FIELD ON COUNTER CIRCUITS

Phys. Abstr. 16223/1963; Ark Geofys (Sweden), Vol. 4, Paper 11, Pgs 271-92, 1963.

D. Müller-Hillebrand

An investigation was made into the behaviour of lightning counters with different filter circuits and with different sensitivities, both to cloud flashes and to earth flashes. Filter circuits which pass elf waves (with the minimum triggering field strength at 0.5 to 1 kc/s) diminish, as the triggering voltage rises, cloud flashes more than earth flashes. The percentage number of recorded cloud flashes falls more rapidly than that of the recorded earth flashes, if the voltage required for triggering is raised. Filter circuits with a minimum triggering field strength of 10 V/m and 10 kc/s and with a bandwidth of 6.7 to 19 kc/s, suppress about 95% of the cloud discharges, but pass through only about one-third of the pulses originating from earth flashes up to a distance of 15 km for recording. This means that the number of the earth flashes recorded is about 7 times greater than that of the cloud flashes recorded. But when there are 4 times more cloud flashes than earth flashes, the proportion of cloud flashes recorded in the total number recorded is considerable. Lightning counters with a triode as the triggering element are sensitive only to field changes in the polarity, which occurs in the case of earth flashes in 98% of cases. A lightning counter with the minimum triggering field strength of 5 V/m at 0.5 kc/s recorded 24.7% of 3328 cloud flashes, and 68.1% of 955 earth flashes

in thunderstorms at a distance generally up to 12 km, and rarely 15 km. On the whole 66% of the number recorded were earth flashes, when there were about 3.5 times more cloud flashes than earth flashes, and 77% when there were 2.2 times more cloud flashes than earth flashes. If an investigation is made simultaneously with two lightning counters, the sensitivity of which is 1:2 or 1:3, then the effective range of the lightning counter can be determined, if the mean triggering distance of the thunderstorm from the lightning counter is known. The investigations were carried out by means of a log-normal distribution of the triggering distances, and the result obtained was that the triode lightning counter with a minimum field strength of 5 V/m has an effective range of about 11 to 12.5 km. The investigation of a lightning counter recommended by the CCIR, with a wide-band filter and a triggering field strength of 3 V/m at 10 kc/s led to results which did not agree with those obtained by Horner (see Abstr. 5638B of 1960; Proc. Instn. Elect. Engrs, Paper 3238E, publ. July 1960 (Vol. 107B, 321-30)). In the case of thunderstorms in Sweden in 1961 and 1962 it did not prove possible to find any correlation between the daily or hourly number of recordings and the local thunderstorms. In the near zone the CCIR counter records a high percentage of cloud flashes, but not in the distant zone. Therefore the effective range in the zone close to the thunderstorm, which was determined by Horner as 30 km, is different from that in the distant zone, where it is considerably greater. With the 3 V/m sensitivity, the effective range is determined as about 100 to 120 km, and with 10 V/m sensitivity as 35 to 45 km.

THE FREQUENCY SPECTRUM OF ATMOSPHERICS

Proc. Research Inst. Atmospherics, Nagoya Univ. (Japan), Vol. 3, Pgs 54-62, 1956.

T. Nakai

A method of frequency analysis is introduced on a basis of the Fourier integral, and is applied to certain types of atmospherics: (1) the atmospherics radiated from return streamer of lightning flash in the daytime, (2) the quasi-sinusoidal waveform at night.

The results thus obtained have been investigated with particular reference to the effects of the distance not only for the complete waveform, but also for each quasi one-cycle of the waveform. They show the decreasing effect of the greatest component frequency in each quasi one-cycle of the waveform as its order number increases in the waveform. Further, they show that there is an atmospheric having two large maximum values in higher frequency region in the amplitude frequency spectrum, corresponding to some feature of the waveform.

ATMOSPHERIC RADIO NOISE RECORDING PROGRAMME

National Bur. of Standards (US), Tech. News Bull 41, 83, June 1957.

No abstract

EPHI - A RADIO SYSTEM FOR INVESTIGATING SPHERICS
Nat. Bur. of Standards (US), Tech. News Bull, 45, 60-61, April 1961.

No abstract

INVESTIGATION OF ATMOSPHERIC RADIO NOISE
Scientific Report 13, Contract AF 19(604)-876, Engineering and Industrial
Experiment Station, University of Florida, Gainesville, Florida, 1st
November 1956. AFCRC-TN-56-788. AD-110 127.
P.J. Nawrocki

Investigation of the electromagnetic field components (E_2 and H_2)
of the ground wave from individual spheric pulses exceeds the theoretical
value obtained from Sommerfeld's theory, and indicates that H_2 and E_2
probably have a common functional dependence upon the distance of propagation.

ATMOSPHERIC STATIC INVESTIGATION. II. (UNDER PROGRAMME ON LIGHTNING
PROTECTION AND RADIO INTERFERENCE REDUCTION FOR AIRCRAFT IN THUNDERSTORMS).
AD 56 986; Lightning and Transients Research, Inst. Minneapolis, Minn.,
24 p., illus., 1954.
M.M. Newman

This report, part II, summarizes the Atmospheric Static Investigation
carried out as one of the phases of a co-ordinated research programme on
Lightning Protection for Aircraft, related Atmospherics, and Precipitation-
Static Reduction, carried on by the LTRI laboratory in 1952-1953. Calculated
current variations are in surprisingly close agreement with magnitudes and
separations of successive current peaks shown by Scholand's photographic
records. Artificial lightning generator and propagation mechanism set-ups
have been constructed illustrating branching streamers tapping cloud charges
and stepped leader strokes to ground. A five beam cathode-ray tube
panoramic analyzer was used to determine atmospherics susceptibility on
five receivers tuned to frequencies ranging from 15 kc and 150 Mc. A camera
simultaneously photographed a wide-band oscillograph in conjunction with
the D.F. screen to provide both direction and waveshape of particular
atmospherics. Methods and equipment for co-ordinated oscillographic measure-
ments were developed, especially with regard to closely synchronized timing
at co-operating laboratories located 1000 miles apart at apexes of a triangle.

RECORDING AND CLASSIFICATION OF THUNDERSTORM ATMOSPHERICS BY COUNTER TECHNIQUES

Supplement to Proc. Conference on Radio Meteorology, University of Texas,
Austin, 9-12 November 1953, Vol. 3 (1954).
M.M. Newman, J.R. Stahmann, J.R. Anderson

Noises from whatever source or wavelength can be measured by counter

analyzers. The rate of rise, amplitude, average level and pulse repetition rate are characteristics which can be measured with some modifications for sferics over other types of noise. Models of counter analyzers are described and illustrated, methods of measurement outlined, correlation with actual reduction in intelligibility discussed and equipment, records, and results illustrated in photographs and graphic forms.

LIGHTNING DISCHARGE MEASUREMENTS

Paper presented at IRE-URSI Symposium, Washington, D.C., 22nd-25th May 1957.

M.M. Newman

Atmospheric interference reduction and lightning protection development for aircraft brought out the need for as yet unavailable data on lightning channel resistivities, surge impedances, velocities of pulse advance, and consequent rates of charge transfer. To facilitate intercepting natural lightning discharges for detailed study, a special mobile artificial lightning generator installation has been designed and installed on an ocean-going schooner.

Parallel studies of artificial lightning pulse radiation using balloon supported channel conductor equivalents are expected to prove useful in lightning sferics propagation studies, particularly as it is calculated it will be possible to produce short-time pulse trains of radiated powers of the order of 100 megawatts in the 10-kc frequency range of interest in the "whistler" type propagation theory.

ARTIFICIAL ATMOSPHERICS GENERATION

A Report, Contract AF 19(604)-1556, Lightning and Transients Research Institute, Minneapolis, Minnesota, September 1957. AFCRC-TR-58-134. AD-152 376.

M.M. Newman

Artificial lightning atmospherics generators, of high enough power, provide a decided advantage in continuing atmospherics propagation investigations, since the source pulse is accurately known both as to exact radiated wave shape and original magnitude.

A mobile 1,000,000 volt impulse generator design has been worked out based on conventional artificial lightning generator design principles, as utilized in many high voltage laboratories. Capacitors are charged in parallel at relatively low voltages of 50 kilovolts each and then switched through an initiating gap system to a series arrangement to produce an impulse discharge with crest voltages of one million volts. A multiple gap trigger system is utilized to provide smooth voltage wave fronts, and a special vacuum tube trigger generator permits a control of the firing time to within two micro-seconds.

LIGHTNING DISCHARGE CHANNEL CHARACTERISTICS AND RELATED ATMOSPHERICS
Recent Advances in Atmospheric Electricity, Pgs 475-484 (Pergamon Press,
London, 1957).
M.M. Newman

Lightning discharge channel phenomena reproduced in laboratory experiments show feasibility of a simple equivalent circuit discharge channel model. An aircraft-intercepted discharge recorded oscillographically provided data on magnitude of currents and charge transfer in a cloud-to-cloud developing discharge which checked closely with model discharge oscillograms.

An artificial lightning generator has been installed in an ocean-going schooner to trigger natural lightning discharges to rocket-launched lines providing connection to oscillographic equipment.

The schooner generator is also used to pulse a helicopter-supported artificial channel conductor, thus reproducing typical lightning atmospherics. The source pulse, being accurately known both as to exact radiated wave shape and original orientation, provides a decided advantage in continuing atmospherics and "whistler" mode propagation investigation.

ARTIFICIAL SFERICS GENERATION FOR INTERFERENCE REDUCTION RESEARCHES
Paper presented at IRE-URSI Symposium, Washington, D.C., 23rd-26th April, 1958.
M.M. Newman

Compact small scale artificial sferics generators are described in application to duplicating natural sferics at radio receiver inputs for evaluation of system vulnerability to lightning atmospherics. On a larger scale, in studying change of wave shapes of propagated sferics, use is made of a mobile high-voltage generator in a sea-going schooner laboratory, pulsing a helicopter-supported wire system duplicating the lightning channel.

Wire lengths of 3000 feet were readily held vertical in preliminary tests, with 10,000 feet apparently readily attainable. One million-volt impulses were fired into the helicopter supported wire, using an insulating length of 200 feet of nylon rope between the helicopter and wire. Possible psychological pilot aversion to being at the receiving end of an artificial lightning discharge was avoided by the research director's coming along on the test flights. A condenser was also installed across the gas tank gauge to prevent induced surges from exploding the fuel tanks. The high voltage safety precautions proved adequate.

ARTIFICIAL PRODUCTION OF LIGHTNING ATMOSPHERICS. SEA-GOING LIGHTNING GENERATOR

M.M. Newmann, and Others
See Section III, Page 248.

THUNDERSTORMS. THE ELECTRIC FIELD VARIATIONS RADIATED FROM LIGHTNING DISCHARGES

Phys. Abstr. 1294/1953; Joint Commission on Radio-Meteorology, Pgs 17-38, 1951.
H. Norinder

Simultaneous operation of specially constructed c.r.c.'s at two stations has allowed variations of the electric field caused by the same lightning discharges to be recorded over the ranges 0-70 km (with stations 17 km apart) and 50-2000 km (with stations 570 km apart). The results are discussed experimentally and theoretically. Near the source there is a main quasi-periodic variation of wavelength 11 km in the pre-discharges. The analysis is simplified at greater distances when the lightning is transformed into atmospherics.

THE WAVEFORMS OF THE ELECTRIC FIELD IN ATMOSPHERICS RECORDED SIMULTANEOUSLY BY TWO DISTANT STATIONS

Arkiv. Geofysik (Stockholm), Vol. 2., Paper 9, Pgs 161-195 (June 1954).
H. Norinder

The electric field variations of atmospherics originating from thunderstorm centres at various distances are investigated by recording them simultaneously at two field stations, 570 km apart. To avoid interference from sources of disturbance closer at hand, the observations were carried out in September. Most of the thunderstorms registered were to the south-west or south, over Europe, and their distances from the northerly station varied between 240 km and 2,400 km. A few sources of disturbance at shorter distances, over Sweden, were also recorded.

MAGNETIC FIELD VARIATIONS FROM LIGHTNING STROKES IN VICINITY OF THUNDERSTORMS

Arkiv. Geofysik (Stockholm), Vol. 2, Paper 20, Pgs 423-451 (1956).
H. Norinder

Two distinct methods are available for investigation of electromagnetic variations in the vicinity region of thunderstorms: (a) the open antenna method, and (b) the closed antenna or frame aerial method. Cathode-ray oscillographs are used in both methods, either directly connected to the antenna or connected with the antenna over aperiodic amplifiers.

The object of the present paper is to furnish a detailed account of measurements carried out by the frame aerial method at the Institute of High

Tension Research at two field stations during the thunderstorm season of 1953. Results from the thunderstorm season of 1954 have also to some extent been included. Therefore, these investigations must be regarded as preliminary, more extensive research to be put in hand during the thunderstorm seasons of the following year.

A NEW METHOD OF MEASURING RAPID MAGNETIC FIELD VARIATIONS FROM ATMOSPHERIC ELECTRIC DISCHARGES BY USING A LOOP SYSTEM ON THE EARTH'S SURFACE
Arkiv. Geofysik (Stockholm), Vol. 2, Paper 23, Pgs 481-489 (1956).
H. Norinder, E. Knudsen

A large loop buried horizontally just below the earth's surface is used to record, with the aid of amplifiers and c.r.o.'s, the vertical component of the field variations produced by lightning discharges to earth at distances up to 100 km. The physical basis of the method is described and typical results are shown to agree with records obtained on frame aerials used in earlier investigations. A frequency distribution of superimposed h.f. oscillations shows a peak in the wavelength region of 11 km. The variation of the wave shape of the signal with increasing distance is illustrated. For distances exceeding 100 km, the radiation wave shapes recorded in the horizontal loops are compared with records obtained on open-wire aerials. Discharges originating in wintry snow squalls are examined.

ANALYSIS OF THE VARIATIONS OF THE ELECTROMAGNETIC FIELD CAUSED BY LIGHTNING DISCHARGES
AD 98 730; 28th May 1956.
H. Norinder

Magnetic field variations of lightning strokes.

VARIATIONS FORMS AND TIME SEQUENCE OF MULTIPLE LIGHTNING STROKES
Arkiv. Geofysik (Stockholm), Vol. 2, Paper 25, Pgs 515-531 (1957).
H. Norinder, B. Vollmer

Typical oscillographic records are reproduced of the magnetic field changes produced by multiple lightning flashes in frame aerials at one or, simultaneously, at two recording stations. A variety of wave shapes was obtained, with or without h.f. oscillations superimposed on uni-directional wave shapes. The variation of wave shape due to successive discharges is illustrated and discussed. Frequency distribution curves are given of the time interval between component strokes and their duration. The relative amplitudes are indicated of the field changes produced by the first six component strokes in multiple flashes.

PRE-DISCHARGES IN RELATION TO SUBSEQUENT LIGHTNING STROKES
Arkiv. Geofysik (Stockholm), Vol. 2, Paper 27, Pgs 551-571 (1957)
H. Norinder, E. Knudsen

Three predominant types of pre-discharge are described as recorded simultaneously by vertical and horizontal frame aeriels. Statistical distribution curves are derived of the time intervals between the various rapid field variations and the amplitudes are plotted as a function of distance, pre-discharges with and without subsequent main field changes (caused by return strokes) being considered. On an average, the maximum amplitudes of rapid pre-discharges amount to about 15% of the subsequent main field changes.

ATMOSPHERIC ELECTRIC DISCHARGES FROM DISTANT SNOW SQUALLS AND OCCLUSION FRONTS
Arkiv. Geofysik (Stockholm), Vol. 2, Paper 26, Pgs 533-550, (1957).
H. Norinder, E. Knudsen

Oscillographic direction-finding equipment is described designed to determine the centres of origin of atmospherics recorded during winter months in the absence of thunderstorms. A series of weather maps are reproduced indicating snow squalls as the sources of these atmospherics. The characteristic shapes and amplitudes of the atmospherics are examined and are compared with others caused by lightning discharges. The cause of electrical discharges in snow and ice clouds is discussed.

THE RELATION BETWEEN LIGHTNING DISCHARGES AND WHISTLERS
Planet Space Sci., Vol. 1, No. 3, Pgs 173-183 (August 1959). Similar material was published as Technical Scientific Report 1 on Lightning Discharges in Relation to Whistlers, Contract AF 61(052)-07, Uppsala University, Sweden (February 1959). AFCRC-TN-59-281. AD-267 353.
H. Norinder, E. Knudsen

A station for analysis of relations between lightning discharges and whistlers was operated near Uppsala. After preliminary tests in 1956-57 a definite programme was realized during the thunderstorm season of 1958. It was found that whistlers occur in groups - whistler situations - with periods often of $\frac{1}{2}$ - $2\frac{1}{2}$ hours, exceptionally of 5-6 hrs. Whistlers sometimes occurred in great numbers for shorter periods of time between total cessations. These extended over hours, days and even weeks. Whistler situations on days with thunderstorms were located by a c.r.o. direction finder. It was found that whilst a thunderstorm in one direction produced whistlers, a simultaneous thunderstorm in another direction at about the same distance sometimes did not. Investigation of variations in the same thunderstorm of the electric field force from atmospherics related to whistlers or not so related showed that atmospherics with the highest field force were always followed by whistlers. This was explained

partially by facilitated propagation for wave-packets in the low-frequency band around 5 kc/s and partially by high initial energy in the discharges causing whistlers. A comparison in the same thunderstorm of waveforms from atmospheric not producing whistlers showed typically irregular variation forms and one single discharge in the lightning path. Waveforms of whistler-producing atmospheric showed regular variational forms with frequencies around 5 kc/s. In several cases the waveforms indicated multiple discharges in the lightning path.

MULTIPLE LIGHTNING DISCHARGES FOLLOWED BY WHISTLERS

Phys. Abstr. 16480/1960; Ark. Geophys. (Sweden), V. 3, Paper No. 12, Pgs 289-98, 1960.

H. Norinder, E. Knudsen

Time intervals of multiple lightning strokes which produced whistlers were analyzed by a cathode-ray oscillograph. The time intervals of the corresponding multiple whistlers were determined by ensuing sonagrams. Within the limits of error a thorough agreement in time intervals is proved. A method is proposed for the analysis of multiple whistlers which originate from separate lightning paths and where whistlers propagate along different ducts.

THE DISPERSION OF WHISTLERS COMPARED WITH THE GEOMAGNETIC LATITUDES OF THEIR SOURCES

Planet, Space Sci., Vol. 5, Pgs 326-328, August 1961.

H. Norinder, E. Knudsen

Observational results are presented which indicate that the geomagnetic latitude of lightning discharges is a factor determining the dispersion constant of the related whistlers.

RECENT RESULTS IN THE INVESTIGATION OF THE RELATION BETWEEN LIGHTNING DISCHARGES AND WHISTLERS

Planet, Space Sci. Vol. 5, No. 1, Pgs 46-49, January 1961.

H. Norinder, E. Knudsen

A station for research into the relation between lightning discharges and whistlers was operated near Uppsala and preliminary results obtained were published in this Journal. Further analysis of data obtained has been carried out. It has been possible by harmonic analysis to show that lightning discharges producing whistlers have a pronounced energy peak around 5 kc/s.

From a comparison of time intervals of multiple lightning discharges recorded by a cathode-ray oscillograph and from corresponding records of multiple whistlers on sonagrams full agreement in time variation between the two phenomena was demonstrated.

SOME DIFFERENT TYPES OF WHISTLERS IN RELATION TO SIMULTANEOUS THUNDERSTORM ACTIVITY

EE Abstr. 2671/1964; Ark. Geofys. (Sweden), Vol. 4, Paper 14, Pgs 333-43, 1963.

H. Norinder, E. Knudsen

It was found that the same thunderstorm region produced usual as well as unusual and mixed variational form of whistlers. The production of the different types proved to be independent of the geographical positions of the active thunderstorm regions. By the aid of different characteristics of lightning discharges it was not possible to draw conclusions as to why different types of whistlers were produced. The reason must be sought in some other geophysical phenomena, and only further systematic experimental investigations will give an answer to this question.

MAGNETIC FIELD VARIATIONS IN THE VICINITY OF LIGHTNING DISCHARGES

EE Abstr. 11409/1963; CEEGB Conf. on Gas Discharges and the Electricity Supply Industry, Leatherhead, 1962. (See Abstr. 3511 of 1963), Pg.74-88.

H. Norinder, E. Knudsen

Three, and sometimes four, field stations situated on open ground outside Uppsala were simultaneously operated during two thunderstorm seasons. The arrangement of the stations made it possible to record simultaneously the magnetic field variations caused by lightning within a radius of 20 km. The records were obtained by frame aerials in combination with aperiodic amplifiers and simultaneously recording cathode-ray oscillographs. The aim was to compare the oscillographic results with simultaneous daylight photographs of lightning channels. These photographs were obtained by a specially developed device. The combined photographic and oscillographic method made it possible to find out if all multiple discharges in a lightning stroke followed the same or different paths.

COMMENTS ON DISTINCT TYPES OF MUSICAL ATMOSPHERICS IN THEIR RELATION TO THUNDERSTORM ACTIVITY

Planet, Space Sci. (GB), Vol. 11, No. 5, Pg 579, May 1963.

Phys. Abstr. 23599/1963.

H. Norinder, E. Knudsen

Whistler-producing lightning discharges are not directly connected with distinct forms of whistlers.

THE PROPAGATION OF ELECTROMAGNETIC WAVES IN IONIZED GASES (WITH SPECIAL REFERENCE TO "WHISTLERS") I-II.

F.H. Northover

See Section I, Page 77.

VERY LOW-FREQUENCY SPECTRA OF ATMOSPHERICS PROPAGATED THROUGH THE IONOSPHERE

T. Obayashi

See Section I, Page 80.

GEOPHYSICAL EFFECTS OF HIGH-ALTITUDE NUCLEAR EXPLOSIONS

T. Obayashi, S.C. Coroniti, E.T. Pierce

See Section IV, Page 322.

MEASURED FREQUENCY SPECTRA OF VERY LOW-FREQUENCY ATMOSPHERICS

T. Obayashi

See Section III, Page 249.

THE EFFECT OF PROTON GYRATION IN THE OUTER ATMOSPHERE REPRESENTED ON THE DISPERSION CURVE OF A WHISTLER

EE Abstr. 1205/1962; J. Geomagn. Geoelect. (Japan), V. 12, No. 1, Pgs 32-7, 1960.

T. Ondoh, S. Hashizume

The complete dispersion curve for the purest short whistler observed at Kyoto during 1958 was compared with that derived from Storey's theory with corrections at high and low audio frequencies for the effects of electron and proton gyration respectively. The influence of proton gyration is expected to be greatest where the proton gyro-frequency is greatest, i.e. at low-latitude stations where the whistler paths are confined to low heights. The effect of proton gyration is clearly revealed in the results for Kyoto, which has a low geomagnetic latitude.

ON THE ORIGIN OF VLF NOISE IN THE EARTH'S EXOSPHERE

J. Geomag. Geoelec. (Kyoto), Vol. 12, No. 2, Pgs 77-83, 1960.

T. Ondoh

The primary cause of VLF noise in the exosphere is Čerenkov radiation due to high-speed protons. The natural thermal noise and proton cyclotron radiation effects are considered to be secondary noise sources.

A POSSIBILITY OF THE GENERATION OF VLF EMISSIONS IN THE OUTER EARTH'S EXOSPHERE

Planet. Space Sic. (GB), Vol. 9, Pgs 69-70, (January/February 1962).

Phys. Abstr. 13054/1962.

T. Ondoh

It is shown that growing waves of Čerenkov radiation are to be expected from fast protons following geomagnetic field lines in the outer exosphere. This may account for the strong and weak bursts of VLF emission and for the dawn chorus.

VLF EMISSIONS AND GEOMAGNETIC DISTURBANCES AT THE AURORAL ZONE
II. CHORUS INCREASES AND GEOMAGNETIC PULSATIIONS AT THE AURORAL ZONE
Phys. Abstr. 11472/1963; J. Geomagn. Geoelect. (Japan), Vol. 14,
No. 2, Pgs 86-98, 1962.
T. Ondoh

A close relation was found between increases of chorus indices continuing for a few hours and geomagnetic pulsations at the auroral zone, using the chorus indices and rapid-run magnetograms at College, Alaska, during July 1959 to December 1960. During this period 79 increases of chorus indices occurred in relatively quiet geomagnetic-conditions after geomagnetic bay-like disturbances. Of 79 chorus increases, 52 were associated with geomagnetic pulsations with periods between 1 and 6 mins and 11 were associated with pulsations having periods of about 30 secs. The chorus increases may be generated by penetration of high speed charged particles into the exosphere, which may also be related to the geomagnetic pulsations. A possible mechanism of the generation of geomagnetic pulsations was discussed.

IONIZATION IN THE OUTER ATMOSPHERE INFERRED FROM WHISTLING ATMOSPHERICS
J. Geomagn. Geoelect. (Japan), V. X, No. 4, 1959.
J. Otsu, A. Iwai

From dispersions of whistling atmospherics ionization-densities in the outer atmosphere are roughly estimated, and diurnal variations of electron density are obtained in lower parts of outer atmosphere. In order to examine the origin of the ionization kp index is compared with rate occurrence of whistlers, but no correlation is obtained, though the correlation is altered slightly positive when value of kp is taken two days in advance, and observations at low latitudes show that an ionized hydrogen atmosphere is likely in the exosphere.

INVESTIGATION OF THE PRESENCE OF IONIZED HYDROGEN IN THE OUTER ATMOSPHERE USING WHISTLER DISPERSIONS
Proc. Research Inst. Atmospherics, Nagoya University (Japan), Vol. 6, Pgs 44-45, 1959.
J. Otsu, A. Iwai

A trial is made to detect the presence of ionized hydrogen in the outer atmosphere following a theory concerning the corrections of the dispersion law of whistlers given by Storey, which involves effects of light ions as well as electrons on dispersion. Four short whistlers most suitable for this purpose are analyzed, which were observed at Toyokawa and Wakkanai stations all on different dates. For they are pure and fairly well defined down to frequencies lower than 1,000 c/sec and one of them is preceded by tweek atmospheric click, which makes the location of time origin easier. The electron density used by Storey is too small to produce the dispersions observed, so different distributions of electron density are assumed so as to satisfy the dispersions observed.

From these distributions two complete dispersion curves are calculated each for the case of Toyokawa and Wakkanai. The dispersions measured from whistler traces agreed fairly well with the theoretical curves. From this result the presence of ionized hydrogen in the outer atmosphere is strongly supported. But it seems to be necessary to investigate the shape of the ray path as exactly as possible in order to solve the problem of distribution of ionization density and get further information about the constituent of the ionization.

SEA AND HISS ASSOCIATED WITH GREAT BURSTS OF SOLAR RADIO EMISSION IN NOVEMBER 1960 - HISS

Proc. Research Inst. Atmospherics, Nagoya University (Japan), Vol. 8, Pgs 13-16, January 1961.
J. Otsu, A. Iwai.

"Hiss" is a relatively steady ionospheric radio noise and it has been frequently observed at high latitudes. During magnetic storms the location of hiss activity has shifted towards lower latitudes. So far no hiss has been reported to have been observed at anywhere lower than about 40° of geomagnetic latitudes.

As a hiss has frequency components usually at the audio-frequency band, it can be observed with an observing apparatus for whistlers. Though we have continued a two-minute observation of whistlers every half-an-hour at Wakkanai (geomag. lat. $34^\circ.3$) since the commencement of IGY, we have been able to confirm hiss generations only for the first time during the present solar radio noise outbursts.

TRANS-RESONANT ELECTRON ACCELERATION

J. Geophys. Research, Vol. 66, No. 9, Pgs 2673-2676; September 1961.
E.N. Parker

Helliwell and Bell have suggested synchronous acceleration of electrons by electromagnetic waves in the whistler range in the geomagnetic field. The acceleration of trapped electrons by electromagnetic waves is here generalized to include non-synchronous or trans-resonant acceleration. It is shown that whistlers will scatter the electron velocity, by an amount inversely proportional to the square root of the time rate of change of whistler frequency, during the time that the whistler frequency is passing over the electron gyrofrequency. Only electrons with initial energy above about 10^2 ev can see the Doppler-shifted whistler frequency at the gyro-frequency and be affected by this transresonant acceleration. Thermal electrons experience no effect. Current observation of whistlers in the outer geomagnetic field is too sketchy to allow a determination of transresonant acceleration rates, so that the relative importance, as compared, for example, with the strong-whistler synchronous acceleration of Helliwell and Bell, cannot be assessed. The importance of whistler acceleration can be established when the whistler frequency spectrum and recurrence rate are known throughout the geomagnetic field.

NOTE ON THE RELATION BETWEEN THE METEOROLOGICAL SITUATION AND THE LOCATION OF SFERICS

Phys. Abstr. 1299/1953; Joint Commission on Radio Meteorology, Pgs 44-52, 1951.

A. Perlat

Since the end of 1944 the location of sferics by the British meteorological services has enabled these to be placed on synoptic weather maps. Considerations are given to a comparison between sferics and visual observations of storms, the diurnal and annual variations in the number of sources detected, and the relation between sources and areas of horizontal wind convergence of the atmosphere.

ATMOSPHERICS FROM LIGHTNING FLASHES WITH MULTIPLE STROKES

Paper presented at the 41st Annual Meeting, American Geophysical Union, Washington D.C., 27th-30th April 1960.

J.H. Piddington, E.T. Pierce

The atmospherics resulting from the individual return strokes of a multiple lightning discharge to the ground are considered. It is shown that there should be **significant differences** between the separate atmospherics and especially between the disturbance due to the first return stroke and the atmospherics produced by subsequent strokes. The differences arise from variations in the upward velocity of the return strokes and in the wave shapes of the current surges. The differences should be detectable both in the wave forms and in the frequency content of the individual atmospherics generated by a distant multiple lightning flash. In this connection some experimental evidence is discussed.

LIGHTNING

Science Progress, Vol. 45, No. 177, Pgs 62-75, January 1957.

E.T. Pierce

A summary of lightning stroke processes is given along with a brief summary of electromagnetic radiation at low and very low frequencies.

ATMOSPHERICS FROM LIGHTNING FLASHES WITH MULTIPLE STROKES

Phys. Abstr. 16482/1960; J. geophys. Res. (USA), V. 65, No. 7, Pgs 1867-71, July 1960.

E.T. Pierce

The atmospherics resulting from the individual return strokes of a multiple lightning discharge to earth are considered. Special attention is paid to the differences between the source spectra for first and subsequent strokes. It is shown that the change in the velocity of ascent of the return stroke, between a first and a following stroke implies a

shift of the spectrum toward the low-frequency end. On the other hand, the more rapid current rise associated with subsequent strokes entails an intensification of the higher frequencies. A combination of these effects suggests that a source spectrum is effectively constant for all strokes at frequencies exceeding 10 kc, and that the main differences occur below this frequency. A straightforward experimental method of checking these conclusions is outlined.

EXCITATION OF EARTH-IONOSPHERE CAVITY RESONANCES BY LIGHTNING FLASHES
Phys. Abstr. 2279/1964; J. Geophys. Res. (USA), Vol. 68, No. 13, Pgs
4125-7, 1st July 1963.
E.T. Pierce

The existence of resonances at frequencies below 100 c/s was originally predicted by Schumann (1952). Their presence has since been experimentally confirmed. In subsequent theoretical development it has largely been assumed that the excitation is due to the return stroke of a flash to earth. Observations in the vlf band (3 to 30 kc/s) were extrapolated to the frequency range of less than 100 c/s. The limitations of this approach are discussed. Simple models are developed on an empirical basis for the temporal variation of electrostatic moment during cloud discharges and flashes to earth. Differentiation and Fourier methods yield the spectral content of the radiating signals exciting the resonances. It is shown that cloud and ground flashes are of comparable effectiveness in the excitation of the lower-frequency resonances. The implications of this conclusion are examined.

SOME ELF (EXTREMELY LOW FREQUENCY) PHENOMENA
E.T. Pierce
See Section IV, Page 324.

EXTREMELY LOW FREQUENCY RECEPTION AT KINGSTON, R.I.
C. Polk, F. Fitchen
See Section III, Page 251.

SCHUMANN RESONANCES OF THE EARTH - IONOSPHERE CAVITY - EXTREMELY LOW FREQUENCY RECEPTION AT KINGSTON, R.I.
J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 3, Pgs 313-18, May-June 1962.
C. Polk, F. Fitchen

Since June 1961 magnetic fields of natural origin in the 5 to 20 c/s frequency range have been recorded in Kingston. The experimental equipment is described briefly, and results are presented. Variations with time of the first resonant frequency of the earth - ionosphere cavity are indicated, and effects of solar activity are discussed. An analysis of the envelope of recorded wave trains show only fair agreement with existing theory.

DIURNAL VARIATION IN THE OCCURRENCE OF "DAWN CHORUS"

Phys. Abstr. 464/1958; Nature (GB), V. 180, Pg 433, 31st August 1957,
J.H. Pope

Observations of "dawn chorus" were made between 1st January and 2nd July 1956, at College, Alaska, with equipment sensitive to frequencies from 1 to 10 kc. The phenomenon was present in 224 of the 2784 one-minute hourly observing periods. A histogram of the records for each hour of the day shows that the time of maximum occurrence of "dawn chorus" is 1400 hrs local time. Observations at other stations in New Zealand, the United States and England, are quoted showing that the local times of the daily maximum in the occurrence of the effect range from 0200 at Wellington, New Zealand, geomagnetic latitude 45° S, to 1400 at Alaska, geomagnetic latitude 65° N, a graph indicating an approximately linear relation between local time of daily maximum and geomagnetic latitude. Since the daily maximum does not, in general, occur at dawn, it is suggested that the phenomenon be referred to simply as "chorus".

OBSERVATION OF A UNIQUE VLF EMISSION

J. Geophys. Research, Vol. 65, No. 8, Pgs 2543-2544, August 1960.
The work reported was sponsored by Electronic Research Directorate, Air Force Cambridge Research Centre. A reprint was published in Contributions of the Geophysical Inst., Series A, University of Alaska, College, Alaska, (1960). AD-251 090.
J.H. Pope, W.H. Campbell

This note describes a form of VLF noise between 2 and 4 kc as observed on whistler recordings near College, Alaska. This form of the noise is incompatible with whistler theory and suggests that its cause is from some other source.

AN INVESTIGATION OF WHISTLERS AND CHORUS AT HIGH LATITUDES

Scientific Report 4, Contract AF 19(604)-1859, University of Alaska, College, Alaska, (April 1959). AFCRC-TN-355. AD-216 522.
J.H. Pope

The whistlers and chorus received at College, Alaska, during the period from December 1955 through March 1958 are studied particularly with respect to temporal variations.

The diurnal curves for whistler activity show maxima after midnight local time while the seasonal variation peaks during the winter. It appears that these variations in whistler activity are in part explainable in terms of very low frequency propagation conditions.

The diurnal variation of chorus shows a maximum at about 1400 hours local time. By the use of data from lower latitude stations a dependence of this time of diurnal maximum on the geomagnetic latitude of the station is shown.

The coefficients of correlation for chorus activity versus magnetic activity were determined on a monthly basis. A seasonal variation in these correlations is indicated which appears to be unique for the geomagnetic latitude of College.

A preliminary statistical study of one of the more easily measured characteristics of chorus is discussed. The characteristic chosen is the mid-frequency in an element of chorus. A diurnal variation in this parameter is indicated.

WHISTLER AND CHORUS OBSERVATIONS

Arctic Propagation Studies at Tropospheric and Ionospheric Modes of Propagation, Pgs 51-67, Final Report, Contract AF 19(604)-1859, University of Alaska, College, Alaska, (October 1959). AFCRC-TR-59-366. AD-231 504. J.H. Pope

A technique has been described which may enable one to measure the electron density of the outer ionosphere to heights reached by whistlers. In developing this technique a method was sought by which a large number of whistlers can be analyzed in order to make statistical studies of the electron density variations. The method presented satisfies these conditions. Unfortunately its accuracy is seriously impaired without an accurate determination of the time of the causative impulse.

The causative tweek is seldom identified with whistlers recorded at College and Kotzebue, Alaska. Therefore, for statistical studies, it seems desirable to modify the technique so that the results are independent of the time of origination or to find a method of deducing the time without a location on the sonagram of the originating impulse.

While the nature of whistlers has been essentially established, virtually nothing is known regarding the origin of chorus. Thus the results of studies of temporal variations and correlations of chorus at all latitudes are significant. The temporal variations at the latitude of College, Alaska, have been determined. The dependence of the diurnal variation on the geomagnetic latitude has been shown to have a later local time of maximum with higher latitude. The correlation between chorus and magnetic activity at College has a complicated seasonal variation which implies that the observed chorus depends on a third phenomenon. It seems probable that this third phenomenon is closely related to ionospheric absorption but there is not sufficient data in a reduced form to determine the validity of this supposition.

A HIGH-LATITUDE INVESTIGATION OF THE NATURAL VERY LOW-FREQUENCY
ELECTROMAGNETIC RADIATION KNOWN AS CHORUS

Phys. Abstr. 11413/1963; J. Geophys. Res. (USA), Vol. 68, No. 1, Pgs 83-99, 1st January 1963.

J.H. Pope

Data from several Alaskan stations observing the natural v.l.f. electromagnetic radiation known as chorus permits a number of statistical investigations, especially of latitudinal variations of the phenomenon. Maximum occurrence lies at 60° to 70° geomagnetic latitude. Seasonal variations at individual stations depend intricately on latitude. Below, but not above, the auroral zone the diurnal maximum depends on an "eccentric geomagnetic latitude". Chorus correlates with other phenomena, such as geomagnetic activity, the correlation varying seasonally and diurnally. Correlations between stations show a diurnal behaviour consistent with the possibility of the existence of isochronic lines for chorus. Temporal variations in the highest frequency (kilocycles per second) of chorus for each sample show a diurnal minimum near noon and seasonal peaks near equinoxes; temporal variations in the rate of change of frequency of chorus show similar patterns.

COMPARISON OF SFERICS PROPAGATED ALONG THE FAIRBANKS-THULE GREAT CIRCLE.
Paper presented at IRE-URSI Symposium, San Diego, California, 19th-21st
October 1959.

J.H. Friedigkeit

More than 50 sferics have been identified as having originated on the great circle passing through the SRI Sferics Measuring Stations located at Fairbanks, Alaska, and Thule, Greenland. These sferics have been simultaneously recorded at both sferic stations with equipment that has a bandwidth of 3 to 3 kc. Spectrum analysis of these waveforms makes it possible to speculate on the relative attenuation of the various frequency components for a specific arctic propagation path. Comparison between sferic waveforms whose sources are in Europe or in the South Pacific makes it possible to investigate reciprocal path propagation.

ON THE EXTREMELY LOW FREQUENCY SPECTRUM OF EARTH-IONOSPHERE CAVITY
RESPONSE TO ELECTRICAL STORMS

J. geophys. Res. (USA), V. 66, No. 5, Pgs 1580-1583, May 1961.

H.R. Raemer

No abstract.

EFFECT OF EQUATORIAL THUNDERSTORMS ON THE ELF NOISE SPECTRUM

Applies Research Lab., Sylvania Electronic Systems, Waltham 54, Mass.,
ARM No. 271, 7 p., plus figs. 1961.

H.R. Raemer

No abstract.

ON THE SPECTRUM OF TERRESTRIAL RADIO NOISE AT EXTREMELY LOW FREQUENCIES
H.R. Raemer
See Section III, Page 251.

DIURNAL AND CYCLIC VARIATIONS OF THE INTENSITY OF NATURAL RADIO NOISE
OF VERY LOW FREQUENCY
C. Renard
See Section IV, Page 324.

IMPULSE FREQUENCY OF ATMOSPHERICS ON TWO DIFFERENT FREQUENCY BANDS IN
CONNECTION WITH LARGE AREA PRESSURE CHANGES, TEMPERATURE CHANGES AND
CURRENTS OVER THE EUROPEAN CONTINENT
Paper presented at Symposium on Very Low Frequency Waves, München,
Germany, 3rd October 1955. In German.
R. Reiter

During the years 1949 to 1954 impulses of atmospherics were
registered in Munich on two ranges of bandwidth:

Range I:	10 - 50 kc
Range II:	4 - 12 kc

The registration was carried out by counting such impulses, the amplitude
of which exceeded the comparatively high input level of the respective
amplifier.

The low frequency activity (impulse frequency of atmospherics) is
an indicator of large-area meteorological processes and changes.

SUN-RISE EFFECTS ON VERY LONG WAVES AND ATMOSPHERICS
Paper presented at Symposium on Very Low Frequency Waves and Atmospherics,
München, Germany, 3rd October 1955. In German.
K. Revellio

Shortly before sun-rise the total number of atmospherics at 27 kc
suddenly decreases sharply. First it passes through a minimum, rises
again to a small secondary maximum and falls then to the daily low number
of disturbances. For the clarification of this effect field strength
measurements of the transmitter Rugby at 16 kc were carried through in
Weissenau. The field strength too, shows corresponding decreases, but
rises afterwards, with the secondary maximum, back to its full night value,
then decreases slowly.

ATMOSPHERICS

EE Abstr. 4353/1953; Onde élect. (France), V. 33, Pgs 165-72, March 1953.

R. Rivault

Summary of papers and discussion presented to Commission IV (Atmospherics) at the 10th General Assembly of U.R.S.I. (Sydney, 1952). Subjects dealt with are: study of lightning; microstructure of individual atmospheric (forms, "whistlers"); mean level and spectrum; direction finding of atmospheric analysis of air masses-localization of storm centres; radio noise of terrestrial origin.

CHARACTERISTICS OF WHISTLERS OBSERVED IN THE COURSE OF ONE YEAR

L'Onde Electrique, Vol. 37, No. 362, Pgs 539-540, May 1957. In French.

R. Rivault

Frequency and waveform characteristics of whistlers were recorded at Poitiers, France. Two types were identified; those of short duration (connected with thunderstorm activity in the Southern Hemisphere) and those of longer duration (preceded by an atmospheric of a particular type associated with lightning in the Northern Hemisphere). Wave forms of long whistlers would indicate that they are closely connected with the mechanisms of formation of the sferics which precede them.

RADIO ELECTRIC DISTURBANCES OF TERRESTRIAL ORIGIN (REPORT OF)

Commission IV, XIIth Gen. Assembly of the International Scientific Radio Union, L'Onde Electrique, Vol. 38, No. 376, Pgs 527-532, July 1958. In French.

R. Rivault

The development mentioned three years ago is now confirmed by the abundance of new results in connection with whistlers and natural low-frequency emissions. Thanks to these phenomena, one can already explore the exosphere which will, in the near future, be sounded as one now sounds the ionosphere. The author summarizes the results obtained in research on parameters modifying the shapes of atmospheric, when studying lightning and whistlers and low-frequency transmissions. He explains the researches made in connection with statistical and goniometrical recording of atmospheric, and also those regarding the meteorological aspects of atmospheric observations.

ON THE RESONANT FREQUENCIES OF SCHUMANN MODES

Applied Research Lab., Sylvania Electronic Systems, Waltham 54, Mass., Engineering Note No. 234, 10 p., illus., 1961.

R. Row

No abstract.

RESEARCH ON RELATIONSHIPS BETWEEN NATURAL ATMOSPHERIC RADIO PHENOMENA
AND GEOMAGNETIC FIELD

Tech. Final Report, Contract AF 61(514)-1309, 1st July 1959. Ionosphere Laboratory, Royal Technical University of Denmark, Report No.7.
J. Rybner, E. Ungstrup

The investigation consists in recording audio-frequency radiowave phenomena at Godhavn, Greenland, in co-operation with the U.S. National Committee of URSI at the request of the American Committee which has erected a chain of stations along the East Coast of America.

STUDY OF THE ATMOSPHERIC RADIO NOISE AT 27 AND 100 KC AT DELHI
EE Abstr. 6024/1958; J. sci. industr. Res. (India), V. 17A, No. 7,
Pgs 262-70, July 1958.
D.K. Sachdev

A preliminary report of the observations on v.l.f. atmospheric radio noise being carried out by the Radio Propagation Unit, National Physical Laboratory of India, New Delhi (28.5°N, 77°E), is presented. Particular attention is given to the study of sudden enhancement of atmospherics (S.E.A.) for which the observations were initially undertaken. It is found that enhancement is observed at both frequencies at the time of a solar flare; the effect at 27 kc is normally larger and earlier than at 100 kc.

SPHERIC OBSERVATIONS OF THE SEVERE WEATHER ON 19TH MAY 1960
J. Geophys. Research 67, Pgs 627-635, February 1962.
C.A. Samson, R.F. Linfield

No abstract

RADIO NOISE ANOMALIES IN AUGUST 1958
J. geophys. Res. (USA), Vol. 68, No. 9, Pgs 2719-26, 1st May 1963.
C.A. Samson (Phys. Abstr. 23595/1963).

Comparison of radio noise data for August 1958 with those for later years shows that the Johnston Island nuclear explosions on 1st and 12th August 1958, affected the atmospheric radio noise over a wide area in the Pacific region. Graphs of the midnight noise level at several frequencies from 13 kc/s to 5 Mc/s illustrate apparent noise anomalies at Cook, Australia; Ohira, Japan; Byrd Station, Antarctica; and Singapore. These anomalies resemble in several respects the well-marked effects previously noted at Kekaha, Hawaii.

ENERGY FLUXES FROM THE CYCLOTRON RADIATION MODEL OF VLF RADIO EMISSIONS
Letter in Proc. IRE, Vol. 48, No. 9, Pg 1650, September 1960.
R.A. Santirocco

Several authors have suggested that certain natural audio frequency electromagnetic background radiations, notably dawn chorus, are due to cyclotron radiation from protons incident on the earth's exosphere. The principal success of this theory is that with the Doppler and ionospheric dispersion effects taken into account, the theory nicely predicts the frequency vs. time characteristics of the observed signals. The purpose of this note is to point out that the cyclotron theory, at least in its simple form, does not seem to account for the observed strength of the radiation.

FREQUENCY SPECTRUM OF THE DAYTIME WAVE FORM OF ATMOSPHERICS RADIATED FROM THE RETURN STREAMER OF A LIGHTNING FLASH
Proc. Research Inst. Atmospherics, Nagoya Univ. (Japan), Vol. 3, Pgs 43-46, (November 1955). Similar material appeared in Bull. Research Inst. Atmospherics, Vol. 5, No. 2, (1955). In Japanese.
K. Sao

Using the expression of field intensity of very long radio waves by the Budden's waveguide mode theory and the results of discharge current variation of lightning flash by Norinder, the author has tried to derive the frequency spectrum of atmospherics radiated from the return streamer, but the computed results are not always coincident with the spectrum of atmospherics observed in practice.

RESEARCHES IN THE FREQUENCY ANALYSES OF WAVE FORMS OF ATMOSPHERICS. PART I.
Proc. Research. Inst. Atmospherics, Nagoya Univ. (Japan), Vol. 5, Pgs 12-30, (March 1958).
K. Sao

In order to illustrate the wave forms of atmospherics with the knowledge of pulses radiated from the origin and theories of propagation of VLF waves, investigations of the frequency spectra obtained with the aid of frequency analyses were proposed. In this field, F.W. Chapman and others observed the responses of a number of narrow-band receivers tuned to various frequencies. The results were based on the smooth daytime type of atmospherics originated at known distances up to about 4000 km. From these results they reduced the frequency characteristics of attenuation factors of very long wave propagation. In this paper the author analyzed a number of smooth type wave forms of atmospherics and tried to investigate the characteristics of frequency spectra. In the consideration of wave forms of received atmospherics there are two problems to be considered; first the discharge current wave forms of lightning strokes, secondly attenuation

characteristics of propagation paths. In dealing with these problems, first of all, current wave forms of strokes observed by Norinder and Dahle were analyzed. Next the author analyzed the wave forms of received atmospheric, not only of smooth daytime type but of general complicated type. The author, however, only reported the frequency spectra of various types of waveforms of atmospheric and of their sources, because the number of results were not enough to derive further detailed studies, i.e. the propagation characteristics of the waves. In addition, a brief description of the frequency analyzer used is given here.

RESEARCH IN THE FREQUENCY ANALYSES OF WAVE FORMS OF ATMOSPHERICS. II.
Proc. Research Inst. Atmospheric, Nagoya University (Japan), Vol. 7,
pg 7, 1960.
K. Sao

Recently our technique of wave form observation has been perfected by using the supersonic delay line with 250 micro-seconds delay time. Employing newly observed wave forms the author tried to deduce the relationship between the characteristics of frequency spectrum and the distance in the propagation of atmospheric, and obtained the following results.

- (1) Phase frequency spectrum of smooth daytime type wave form seems to correspond to the effect of propagation distance.
- (2) Amplitude-frequency spectrum of night-time regular peak type wave form is characterized by a minimum component around 2 kc/s.
- (3) Frequency spectrum of night-time quasi-sinusoidal type wave form shows comparatively similar characteristics to the smooth daytime type wave form.

RESEARCHES IN THE FREQUENCY ANALYSES OF WAVE FORMS OF ATMOSPHERICS - III.
Proc. Research Inst. Atmospheric, Nagoya Univ. (Japan), Vol. 8, Pgs 19-21,
January 1961.
K. Sao, H. Jindo

As to researches of atmospheric wave forms and their frequency spectra, we have tried to derive the traversed distance from the source, employing the results of wave form analyses. This is because the base lines of our spherics network in Japan are not adequate in locating atmospheric origins. Recently we could find the fact that the phase-frequency spectra analysed from wave forms have a strong connection with the propagated distances from their sources. It is the purpose of this paper to suggest a method of approximating the location of origins by wave form analyses.

A NOTE ON THE PHASE-FREQUENCY SPECTRA ANALYSED FROM WAVEFORMS OF
ATMOSPHERICS

Phys. Abstr. 6966/1963; J. atmos. terrest. Phys. (GB), Vol. 24,
Pgs 993-6, November 1962.

K. Sao

Analysis of phase-frequency spectra of atmospheric is suggested as a possible means of locating atmospheric sources using only one station; the received phase spectrum is affected mainly by propagation effects and only to a small extent by the source phase spectrum. Using waveguide theory an expression in terms of frequency and phase is obtained which depends only on distance. Experimental results are used to modify this expression to eliminate source effects altogether.

SHORT TERM AMPLITUDE PROBABILITY DISTRIBUTION OF IMPULSIVE ATMOSPHERIC
RADIO NOISE

Phys. Abstr. 3471/1963; J. sci. industr. Res. (India), Vol. 21D, No. 7,
Pgs 221-7, July 1962.

M. Satyam

The quasi-peak value of the atmospheric noise impulses received on 3.0 and 4.5 Mc/s within a bandwidth of 6 kc/s at 6 dB down during 1200-1800 hr IST at Bangalore (12°58'N, 77°35'E) was measured for a continuous period of 10 mins selected at random over the period of observation, using the noise meter described by S.V.C. Aiya (1954). The amplitude probability distribution (APD) is found to be log-normal with a standard deviation lying between 3 and 4 dB. The range of variation of the standard deviation is between 2 and 3 dB. The Aiya annoyance value which gives the average of the 10 highest impulses per minute is found to be ~ 3 dB higher than the mean value. These short term APD characteristics have been compared with the results of Horner (Abstr. 1988 of 1960) in England which give a standard deviation lying between 10 and 12 dB, for measurements at 10 kc/s, with 300 c/s bandwidth. The probable causes for the difference are discussed. The results of Fujita (1954) in Japan at 1600 kc/s agree with the measurements reported here.

RAY TRACING FOR WHISTLER-MODE SIGNALS AT LOW FREQUENCIES

Paper presented at IRE-URSI Symposium, San Diego, California, 19th - 21st
October 1959.

E.R. Schmerling, R. Goerss, S. Miluschewa, P. Hertzler, I. Pikus

A number of whistler-mode ray-paths have been traced in an IBM 650 computer using Haselgrove's equations. A frequency of 5 kc was taken at a geomagnetic latitude of 50° for various initial propagation angles. A centered dipole was used for the earth's field, and a simple ionospheric electronic-density model based on Seddon's (1957) composite curve. The

purpose of the work was to examine the path spreading as a function of initial angle, not to obtain the exact conjugate points, so that the simple model was considered adequate. This problem has a special bearing on second-hop signals and satellite originated signals, since signals originating on the ground are not expected to have a large spread of angle at heights of the order 100 km. A decided shift of the downcoming rays towards the equator, and a large spread of the order 1000 km for the angular spectrum, were found.

THE DETERMINATION OF THE DISTANCE OF ATMOSPHERICS FROM THEIR WAVEFORMS
Z. Meteorol, Vol. 14, Pgs 212-217, July-September 1960. In German.
R. Schminder

Diagrams facilitating the determination of the distance of atmospherics are given; their use is discussed with reference to the results of measurements. A reflection height of 70 km was assumed for daytime conditions and 90 km for night-time propagation.

GRAPHICAL METHODS FOR THE DETERMINATION OF THE DISTANCE OF ATMOSPHERICS FROM THEIR WAVEFORM
Geofis. Pura e Appl, Vol. 47, Pgs 101-113, September-December 1960. In German.
R. Schminder

This paper presents an extension of the graphical method outlined in July. Delay-time diagrams are given for reflection heights of 70, 80 and 90 km; comparisons are made with tabulated meteorological data.

REFLECTION OF ATMOSPHERICS FROM THE IONOSPHERE
R.F.J. Schonland, and Others
See Section I, Page 90.

UBER DIE AUSBREITUNG SEHR LANGER ELEKTRISCHER WELLEN UND DER BLITZENTLADUNG UM DIE ERDE
Z. angew. Phys. (Germany), V. 4, No. 12, Pgs 474-479, 1952.
W.O. Schumann

No abstract

UBER DIE DAMPFUNG DER ELEKTROMAGNETISCHEN EIGENSCHWINGUNGEN DES SYSTEMS ERDE-LUFT-IONOSPHERE
Z. Naturforsch (Germany), V. 7A, Pgs 250-252, 1952.
W.O. Schumann

This is a continuation of an earlier paper in which approximate

formulae are now derived for the damping of electromagnetic waves of frequency corresponding to the natural oscillation frequency of the atmosphere between the earth and the ionosphere.

THE PROPAGATION OF VERY LONG RADIO WAVES ROUND THE EARTH AND SIGNALS FROM LIGHTNING

W.O. Schumann

See Section I, Page 90.

ON THE PROPAGATION OF VERY LONG ELECTRIC WAVES AND THE WAVE SPECTRUM OF THE LIGHTNING DISCHARGE

W.O. Schumann

See Section I, Page 90.

ON THE PROPAGATION ALONG THE EARTH'S SURFACE OF VERY LONG ELECTRIC WAVES AND THE LIGHTNING DISCHARGE

W.O. Schumann

See Section I, Page 90.

ON THE HIGH-FREQUENCY FIELD PRODUCED DURING THE PROPAGATION AROUND THE WORLD OF LONG ELECTRICAL WAVES AND LIGHTNING SIGNALS

W.O. Schumann

See Section I, Page 90.

UBER DIE OBERFELDER BEI DER AUSBREITUNG LANGER, ELEKTRISCHER WELLEN IM SYSTEM ERDE-LUFT-IONOSPHERE UND 2 ANWENDUNGEN (HORIZONTALER UND SENKRECHTER DIPOL)

W.O. Schumann

See Section II, Page 178.

OBSERVATION OF "ATMOSPHERICS" WITH VERY LOW FREQUENCIES

AD 47 805; English translation of Naturwissenschaften (Germany), V. 41, No. 8, Pgs 183-4, 1954, by J.G. Estam, AF Cambridge Research Center, Cambridge, Mass.

W.O. Schumann, H. König

A special amplifier with a bandwidth from 1 to 25 cps was developed for the observations at the Technische Hochschule, Munich, a narrow-band filter being incorporated to eliminate interference from railway systems on 16 2/3 cps. The results of 24-hour recordings and frequency analysis are presented. Two principal types of atmospheric were noted. The first has a frequency of about 9 cps and is nearly sinusoidal in character, the

duration of the wave trains ranging from 0.3 to 30 sec. The shortest of these wave trains (0.3-3 sec) tend to be repeated twice; they start with small amplitude, increase to a maximum which in many cases reaches 100 μ V input potential and then decrease steadily again. Cloudless skies favour the occurrence of this type of atmospheric, which occurs much more frequently in summer at 16-18 hrs and in winter at 13-15 hrs, but practically never during the night. Wave trains of the first type of longer duration (15-30 sec) usually have an input amplitude of about 5 μ V and their frequency and amplitude usually remain constant. Some of the longest (> 30 sec) have amplitudes from 100 to 500 μ V, start usually with a frequency of 6-9 cps and after about 15 sec have v.l.f. variations (0.5-2 cps) superposed. Similar long-duration wave trains have been observed over a period of half a year at sunrise. The second principal type of wave train has frequencies of 3 to 6 cps. Such trains are mostly of longer duration and may last for over an hour; they contain many harmonics and their fundamental frequencies often vary. Their occurrence during the presence of low cloud appears to indicate some relation with rain incidence. The results are discussed with reference to meteorological phenomena.

ON THE INTERPRETATION OF THE ATMOSPHERICS PRODUCED BY LIGHTNING DISCHARGES.
Z. Angew. Physik, Vol. 8, No. 1, Pgs 24-28, 1956. In German.
W.O. Schumann

The wave shapes of atmospheric recorded at night at distances exceeding 2000 km, and at dawn and dusk at shorter distances, have been interpreted by the horizontal components of the radiating lightning discharges. A mathematical derivation is given of the fields produced at different distances by vertical and horizontal dipoles and the effects are examined which are exerted in successive reflections by the curvature of the earth's surface and by a limited conductivity of the reflecting layers. It is claimed that the theory outlined is capable of explaining the characteristic wave shapes of the atmospheric recorded during the earlier investigations.

ON THE PROPAGATION OF LONG ELECTRIC WAVES ROUND THE EARTH AND CERTAIN APPLICATIONS TO TRANSMITTER INTERFERENCES AND STATIC SIGNALS
W.O. Schumann
See Section I, Page 91.

UBER ELEKTRISCHE EIGENSCHWINGUNGEN DES HOHLRAUMES ERDE-LUFT-IONOSPHERE,
ERREGT DURCH BLITZENTLADUNGEN
Z. angew. Phys. (Germany), V. 9, No. 8, Pgs 373-378, August 1957.
W.O. Schumann

No abstract.

ATMOSPHERIC WHISTLERS AND THE ELECTRON DENSITY IN THE IONOSPHERE
Report 6-30, Contract AF 19(604)-5504, Electrical Engineering Research
Lab., University of Texas, Austin, Texas. (21st October 1959).
AFCRC-TN-54-790.
F.H. Shammatt

Some of the electromagnetic energy released from lightning strokes travels a path through the ionosphere essentially parallel to the magnetic lines of the earth's magnetic field. It arrives at the ground in the opposite hemisphere as a frequency dispersed wave train with time delay increasing with decreasing frequency. The extent of this dispersion has previously been shown to be a function of the height distribution of electron density in the ionosphere along the path traveled. This report presents a method of computing the dispersion from a knowledge of the electron density and compares observed and computed dispersions based on an assumed exponential electron density height distribution. The correlation between the two sets of curves is sufficiently good to lend credence to the assumed electron distribution. This research was carried out as one phase of a general propagation study designed to investigate various tropospheric and ionospheric refractive index distribution models.

SPREAD-F AND THE LATITUDE VARIATION OF OCCURRENCE OF WHISTLERS
Nature, Vol. 189, Pgs 215-216, 21st January 1961.
D.G. Singleton

The decrease in whistler activity which occurs for geomagnetic latitudes $< \sim 50^\circ$ has previously been explained in terms of whistler propagation within field-aligned ducts. It is shown that this theory is consistent with the view that the lower extremities of these whistler ducts are the irregularities in the F2 layer postulated to account for the frequency spreading component of spread-F.

THE WAVEFORM CHARACTERISTICS OF EXTREMELY LOW FREQUENCY ATMOSPHERICS
Abstract, Symposium on ELF Propagation and Wave Forms, Programme of
Joint IRE-URSI Meeting, Washington DC, 2nd-5th May 1960, Pg 104.
E.J. Smith

The variation in the waveform characteristics of ELF sferics has been investigated experimentally by the simultaneous recording at widely separated stations of the time-varying electric field. The time interval, t , from the time of arrival of the signal to the time at which it crosses the axis, has been determined for signals received at two stations. The sources have been located geographically using time-difference methods. The characteristic variation of t as a function of the distance to the source has been studied. The present results agree more closely with a previous empirical result (Hepburn-Pierce) than with the predictions of theory (Schumann-Liebermann). The results indicate that t depends on

the ELF characteristics of the source. Furthermore, a comparison of t at two receiving stations reveals a dependence on path, a result obtained previously from a study of the attenuation coefficient at **extremely-low-frequencies**. Atmospheric waveforms are presented which have propagated over both the short (less than 180°) and long (greater than 180°) great circle paths from source to receiver. The velocity of propagation of ELF spherics is discussed; an experimental value is derived for distance sources which is 250 km/ms by night and 230 km/ms by day.

AN EXPERIMENTAL INVESTIGATION OF THE PROPAGATION OF ATMOSPHERES WITH EMPHASIS ON EXTREMELY-LOW-FREQUENCIES

Final Report, Contract AF 19(604)-3466, Inst. of Geophysics, University of California, Los Angeles, California, June 1960. AFCRC-TR-60-269. AD-243 789.

E.J. Smith, L.R. Tepley.

The propagation of extremely-low-frequency electromagnetic waves caused by lightning (atmospherics) was investigated experimentally by the simultaneous recording at widely separated stations of the time-varying electric field. Individual waveforms were harmonically analyzed and the attenuation coefficient was determined at frequencies from 50 to 150 kc. Evidence is presented to show that attenuation is a function of the particular path from the source to each receiver. The dependence on path is a persistent feature of ELF propagation with the same paths being favoured from one day to another. The data is consistent with north-south propagation being favoured over east-west propagation, **and with symmetry between east-west and west-east paths**. The frequency dependence of the attenuation coefficient indicates that: (1) only the magnitude differs from path to path, (2) for night-time propagation, empirical results agree well with theories employing a sharply-bounded, homogeneous ionosphere, and (3) for daylight paths, the empirical results depart from theory. Evidence is presented that variations in ionospheric conductivity are responsible for path dependence. Existing theories based on the influence of the earth's magnetic field on attenuation appear to be unable to explain the effect.

CALCULATION OF THE ELECTRON DENSITY OF THE OUTER IONOSPHERE USING WHISTLERS

R.L. Smith, R.A. Helliwell
See Section I, Page 94.

ELECTRIC FIELD-CHANGE STUDIES OF LIGHTNING

Phys. Abstr. 21392/1960; J. atmos. terrest. Phys. (GB), V. 15, No. 3, Pgs 251-2, October 1959.
L.G. Smith

Leader strokes, preceding return strokes of earth discharges, are initiated in a cloud about 100 msec before the first leader emerges below the cloud. Slow junction streamers between component strokes tap successively higher charge regions. In contrast to earth strokes, cloud strokes have no superimposed fast field changes and are characterized by a most frequent duration of 0.3 sec. Their vertical length is of the order of 5 km.

THE GUIDING OF WHISTLERS IN A HOMOGENEOUS MEDIUM

J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 5, Pgs 505-8, September-October 1960.
R.L. Smith

The velocity of energy flow of whistlers in a homogeneous medium is computed as a function of wave-normal angles. The maximum allowable cone of ray angles approaches $19^{\circ} 29'$ at very low frequencies, decreases with frequency to a minimum of 11° at a wave frequency of one-fifth the gyrofrequency, then increases to 90° at the gyrofrequency. The velocity of energy flow departs markedly from the longitudinal value except at very low frequencies or very small wave-normal angles.

CONVERSION OF THE AMPLITUDE-PROBABILITY DISTRIBUTION FUNCTION FOR ATMOSPHERIC RADIO NOISE FROM ONE BANDWIDTH TO ANOTHER

Phys. Abstr. 5858/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 6, Pgs 713-20, November-December 1962.
A.D. Spaulding, C.J. Roubique, W.Q. Crichlow

The amplitude-probability distribution function of atmospheric radio noise can be predicted with reasonable accuracy for a given bandwidth using only the first two moments of the noise measured at that bandwidth. This paper presents a method for predicting this distribution function for any specified bandwidth from the moments of the noise measured at a particular bandwidth.

THE PROPAGATION OF A RADIO ATMOSPHERE

Proc. IRE (London), Vol. 103B, No. 10, Pgs 542-546, July 1956.
C.M. Srivastava

On the assumption that the space between the earth and the ionosphere acts as a waveguide, the mechanism of propagation of an atmospheric has

been considered from the viewpoint of plane-wave reflection. The pulse at the origin has been assumed to be rectangular and of duration 100 microsec. It has been possible to give a physical picture of the mechanism and to explain the oscillatory waveform of distant atmospherics.

STUDIES OF THE WAVEFORMS OF ATMOSPHERICS DURING THE REGULAR WORLD DAYS AND WORLD METEOROLOGICAL INTERVALS

J. Sci. Indust. Research (New Delhi), Vol. 18A, No. 9, Pgs 426-429, September 1959.

R.S. Srivastava, S.R. Khastgir

Some of the features of the waveforms of the atmospherics recorded at Banaras during the Regular World Days and the World Meteorological Intervals from June to October 1957 are discussed, and the automatic atmospherics recorded employed during the investigations is described. It was observed that the general character of the waveforms from near and distant sources changed only slightly during the Regular World Days with or without unusual meteoric activity, and also during the World Meteorological Intervals.

AN INVESTIGATION OF WHISTLING ATMOSPHERICS

EE Abstr. 4352/1953; Phil. Trans. (GB), V. 246A, No. 908, Pgs 113-41, 1953.

L.R.O. Storey

Experimental study of "whistlers" (i.e. atmospherics observed at frequencies below 15 kc giving a characteristic whistling tone of descending pitch) and their association with "click" type atmospherics. The whistlers were recorded on magnetic tape and analyzed on the sound spectrograph. The law of variation of their frequency with time was determined, and also their diurnal and annual variations and association with magnetic activity. A theory is developed that whistlers are due to waves which originate in normal impulsive atmospherics and travel through the outer ionosphere following the lines of force of the earth's magnetic field. The electron densities required at very great heights in the atmosphere are rather large, demanding either a temperature as high as 7200° K for the outer ionosphere or an extra-terrestrial electron source, such as solar corpuscular streams.

WHISTLERS

Scientific American, Vol.194, No. 1, Pgs 34-37, January 1956.
L.R.O. Storey

Whistlers differ from radio atmospheric in that they occur at long wave lengths are drawn out rather than abrupt (as are clicks) and occur repeatedly at fixed intervals (as echoes do) when they are reflected back from the opposite hemisphere via the ionosphere. The theory is explained and illustrated and recorders (sound spectrograph) and records described and illustrated. The timing of the whistlers (and their length) after the lightning click gives a clue to the distance travelled, if frequency is taken into account. Results indicate that atmosphere (400 electrons/cc) extends up to 7,000 miles instead of 1,500 miles and consists of ionized hydrogen, perhaps picked up by geomagnetic field as earth passes through space.

A METHOD FOR INTERPRETING THE DISPERSION CURVES OF WHISTLERS

Canad. J. Phys., V. 35, Pg 1107, 1957.
L.R.O. Storey

This paper considers how the dispersion curves of whistlers may be interpreted to provide information on the distribution of electron density with height in the outer atmosphere.

The simpler inverse problem, that of computing the dispersion curve for a given distribution, is considered first. On the assumption of longitudinal propagation in a dipole magnetic field, the dispersion curve is derived in the form of an equation relating the product $tf^{1/2}$ to the frequency f . The equation can be represented by a power series f , which is useful for estimating departures from the elementary $f^{-1/2}$ - t relationship at frequencies where these departures are small. The coefficient of f^n in this series is termed the "dispersion constant of order n ".

WHISTLER THEORY

Proc. URSI Gen. Assembly, London, England, 5th-15th September 1960, Publication 880, Nat. Acad. of Science, National Research Council, Washington DC (1961).
L.R.O. Storey

The general picture of how whistlers arise became clear several years ago. Subsequent research has confirmed this picture and added to it, so that the broad features of the phenomenon are now understood quite well. Current theoretical work is concerned either with understanding details, albeit significant, of the way that whistlers are propagated, or with the problem of analyzing whistler records to obtain information about the physical condition of the exosphere. In this review, the topic of whistler theory is dealt with under two headings - "pure theory" and "applied theory".

GENERATION OF RADIO NOISE IN THE VICINITY OF THE EARTH

J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 2, Pgs 153-7, March-April, 1962. Phys. Abstr. 15203/1962.

P.A. Sturrock

A tentative classification of possible sources of radio noise in the vicinity of the earth may be obtained by examining separately available sources of power and known mechanisms for conversion of this power. Among the former one may list high-energy electrons such as those trapped in the Van Allen belts; the solar wind; bursts of high-energy particles ejected by the sun; shock waves in the interplanetary medium originating in the sun; and the rotational energy of the earth. Mechanisms of conversion may be classified as "direct", such as synchrotron and Cherenkov radiation, and "indirect". Indirect conversion involves the excitation of an intermediate state by the available sources of power and subsequent radiation by this state. This intermediate state may be localized heating, the formation of unstable current patterns, the acceleration of particles, or the generation of waves which are themselves non-radiative, such as plasma oscillations. The following mechanisms which are relevant to the generation of radio noise receive special attention: Cherenkov radiation, two-stream instability, and the coupling of waves by inhomogeneity and non-linearity.

INVESTIGATION OF ATMOSPHERIC RADIO NOISE

Scientific Report 9, Contract AF 19(604)-876, Engineering and Industrial Experiment Station, University of Florida, Gainesville, Florida, (15th October 1955). AFCRC-TN-55-773. AD-83 662.

A.W. Sullivan, S.P. Hersperger, R.F. Brown, J.D. Wills

Efforts leading toward the design of a noise meter to measure the defining parameters of the logarithmic-normal probability distribution have resulted in a logarithmic amplifier possessing a dynamic range of 100 db. The amplifier is shown to be capable of measuring the mean logarithmic amplitude of the noise distribution.

The complete radioteletype system employing four independent information channels is described. Studies of the waveform of the ground wave of an atmospheric as a function of distance are presented.

Further investigations of the probability distribution of atmospheric noise have shown that the departure from the logarithmic - normal law at very low probability levels has very little effect on the calculated values of average and root-mean-square values of amplitude. These results further substantiate the validity of adopting the logarithmic-normal law as a suitable description of atmospheric noise characteristics. Additional studies of the effect of pre-detection power bandwidth on the distribution of envelope noise amplitude have led to a more definite relationship. The range of bandwidths involved is 40 to 4000 cps.

SOME CHARACTERISTICS OF THE GROUND WAVE OF VLF SPHERICS

Prepublication Papers NBS-IRE PGAP Symposium on Propagation of VLF Waves, Boulder, Colorado, 23rd-25th January 1957. Vol. III, Paper 30.

A.W. Sullivan

Simultaneous observations were made of the waveform of spheric pulses at locations within a few miles of the source at sites distant from the source. From these experimental studies information was obtained relative to the change in waveform, variation in the rise-time of the leading edge of the pulse and the attenuation of the peak field intensity over various distances.

In addition, statistical distributions of the peak amplitudes were computed for conditions near the thunderstorm and at a distance from the storm. Both cases could be approximated by the logarithmic-normal distribution function.

INVESTIGATION OF ATMOSPHERIC RADIO NOISE

Scientific Report 14, Contract AF 19(604)-876, Engineering and Industrial Experiment Station of Dept. of Electrical Engineering, Univ. of Florida, Gainesville, Florida, 15th February 1957. AFCRC-TN-56-984. AD-110 182.

A.W. Sullivan, P.J. Nawrocki

Investigation of the E_2 and H_2 field components present in the ground wave of spherics is continuing. Modifications were made in the H_2 waveform recorder to ensure identical frequency and phase response for both E_2 and H_2 in the 10 kc to 100 kc range. Measurements of the ratio H_2/E_2 tended to substantiate the interpretation of this ratio as a measure of the deviation of the lightning channel from the vertical.

The final design of a recorder for automatically sampling the duty cycle and number of individual bursts exceeding arbitrary level of received meteoric signal is described in detail.

THE EFFECT OF POSITIVE ION COLLISIONS ON WHISTLER PROPAGATION

J. Geophys. Res. (USA), Vol. 67, No. 3, Pgs 1175-7, March 1962.

Phys. Abstr. 15202/1962

D.W. Swift

Collisions between positive ions and neutral particles can account for significant attenuation at the lower frequencies of the whistler spectrum. This effect is determined from the dispersion relation for hydro-magnetic waves at whistler frequencies, including the Hall effect terms. It is shown that maximum attenuation occurs at frequencies between 100 and 300 rad/sec, the ion gyrofrequency being 240 rad/sec. The positive ion effect should be most noticeable during times of high E- and F-region electron density and relatively low D-region absorption.

PRELIMINARY STUDIES OF THE ENERGY SPECTRUM OF NEAR ATMOSPHERICS OVER
THE FREQUENCY RANGE 3-15 KC

B.A.P. Tantry, R.S. Srivastava

See Section III, Page 263.

WAVEFORMS OF ATMOSPHERICS

B.A.P. Tantry, R.S. Srivastava

See Section III, Page 264.

POLARIZATION OF ATMOSPHERIC PULSES DUE TO SUCCESSIVE REFLECTIONS FROM
THE IONOSPHERE

J. Geophys. Research, Vol. 63, No. 3, Pgs 527-538, September 1958.

B.A.P. Tantry, R.S. Srivastava

In determining the direction of arrival of atmospheric pulses by using a "crossed" - loop cathode-ray tube direction-finder, it was found that, on occasions, in addition to the usual straight-line responses on the oscillographic screen, there were elliptic patterns of gradually decreasing eccentricity, size, and tilt-angle. The observed elliptic patterns are considered as due to the abnormal polarization of the atmospheric pulses reflected successively from the ionosphere, while the linear responses are due to the direct atmospheric pulses. It has been shown in the paper how from the observed polarization ellipses and the orientation of the linear response, the polarization characteristics of the atmospheric pulses reflected successively from the ionosphere can be determined. On analyzing the observed patterns, it is found that, in general, the phase-difference between the normal and abnormal components increases gradually with the increasing order of reflection. It is suggested that the observed straight lines in the D/F pattern, bunched within a small angle, are due to the radiation pulses originating at the branching points of a long horizontal or slightly inclined lightning channel from one cloud to another. The approximate calculation from the observed angular width of the bunch of straight lines has shown that the horizontal length of the channel is consistent with Shipley's observations of horizontal lightning channels along the lower edge of a cloud.

WAVEFORMS OF ATMOSPHERICS WITH SUPERIMPOSED PULSES RECORDED WITH AN
AUTOMATIC ATMOSPHERICS RECORDER

J. Atmos. Terrest. Phys., Vol. 13, Nos. 1/2, Pgs 38-42, December 1958.

B.A.P. Tantry, R.S. Srivastava

The automatic atmospheric recorder constructed and used by the authors has been briefly described. Of the various types of superimposed pulses recorded with its help, the "stepped" pulse from a lightning source, superimposed on the waveform due to a different lightning discharge has not been observed by previous investigators.

Superimposed pulses, reflected successively from the ionosphere have been shown, where the superimposed pulses and the waveform on which they are superimposed originate from two different lightning sources or from the same lightning discharge. The "hook" components of Malan and Schonland have also been recorded.

VERY LOW-FREQUENCY RADIATION SPECTRA OF LIGHTNING DISCHARGES

W.L. Taylor, A.G. Jean

See Section III, Page 265.

SPECTRUM ANALYSIS OF SFERICS

Prepublication Papers, NBS-IRE PGAP Symposium on Propagation of VLF Radio Waves, Boulder, Colorado, 23rd-25th January 1957, Vol. III, Paper 33.

W.L. Taylor

The spectra of a number of sferics are presented. The data is divided into two groups: (1) sferics originating over the Pacific Ocean at ranges of 2000-4000 km from Boulder, Colorado, and (2) sferics originating over the Dakotas at ranges of 500-700 km from Boulder. Spectra of whistler-producing and non-whistler-producing sferics are shown for both ranges. Individual and composite spectra of the ground-wave pulse and the sky-wave pulse recorded at Boulder, Colorado, are discussed.

ATTENUATION AT VLF USING SFERICS

Paper presented at IRE-URSI Symposium, Washington, DC, 23rd-26th April 1958.

W.L. Taylor

Simultaneous observations have been made of the waveforms of sferics at distances from 100 km to 6500 km. The recording stations were located at Boulder, Colorado; Delta, Utah; Palo Alto, California; and Mani, T.H. The experiment consisted of recording the broadband waveform from a vertical antenna and from crossed-loop antennas, the direction of arrival, and time. Interpretation of this data was limited to the vertical electric field during hours of darkness.

Spectral analysis was performed over a frequency range of 1-50 kc. Waveforms, amplitude spectra, and energy content are presented. The amplitude spectra are compared for each pair of the four-station net, and the results presented in the form of attenuation vs. frequency.

SOME CHARACTERISTICS OF VLF PROPAGATION USING ATMOSPHERIC WAVEFORMS

Recent advances in Atmospheric Electricity, Pgs 609-617, Pergamon Press, New York, 1958.

W.L. Taylor, L.J. Lange

Simultaneous observations have been made of the waveforms of atmospherics at four widely separated stations. VLF attenuation characteristics have been computed by comparing the spectra of the waveform recorded at the four locations for each discharge. The results of some preliminary measurements of VLF attenuation are presented for the band of frequencies from 4 kc to 30 kc at distances of 1200 km to 6500 km.

RADIATION FIELD CHARACTERISTICS OF LIGHTNING DISCHARGES IN THE BAND 1 KC/S TO 100 KC/S

J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 5; Pgs 539-50, September-October 1963; Phys. Abstr. 23598/1963.

W.L. Taylor

The groundwave portion of atmospheric waveforms was examined to determine various characteristics of the radiation field from lightning discharges. Sixty-nine representative waveforms were selected from 1029 atmospherics from 21 thunderstorms in the Oklahoma and North Texas area. The average amplitude and phase spectra, from 1 to 100 kc/s are presented for several groups of atmospherics having distinguishable characteristics: Various relationships involving the total radiated energy, peak field strength, first half cycle length, spectral amplitude peak and frequency of spectra peak are presented. The "normal" type of atmospheric, composing 86% of the total, is predominately of positive initial polarity, has a spectrum peak near 5 kc/s and has well defined relationships between the parameters mentioned above. All "other" types of atmospherics are predominately of negative initial polarity, have a spectrum peak from less than 1 to 18 kc/s and have no well defined relationships between the various parameters.

A COMPARISON OF SPHERICS AS OBSERVED IN THE VERY LOW-FREQUENCY AND EXTREMELY LOW-FREQUENCY BANDS

L.R. Tepley

See Section III, Page 266.

SLOW TAILS FROM INTRA-CLOUD LIGHTNING DISCHARGES

Presented at Forty-First Annual Meeting of American Geophysical Union, Washington, DC, 27th-30th April 1960.

L.R. Tepley

It has been observed experimentally that a high percentage of slow tails (ELF spherics) are of negative polarity, whereas signals of positive polarity would be expected from most cloud-to-ground lightning discharges.

It may be hypothesized that intra-cloud strokes are a prolific source of negative slow tails. An alternative hypothesis is that a polarity inversion occurs during propagation. The wave form of the VLF sferic associated with the negative slow tail supplies some evidence in favour of the former hypothesis, since it is generally more ragged in appearance than the VLF wave form associated with the positive slow tail. This implies that the spectral energy maximum occurs at a relatively higher frequency as may be expected for radiation from an intra-cloud discharge.

SFERICS FROM INTRACLOUD LIGHTNING STROKES

J. Geophys. Research, Vol. 66, No. 1, Pgs 111-123, January 1961.

L.R. Tepley

It is well known that cloud-to-ground lightning strokes are prolific sources of very low frequency (VLF) sferics. The contributions of other types of discharges, however, have been largely ignored in the literature. This paper shows that intracloud lightning strokes also radiate significant energy at both very low frequencies and extremely low frequencies (ELF). This conclusion is based primarily on the experimental observation that most ELF sferics (slow tails) are of negative polarity.

From a study of a number of possible mechanisms for generating negative slow tails, the following conclusions were made: (1) only the intracloud stroke (specifically the element of the discharge frequency referred to as the "K change") is likely to be statistically important; (2) intracloud strokes also radiate significant VLF energy; (3) the properties of ELF sferics are uniquely suited for the study of the electrical "fine structure" of thunderstorms at many thousands of kilometers under night-time conditions.

SELECTIVE ANNOTATED BIBLIOGRAPHY ON THUNDERSTORM SFERICS (SUPPLEMENT)

EE Abstr. 5569/1959; Meteorol. Abstr. (USA), V. 10, No. 4, Pgs 588-624, April 1959.

G. Thuronyi

Brings up to date the bibliography published *ibid.*, V. 4, No. 11, November 1953, 158 references.

VLF EMISSIONS AND GEOMAGNETIC DISTURBANCES AT THE AURORAL ZONE

I. CHORUS BURSTS AND PRECEDING GEOMAGNETIC DISTURBANCES

Phys. Abstr. 1481/1963; J. Geomagn. Geoelect. (Japan), Vol. 14, No. 1, Pgs 33-40 (1962).

H. Tokuda

Some studies of the relation between the chorus activity and geomagnetic activity showed that the strength of the occurrence of chorus is maximum at the auroral zone on days of moderate geomagnetic activity, and that the region of maximum strength or occurrence shifts towards lower latitudes on stormy days. A relation is examined between the chorus and geomagnetic conditions at the auroral zone in details, using the chorus indices, normal-run magnetograms, and the auroral echo indices observed at College, Alaska, from August 1959 to December 1960. The result indicates that most of the intensity increases of chorus occurred at magnetically quiet times and followed the negative bay-type magnetic disturbances. Moreover, a good correlation is found between the magnitudes of the preceding bay-type disturbances and the rising times of strength increases of choruses.

STATISTICAL ANALYSIS ON LIGHTNING CURRENTS

Phys. Abstr. 16224/1963; Bull. Electrotech Lab. (Japan), Vol. 26, No. 10, Pgs 1-7; October 1962; in Japanese.

S. Tsurumi, K. Kinoshita, T. Kasai, K. Yamamori

The lightning current measurement was carried out by the frame aerial method developed by H. Norinder. Ninety oscillographic records were obtained during the lightning seasons from 1959 to 1962. These oscillograms are examined according to the current amplitude, the wave front time and the wave tail. A statistical analysis is undertaken on the distribution law of each characteristic value of the lightning currents and also on the correlations between them. The following results are obtained: (1) The lightning current amplitude (I) follows the logarithmic normal distribution, the mean value and the standard deviation being $\log(17.8 \text{ kA})$ and $\log(2.5 \text{ kA})$ respectively. (2) The wave front time (T) of the lightning current follows the logarithmic normal distribution, the mean value and the standard deviation being $\log(4.4 \mu\text{s})$ and $\log(1.5 \mu\text{s})$ respectively. (3) The wave tail (T_t) follows the normal distribution, the mean value and the standard deviation being $47 \mu\text{s}$ and $22 \mu\text{s}$ respectively. (4) The steepness (I/T_f) of the lightning current follows the logarithmic normal distribution with the mean value of $\log(5.2 \text{ kA}/\mu\text{s})$ and the standard deviation of $\log(2.5 \text{ kA}/\mu\text{s})$ respectively. (5) The correlation between $\log I$ and $\log T_f$ is not significant. (6) The correlation between $\log I$ and $\log T_t$ is not significant. (7) A strong positive correlation is observed between $\log I$ and $\log I/T_f$. (8) A strong positive correlation is observed between $\log T_f$ and T_t .

OBSERVATIONS OF "WHISTLERS" AND VERY LOW FREQUENCY PHENOMENA AT GODHAVN, GREENLAND.

Phys. Abstr. 4818/1960; Nature (GB), V. 184, Pgs 806-7, 12th September 1959. Ionosphere Lab., Royal Technical University of Denmark, Report No. 8.

E. Ungstrup

Preliminary analysis of whistler data obtained at Godhavn over the period July 1957 - July 1958 shows that, compared with observations at lower latitudes, there is a lack of low frequencies (minimum frequency ~ 5 kc) and a high "noise frequency" (~ 16 kc). This suggests that the whistlers penetrate the ionosphere at about 27° south of Godhavn, and travel by waveguide propagation along the earth to the observation point. Some details of observations of tweeks, chorus, and hiss are also given.

OBSERVATIONS OF VLF RADIO NOISE AT GODHAVN, GREENLAND.

Tech. Final Report, Contract AF61(052)-298, September 1962. Ionosphere Lab., Royal Technical University of Denmark, Report No. 12.

E. Ungstrup

No abstract

OBSERVATIONS OF "WHISTLERS" AND VLF PHENOMENA AT GODHAVN, GREENLAND

TN. No. 2, Contract AF61(514)-1309, July 1959; Ionosphere Lab., Royal Technical University of Denmark, Report No. 6.

E. Ungstrup

No abstract

OBSERVATIONS OF CHORUS BELOW 1500 CYCLES PER SECOND AT GODHAVN, GREENLAND, FROM JULY 1957 TO DECEMBER 1961

Phys. Abstr. 18518/1963; J. Geophys. Res. (USA), Vol. 68, No. 8, Pgs 2141-6; 15th April 1963. Ionosphere Lab., Royal Technical University of Denmark, Report No. 17.

E. Ungstrup, I.M. Jackerott

Whistlers and vlf phenomena were observed at Godhavn, Greenland, (79.9°N geomagnetic latitude), during a period of $4\frac{1}{2}$ years. Of the phenomena observed, only chorus is treated in this paper. The chorus observed is usually below 1500 c/s, and the diurnal variation of the occurrence shows a peak at 1235 UT (0901 LMT) independent of the time of year. The seasonal variation of occurrence shows a maximum in the summer months. The correlation between the daily sum of the local K index and the number of hours per day with chorus is negative. Since the features of chorus observed at Godhavn are different from those at middle-latitude stations, it is proposed to introduce the term "polar chorus" as a name for this type of emission.

ON THE ORIGIN OF VERY LOW FREQUENCY EMISSIONS

Report 1116-9, Scientific Report 5, Contract AF 19(604)-7270, Antenna Lab., the Ohio State University Research Foundation, Columbus, Ohio, (15th August 1961). AFCRL-750. AD-264 400. Phys. Abstr. 21656/1962; J. atmos. terrest. Phys. (GB), Vol. 24, Pgs 685-9, August 1962.
H. Unz

The magneto-ionic theory for drifting plasma is applied to the theory on the origin of very low-frequency emissions. The frequency at which there will be interaction, and possible amplification, between two different streams of electrons is found. It is shown that physical phenomena are explained by interaction between several streams of electrons of different plasma frequency and different velocity.

ON THE THEORY OF HYBRID WHISTLERS

Phys. Abstr. 24024/1962; J. atmos. terrest. Phys.(GB), Vol. 24, Pgs 765-70, September 1962.
H. Unz

It is suggested that the reason for the multipole, discrete, well-defined components in the noise whistlers is the different electron streams of discrete velocities along the same geomagnetic line. This new hypothesis is discussed in detail, and it is shown that the experimental evidence agrees with the analysis.

STATISTICAL AMPLITUDE SPECTRUM OF ATMOSPHERICS

Phys. Abstr. 23603/1963; Z. angew. Phys. (Germany), Vol.15, No. 6, Pgs 541-7, June 1963. In German.
H. Volland, G. Heydt.

Describes measurements of the frequency components of atmospherics between five and fifty kc/s. 77% by day and 13% by night come from our own hemisphere.

DETERMINATION OF THE WAVE FRONT OF LIGHTNING STROKE CURRENTS FROM FIELD MEASUREMENTS

C.F. Wagner
See Section III, Pg. 268.

ON THE WAVEFORM OF A RADIO ATMOSPHERIC AT SHORT RANGES

Proc. Inst. Radio Engrs (USA), V. 44, No. 8, August 1956.
J.R. Wait

No abstract.

ON THE THEORY OF THE SLOW-TAIL PORTION OF ATMOSPHERIC WAVEFORMS
J. geophys. Res. (USA), V. 65, July 1960.
J.R. Wait

The propagation of the slow-tail portion of atmospherics is considered from the waveguide mode view-point. The source, which is a lightning discharge, is represented by a vertical dipole. The transient response of the distant electric field is then computed for various forms of the source current waveform. The results are then employed to re-interpret the experimental data of Hepburn. As suggested by the present theory it is found that the observed separation t_s between the oscillatory head of the atmospheric and the maximum of the slow-tail amplitude varies with distance ρ to the source according to a law of the form:

$$(t_s)^{\frac{1}{2}} = A + B\rho$$

The constant A is related to the pulse width of the source and the constant B depends on ionospheric parameters. Values of effective ionospheric conductivities deduced from the theory are consistent with earlier results for the VLF band. The influence of non-vertical currents in the discharge channel is also briefly discussed.

INTERPRETATION OF ATMOSPHERIC WAVEFORMS

EE Abstr. 4371/1963; J. atmos. terrest. Phys. (GB), Vol. 25, No. 1, Pgs 35-41, January 1963.
C.P. Wang

Since the radiation field of a lightning discharge is proportional to the second derivative of the thundercloud moment, while the electrostatic field is directly proportional to the moment, atmospherics, both day-time and night-time and with their first half-waves positive-going, will indicate a downward movement of negative charge or an upward movement of positive charge, and those with their first half-waves negative going, will indicate a movement of charge in the opposite direction. Thus a dart and a stepped downward streamer, and the upward return stroke will all give positive-going atmospheric waveforms, while an upward developing stepped or dart streamer will give a negative-going waveform. Differentiation of atmospherics due to these three types of streamers (stepped, dart and return) may be made from the general shape of their waveforms, whether simple or complex, and to some extent from the relative wave amplitudes and the length of the train. The correctness of the sign interpretation was verified by the results obtained from analysing nearly 2000 atmospheric wave forms with the initial portions of their first waves clearly delineated. The interpretation given thus offers the possibility of eventually classifying the atmospheric waveforms according to their originating discharges.

INTERPRETATION OF ATMOSPHERIC WAVEFORMS

Phys. Abstr. 9047/1963; J. atmos. terrest. Phys. (GB), Vol. 25, No. 1, Pgs 35-41, January 1963.

C.P. Wang

Since the radiation field of a lightning discharge is proportional to the second derivative of the thundercloud moment, while the electrostatic field is directly proportional to the moment, atmospherics, both day-time and night-time and with their first half-waves positive-going, will indicate a downward movement of negative charge or an upward movement of positive charge, and those with their first half-waves negative-going will indicate a movement of charge in the opposite direction. Thus a dart and a stepped downward streamer, and the upward return stroke, will all give positive-going atmospheric waveforms, while an upward developing stepped or dart streamer will give a negative-going waveform. Differentiation of atmospherics due to these three types of streamers (stepped, dart and return) may be made from the general shape of their waveforms, whether simple or complex, and to some extent from the relative wave amplitudes and the length of the train. The correctness of the sign interpretation was verified by the results obtained from analysing near 2000 atmospheric waveforms with the initial portions of their first waves clearly delineated. The interpretation given thus offers the possibility of eventually classifying atmospheric waveforms according to their originating discharges.

MEASURED STATISTICAL CHARACTERISTICS OF VLF ATMOSPHERIC RADIO NOISE

A.D. Watt, E.L. Maxwell

See Section III, Page 271.

VARIATIONS IN THE STATISTICAL CHARACTER OF ATMOSPHERIC NOISE

Paper presented at IRE-URSI Symposium, Washington, DC, 30th April, 1st-3rd May 1956.

A.D. Watt

Measured amplitude-and-time distributions of the envelope of atmospheric noise for various frequencies, bandwidths, times and geographic locations will be presented. The manner in which these various factors effect the resulting distributions will be discussed, and examples of the effects of variations in these factors will be shown.

CHARACTERISTICS OF ATMOSPHERIC NOISE FROM 1 TO 100 KC

EE Abstr. 5217/1957; Proc. Inst. Radio Engrs. (USA), V. 45, No. 6,
Pgs 787-94, June 1957.
A.D. Watt, E.L. Maxwell

The results of some preliminary statistical measurements of the envelope of narrow-band atmospheric noise are presented for a range of centre frequencies from 1 to 100 kc. The variation of level and dynamic range, as a function of frequency, is examined and compared with results expected on the basis of lightning discharge spectra, thunderstorm distribution, and propagation phenomena.

ELF ELECTRIC FIELDS FROM THUNDERSTORMS

EE Abstr. 3172/1962; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 5,
Pgs 425-33, September-October 1960.
A.D. Watt

The varying electromagnetic fields produced by thunderstorms and associated lightning discharges are examined. Calculated field variations produced by an assumed typical cloud-to-ground discharge model are found to agree well with observed fields. The magnitude of these vertical electric changes are observed to decrease very slowly with distance from the source for values comparable to discharge channel heights. From 4 to 20 km a $1/d^3$ relation is observed, and beyond 30 km the field variations appear to follow a $1/d$ relation. The expected radiation field frequency spectra from 1 cps to 100 kc are calculated employing models assumed to be typical of "long" and "short" discharges. The radiation spectra obtained from 1 to 100 kc for observed cloud-to-ground discharge field variations normalized to 1 km are seen to agree within expected limits with calculated values. The models employed indicate that below 300 cps "long" discharges produce much more energy than "short" discharges, and that inter- and intra-cloud discharges may produce as much energy as cloud to ground discharges. Anticipated variations of total vertical electric field frequency spectra as a function of distance, based on the work of Wait, are shown for the frequency range from 1 to 100 kc.

AUDIO-FREQUENCY ELECTROMAGNETIC HISS RECORDED AT BOULDER IN 1956.

J.M. Watts

See Section III, Page 272.

AN OBSERVATION OF AUDIO-FREQUENCY ELECTROMAGNETIC NOISE DURING A PERIOD OF SOLAR DISTURBANCES

J. Geophys. Research 62, Pgs 199-206, June 1957.

J.M. Watts

DIRECTION FINDINGS ON WHISTLERS (LETTER)

J. Geophys. Research 64D, Pgs 2029-2030, November 1959.

J.M. Watts

No abstract

OBSERVATIONS AND RESULTS FROM THE "HISS RECORDER", AN INSTRUMENT TO CONTINUOUSLY OBSERVE THE VLF EMISSIONS

EE Abstr. 13943/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 5, Pgs 569-79, September-October 1963).

J.M. Watts, J.A. Koch, R.M. Gallet

An instrument developed at NBS, has enabled continuous observations of vlf emissions. The continuous data has permitted the identification of some new characteristics of vlf emissions, and new information on the statistics of the occurrence of vlf emission activity. The continuous recordings are able to document the morphology of vlf emission events and, therefore, accurate correlations with other geophysical phenomena are possible. Correlations of vlf emission activity with abnormal-D-region absorption, X-ray events, and magnetic activity are presented.

SFERIC MEASUREMENTS AT THREE ARCTIC STATIONS - SEPTEMBER 1958 THROUGH MARCH 1959.

Paper presented at IRE-URSI Symposium, San Diego, California, 19th-21st October 1959.

A.L. Whitson

From September 1958 through March 1959, SRI operated a three-station spheric net at Fairbanks, Alaska; Thule, Greenland; and St. Johns, Newfoundland. Three forms of data were collected: (1) broadband, 3- to 30-kc spheric waveforms and instantaneous direction of arrival were recorded on 35-mm film; (2) omni-directional spheric rates exceeding fixed field strengths in quarter GMT days were recorded on mechanical counters; and (3) rms noise level in a 100 cycle bandwidth from a 12- to 30-kc slow-scanning receiver was recorded on a strip chart. These data have been processed to obtain monthly and diurnal variations of spheric rates, distributions of amplitude, and direction of arrival and rms atmospheric noise level from 12 to 30 kc.

Typical examples of the above data representing spheric activity in the entire northern hemisphere will be presented. Correlation of data collected at the three stations will be discussed to show the variations in received spheric activity as a function of measurement location.

ARCTIC ATMOSPHERIC NOISE AND PROPAGATION STUDIES, PART A.
Final Report, SRI Project 2418, Contract AF 19(604)-2409, Stanford
Research Inst., Menlo Park, California, February 1960. AFCRC-TR-60-118(A).
A.L. Whitson

From August 1958 through March 1959 Stanford Research Institute operated sferic monitoring stations at Fairbanks, Alaska, at Thule, Greenland; and at St. Johns, Newfoundland, to record sferic 3- to 30-kc waveforms, direction of arrival and rates of occurrence of sferics, and atmospheric noise levels from 12 to 30 kc.

Large amounts of the above data have been recorded. Also, uniformly distributed samples of the data have been analyzed to determine sferic amplitude and direction-of-arrival distributions, sferic waveform types, sferic ELF content, sferic source locations in all portions of the Northern Hemisphere, and RMS atmospheric noise levels as functions of time of day and season. In addition, the application of the data collected to the better understanding of VLF propagation and of the influence of geophysical phenomena is discussed.

The preliminary results of this analysis have been published in eight Monthly-Data-Summary Bulletins and seven Monthly-Data-Summary Bulletin Supplements, "Sferic Source Locations".

The equipment used has been described in Technical Report No. 1 on this contract, "SRI Sferic Monitoring System", AD-214 947.

SFERIC ELF CONTENT, Abstract
Symposium on ELF Propagation and Wave Forms, Programme of Joint IRE-URSI Meeting, Washington DC, 2nd-5th May 1960; Pgs 104-105.
A.L. Whitson, J.H. Friedigkeit

The individual sferics of atmospheric noise are sometimes accompanied by slow tails which contain energy below 1 kc (ELF). Stanford Research Institute has recorded many thousands of sferics using equipment with a bandpass between 30 cycles and 30,000 cycles. This data was recorded simultaneously at Thule, Greenland, and at St. Johns, Newfoundland.

From the above data, the sferic ELF content is presented as the peak-to-peak amplitude ratio of the VLF (above 1 kc) component to the ELF (below 1 kc) component. This VLF to ELF ratio is log normal distributed and the mean value is a function of time of day and distance from the source.

Polarity of the first half cycle of the slow tails is presented to show diurnal variations and the effects of polarity on VLF to ELF ratio.

Relative propagation attenuation for the VLF and ELF components are discussed and correlated with the observed data.

MAGNETIC ATMOSPHERICS

U.S. Naval Ordnance Lab., White Oak, Maryland, NAVORD Rept. No. 2293,
35 p., illus., 1952.
J.B. Wilcox.

Naturally occurring electromagnetic disturbances, commonly called atmospheric, have been investigated from the standpoint of their contribution to geomagnetic field oscillations in the audio frequency range. Thunderstorms and their accompanying electrical discharges have been surveyed as the major source of atmospheric. It has been found that currents in the idealized vertical lightning stroke of known length and location may be determined by the observation of magnetic atmospheric wave forms at two stations removed from the discharge by distances large compared to its lengths. It would appear that appreciable audio frequency fluctuations in the geomagnetic field should be observed as a result of thunderstorm activity and that such fluctuations would be most intense near the equator and least intense in the polar regions, in opposition to the lower frequency fluctuations.

ORIGIN AND PROPAGATION OF AUDIO-FREQUENCY GEOMAGNETIC FIELD FLUCTUATIONS
Prepublication Papers NBS-IRE PGAP Symposium on Propagation of VLF Waves,
Boulder, Colorado, 23rd-25th January 1957, Vol. I, Paper 7.
J.B. Wilcox, E. Maple

Measurements in the frequency range 40 c/s to 15 kc/s were made simultaneously at Point Barrow, Alaska; White Oak, Maryland; and Panama City, Florida, during the fall of 1952. Instrumentation and data reduction techniques are described in NAVORD 4009, in process of publication at the Naval Ordnance Laboratory.

The results indicate that substantially all of the audio-frequency fluctuations are associated with atmospheric generated chiefly in the lower latitudes and propagated poleward;

- (1) Throughout the audio-frequency range, fluctuation intensity decreased with increasing latitude, this effect being greater for the vertical than for the horizontal components.
- (2) The audio-frequency spectra linked well at all latitudes with VLF measurements of others.
- (3) Directional patterns of fluctuation intensity agreed moderately well with data on the geographic distribution of thunderstorms, and significant correlations between the fluctuation intensities at two of the stations appeared under suitable conditions.

Negative arguments were developed against appreciable ionospheric or extra-terrestrial sources, which were considered at the outset to be the two chief possibilities other than lightning discharges.

Although other contributions cannot be excluded entirely, it seems clear that thunderstorm activity is by far the most important source. The data may therefore be used as an indication of propagation effects at these frequencies.

MAGNETIC MEASUREMENTS OF THUNDERSTORM CURRENTS. I. CONTINUING CURRENTS IN LIGHTNING

Phys. Abstr. 23596/1963; J. geophys. Res. (USA), Vol. 68, No. 10, Pgs 3243-7, 15th May 1963.
D.P. Williams, M. Brook

Long-continuing currents in lightning were measured with a fluxgate magnetometer. The results confirm earlier New Mexico work in which electrostatic field and photographic measurements were used in calculating these currents. On the basis of an analysis of 14 long-continuing strokes, the currents are found to average 184A. The average negative charge lowered to earth is 31C, and the average duration is 174 msec. A comparison of these results with the direct strike measurements of Hagenguth and Anderson (1952), and Berger (1961), shows reasonable agreement. Magnetic effects produced by the stepped leader, in two instances, were used in estimating the leader current. Values of 50 and 63A are indicated. It appears feasible to use a magnetometer of shorter time response (1 msec or better) to measure leader currents and such intracloud current events as K changes. It is concluded that the magnetometer method is well suited to the measurement of thunderstorm current phenomena "at a distance".

WHISTLER RAY PATTERNS FOR VARIOUS ELECTRON-GRADIENT DISTRIBUTIONS

Abstract, Symposium on Whistlers, Programme of Joint IRE-URSI Meeting, Washington, DC., 2nd-5th May 1960. Pgs 117.
M.S. Wong

Use of an electronic differential analyzer is described for rapidly computing whistler ray patterns - consisting of rays emitted in various directions from fixed transmitter points - for various frequencies.

The centred dipole geomagnetic field is used. A typical electron density profile, varying with altitude and latitude co-ordinated only, is used for the ionosphere. Various configurations, aligned along geomagnetic lines, of electron-density gradients are assumed for the exosphere. The aim is to survey conditions under which trapping of rays can occur in exospheric ducts for whistlers.

VARIATIONS IN THE VLF EMISSIONS WITH REFERENCE TO THE EXOSPHERE
Phys. Abstr. 23619/1963; Rep. Ionosphere Space Res. Japan, Vol. 16,
No. 4, Pgs 387-409, December 1962.
S. Yoshida, T. Hatanaka.

An analysis of the vlf emissions and whistlers was carried out by using the data observed at 19 stations. The period studied was from July 1957 to December 1959. The statistical results obtained are summarized as follows: (a) At middle latitudes the probability of occurrence of dawn chorus and hiss increases as the magnetic activity (k_p) increases, but at higher latitudes, the probability increases at first as the increase of k_p and then begins to decrease as further increase of k_p . (b) A pronounced diurnal variation in dawn chorus appears during the time of magnetic disturbance with its maximum at around 6 hr. local time, and the time of the maximum moves towards the local noon as the position of the generations moves away from the earth. (c) The probability of occurrence of all dawn chorus and hiss can be represented by a smooth function of the radial distance from earth's centre on the equator, when the real geomagnetic field is used, and at the time of magnetic disturbance, the positions of the maximum generations shift inwards towards the earth's surface both for dawn chorus and hiss. In order to separate the variation in the generation and propagation of the vlf emissions whistler data are used. It is suggested that both the generation and propagation of dawn chorus and hiss have close connection with the physical nature of the exosphere and that dawn chorus and hiss have different mechanisms in their origin.

PART VI

PART VI

PROPAGATION OF TRANSIENTS, SCATTERING

THE REFLECTION OF ELECTRO-MAGNETIC WAVES BY A SPHERE

Admiralty Research Lab., Teddington, Middlesex, England, A.R.N./N.4/86.
43/H, 12 p., plus figs., 1948.

No abstract

FREQUENCY SPECTRA OF TRANSIENT E.M. PULSES IN A CONDUCTING MEDIUM

University of New Mexico, Albuquerque, New Mexico, Technical Rept.,
No. 33-30, 12 p., plus figs., 1959.
W.L. Anderson, R.K. Moore

The energy density spectra of transient electromagnetic fields generated by a pulsed ideal dipole source in an infinite conducting medium have been investigated for various distances from the source. A characteristic frequency ω_c , corresponding either to the peak of the spectrum or to its half-width, is defined and shown to vary inversely as the square of distance at large distances. The behaviour of ω_c with distance is a measure of the behaviour of the pulse energy. Thus at large distances it appears that the attenuation factor associated with ω_c , $\exp\left\{-r\sqrt{\frac{2\mu\omega_c}{\lambda}}\right\}$, independent of r , due to the constancy of the product $r\sqrt{\omega_c}$. From this point of view, the transient fields do not decrease exponentially as r , but as inverse powers of r . This should not be construed as meaning the transient possesses an advantage over C.W. The attenuation for monochromatic components of the pulse is the same as for continuous waves of the same frequency and at large distances the energy put into the high frequency components is wasted. The phenomenon is illustrated by calculations that have been carried out for the case of pulses in sea water.

THEORY OF PROSPECTING WITH ELECTROMAGNETIC TRANSIENTS

AD 50 237; English translation of Geof. Appl. (Italy), V. 14, No. 1,
Pgs 3-13, 1953, by E.R. Hope, DRB, Canada.
A. Belluigi

The author recalls for the reader his paper of a year ago, which introduced the "Matranslog". After briefly summarizing the theory underlying his new method, the author: (1) gives the solution for the magnitude of the voltage-drop in the elementary "Eltranslog"; (2) completes the description of the properties of the "Matranslog", bringing out further characteristics of the time-development of the electromagnetic transients; (3) attacks the problem of "mutual-induction

reception" in the Matranslog, giving some solution for it and bringing out certain consequences relative to practical application; (4) introduces a new technique of lateral electromagnetic "Translog" determinations.

PROPAGATION OF TRANSIENT ELECTROMAGNETIC WAVES IN A CONDUCTING MEDIUM
Geophys. (USA), V. 20, Pgs 959-961, October 1955.
B.K. Bhattacharyya

No abstract

FIELD ON THE EARTH'S SURFACE DUE TO A TRANSIENT ELECTROMAGNETIC DISTURBANCE
EE Abstr. 3253/1957; J. Technol. (India), V. 1, No. 2, Pgs 151-62, December 1956.
B.K. Bhattacharyya

Formulae of the electric and magnetic fields above a homogeneous earth have been derived for a small loop aerial energized by transient currents, e.g., step-and ramp-function types. The mutual impedance function between a small length of wire and a small loop-aerial has been determined. A formula for the voltage induced in a secondary loop of area dA_1 , due to the circulating current in another loop of area dA has also been deduced. The mutual impedance function $Z_m(t)$ and the induced voltage $v(t)$ are plotted as a function of time for both step-and ramp-function current sources. The nature of variation of $Z_m(t)$ and $v(t)$ with the change in steepness of the pulse-fronts of energizing current is discussed.

PROPAGATION OF TRANSIENT ELECTROMAGNETIC WAVES IN A MEDIUM OF FINITE CONDUCTIVITY
Phys. Abstr. 1623/1959; Geophys. (USA), V. 22, No. 1, Pgs 75-88, January 1957.
B.K. Bhattacharyya

Transient electric and magnetic fields were calculated for ramp function and sawtooth current sources immersed in a semi-conducting medium. An electric dipole source is assumed. In the case of a ramp-function input, it is observed that the peaks of the overshoots in the O-component of the electric field decrease in magnitude with the increase in rise-time of the input pulse. It is also shown that the rise-time of the current pulses has a definite effect upon the rise time and amplitude of the electric fields and that the sawtooth exciting pulses having large values of rise-time may be conveniently used obtaining measurable values of the electric and magnetic fields.

PROPAGATION OF AN ELECTRIC PULSE THROUGH A HOMOGENEOUS AND ISOTROPIC MEDIUM

Phys. Abstr. 485/1959; Geophys. (USA), V. 22, No. 4, Pgs 905-21, October 1957.

B.K. Bhattacharyya

The propagation is considered of a step-function pulse in a medium characterized by the three electric constants, permittivity ϵ , permeability μ and conductivity σ . The effect of the displacement current on the propagation is fully taken into account. Expressions for the electric and magnetic fields are determined. It is shown that the time of travel of the pulse and the initial and final values of any one of the non-vanishing field components (all of which can be measured) fully specify the values of conductivity and permittivity of the medium.

ELECTROMAGNETIC FIELDS OF A TRANSIENT MAGNETIC DIPOLE ON THE EARTH'S SURFACE.

Phys. Abstr. 7216/1959; Geophys. (USA), V. 24, No. 1, Pgs 89-108, February 1959.

B.K. Bhattacharyya

Transient electric and magnetic fields close to the surface of the earth, as developed by a step-function current flowing in a circular loop of wire, are determined. The effect of the insulating air region is fully taken into account. It is observed that the air region has an appreciable influence on the fields over the surface of the earth. The effect of displacement current within the earth is also considered. Expressions of electric and magnetic fields are utilized to determine (a) the mutual impedance function between the primary loop and a small length of wire and (b) the voltage induced in a secondary loop. Both these functions are found to have appreciable magnitudes only during the time interval between the arrival of the wave travelling through air and that of the wave via the conducting medium. From a study of this duration and the initial amplitude of either of the two functions, it is impossible to obtain values of conductivity and permittivity of the earth. Curves are plotted to depict the nature of variation of these functions with time for different values of the electric constants of the earth.

THE PULSE SOLUTION CONNECTED WITH THE SOMMERFELD PROBLEM FOR A DIPOLE IN THE INTERFACE BETWEEN TWO DIELECTRICS

Electromagnetic Waves, University of Wisconsin Press, Pgs 39-64, 1962, edited by R.E. Langer.

H. Bremmer

No abstract.

D.C. SIGNALLING IN CONDUCTING MEDIA
C.R. Burrows
See Part II, Page 139.

TRANSIENT RESPONSE IN AN IMPERFECT DIELECTRIC
EE Abstr. 1182/1964; IEEE Trans. Antennas and Propagation (USA),
Vol. AP-11, No. 3, Pgs 286-296, May 1963.
C.R. Burrows

Gives the transient electric field response to an electric current element in an infinite linear homogeneous isotropic medium for all values of the parameter $b = r\sigma\sqrt{\mu/\epsilon}$ upon which its shape depends. It is shown that the response cannot be separated into that resulting from (1) the charge, (2) the current, and (3) its derivative when b is appreciably different from zero. The initial response occurs at the time $t = q = r\sqrt{\epsilon\mu}$. The radial component of the field is a monotonically increasing function of time approaching a constant asymptote. Its initial value has a maximum of 0.7358 times its final value at $b = 2$. The shape of the transient changes radically at $b = 2$. For values of $b > 20$ the initial value is negligible and the response is closely approximated by the asymptotic expression for b large. The tangential component approaches its constant asymptote from larger values. For small b the maximum occurs when t is large. The tangential component is approximately the same as the radial component for $b < \frac{1}{2}$. For larger values of b the maximum occurs at earlier times occurring when $t = q$ for $2.243 < b < 6.600$. It has its maximum initial value of 1.692 times its final value for $b = 5.043$. For values of $b > 6.6$ the maximum occurs at increasingly later times. For $b > 24$ the initial value is negligible and the response is approximated by the asymptotic expression for b large. Curves are given for the response not only as a function of time for various values of b but also as a function of b for various times. Comparison of experiments with these curves will allow the determination of b , and, hence the conductivity. The response is also given as a function of distance for various times. The Bessel function integral involved in this problem has been evaluated and presented in the form of curves for all values of b and all values of t for which it makes an appreciable contribution to the result.

TOTAL ELECTROMAGNETIC CROSS-SECTION OF IMPERFECTLY CONDUCTING CYLINDERS
J. appl. Phys. (USA), V. 31, Pgs 737-740, April 1960.
E.S. Cassedy, J. Fainberg

Experimental and theoretical results are discussed for the case of scattering from cylinders with length comparable to and with diameter small compared with the wavelength of illumination.

ON THE DIFFRACTION OF A PULSE BY A HALF-PLANE
EE Abstr. 10914/1962; Nuovo Cimento (Italy), Vol. 25, No. 1,
Pgs 69-85, 1st July 1962.
R.C.T. da Costa

The physical properties of the solution in the diffraction of an electromagnetic pulse by a perfectly conducting half-plane are studied from the standpoint of energy propagation. The form of the energy current lines and of the level lines of the energy density is given, for several instants of time after the arrival of the main part of the incident pulse at the half-plane. The splitting of the incident wave front into a transmitted and a reflected one leads to the formation of an energy reservoir near the edge. The energy contained in this reservoir is then re-emitted, giving rise to the diffracted pulse. Lines of zero energy current play an important role in this process; their formation and evolution is discussed, as well as the growth of the diffracted wave front. The asymptotic behaviour of the diffracted pulse for large times is considered.

PROPAGATION OF AN ELECTROMAGNETIC IMPULSE IN A MEDIUM IN WHICH THE ANGLE OF DIELECTRIC LOSS IS ALMOST INDEPENDENT OF FREQUENCY
EE Abstr. 5911/1959; CR Acad. Sci. (France), V. 248, No. 22, Pgs 3142-4, June 1, 1959.
M. Cotte

Discusses an approximate solution for the disturbance set up in a semi-infinite medium (with complex dielectric constant independent of frequency) by an impulse at the boundary.

ON THE PLANE-WAVE EXTINCTION CROSS-SECTION OF AN OBSTACLE
Appl. sci. Res. (Netherlands), V. B7, No. 6, Pgs 463-469, 1959.
A.T. de Hoop

The relation between the extinction cross section of an obstacle which both absorbs and scatters power, and the amplitude and phase of a scattered time-harmonic plane electromagnetic wave is proved using an explicit representation of the scattered field. The result is valid for a plane wave with arbitrary elliptic polarization.

RADIATION OF PULSES GENERATED BY A VERTICAL ELECTRIC DIPOLE ABOVE A PLANE, NON-CONDUCTING, EARTH
A.T. de Hoop, H.J. Frankena
See Section II, Page 141.

A MODIFICATION OF CAGNIARD'S METHOD FOR SOLVING SEISMIC PULSE PROBLEM
Appl. Sci. Res. (Netherlands), V. 8, Sec. B, No. 4, 1960.
A.T. de Hoop

A modification of Cagniard's method for solving seismic pulse problems is given. In order to give a clear picture of our method, two simple problems are solved, viz. the determination of the scalar cylindrical wave generated by an impulsive line source and the scalar spherical wave generated by an impulsive point source.

THE MAGNETIC FLASH OF THE NUCLEAR TEST OF 13TH FEBRUARY 1960 AT REGGANE
J. Delloue
See Section I, Page 30.

DIFFRACTION OF ELECTROMAGNETIC WAVES AT A CONDUCTING PLATE IN A CONDUCTING MEDIUM
Phys. Abstr. 2125/1963; Iz. Akad. Nauk SSSR, Ser. geofiz. 1962, No. 6, Pgs 731-5. In Russian. English trans in: Bull, Acad. Sci., USSR, Geophys. Ser. (USA), No. 6, Pgs 475-7, (June 1962; publ. Sept. 1962).
V.I. Dmitriev

The diffraction of electromagnetic waves at a plate with a finite conductivity embedded in a conducting half space is discussed in this paper. The problem is reduced to an ordinary Fredholm equation of the second kind.

PULSE SKY WAVE PHENOMENA OBSERVED AT 100 KC
R.H. Doherty
See Section I, Page 32.

SPACED OBSERVATIONS OF THE LOW-FREQUENCY RADIATION FROM THE EARTH'S UPPER ATMOSPHERE
J. Geophys. Research, Vol. 66, No. 1, Pgs 19-23, January 1961.
G.R.A. Ellis

Observations of 5 kc/s radio noise with a network of four stations extending across southern Australia are described. It is shown that there is often good correlation of the amplitude variations over a distance of 3000 km and that the observed amplitude differences may be explained by assuming that the radiation propagates in the earth ionosphere wave guide from geographically large sources. Some discrete sources were observed.

TRANSIENT PHENOMENA ASSOCIATED WITH SOMMERFELD'S HORIZONTAL DIPOLE PROBLEM

EE Abstr. 6805/1962; Appl. sci. Res. (Netherlands), V. 8, No. 4, Pgs 357-68, 1960.

H.J. Frankena

A horizontal electric dipole, located above the plane interface of two non-conducting media, has a dipole moment which is an arbitrary but given function of time when $t > 0$ and which is zero when $t < 0$. Travelling electromagnetic waves, generated by this dipole, are calculated with the aid of a modification of Cagniard's method. For the electric field vector above and at the interface expressions are obtained for the direct and reflected waves in the case that the velocity of light in the medium containing the source is the larger one.

IMPULSE EXCITATION OF A CONDUCTING MEDIUM

J. Galejs

See Section II, Page 147.

SCATTERING FROM A CONDUCTING SPHERE EMBEDDED IN SEMI-INFINITE DISSIPATIVE MEDIUM

J. Galejs

See Section II, Page 148.

THE FIELD OF A PULSED DIPOLE IN AN INTERFACE

C.S. Gardner, J.B. Keller

See Section II, Page 149.

SCATTERING FROM A SMALL ANISOTROPIC ELLIPSOID

Canad. J. Phys., V. 36, Pgs 1059-1071, 1958.

R.A. Hurd

Electromagnetic waves. The fields are expanded as power series in λ^{-1} .

PROPAGATION OF THE RADIOFREQUENCY GROUND WAVE TRANSIENT SINUSOID OVER A FINITELY CONDUCTING PLANE EARTH

Prepublication Papers NBS-IRE PGAP Symposium on Propagation of VLF Waves, Boulder, Colorado, 23rd-25th January 1957. Vol. II, Paper 16.

J.R. Johler

The theory of the propagation of the radiofrequency transient sinusoid over a finitely conducting plane earth is presented. Three cases are considered: (1) a wave train chopped off at one point in

time ($t = 0$); (2) a wave train chopped off at two points in time ($t = 0, T_2$); and (3) a wave train chopped off at one point in time followed by exponential delay. Several numerical examples of the first case with a cosine wave applied to the dipole source are presented.

TRANSIENT RADIOFREQUENCY GROUND WAVES OVER THE SURFACE OF A FINITELY CONDUCTING PLANE EARTH

J. Research NBS, Vol. 60D, No. 4, Pgs 281-285 (April 1958). Similar material was published in Geofis. Pura e Appl. (Milan), Vol. 37, Pgs 116-126 (1957); and as NBS Report 5094, US Nat. Bur. of Standards, Boulder, Colorado, (26th July 1957).

J.R. Johler

The complete transient signal is reconstructed after propagation via the groundwave mode over a finitely conducting plane earth in which the displacement currents are neglected. The theory is illustrated by computations that have been made on formulas derived by the method of the inverse Laplace transformation. The results of this analysis indicate that current sources with sinusoidal form in the time domain could be used to stimulate spherics. The methods employed in this analysis can be used to reconstruct propagated signals of pulsed radio-navigation systems.

A NOTE ON THE PROPAGATION OF CERTAIN LOW FREQUENCY PULSES UTILIZED IN A RADIO NAVIGATION SYSTEM

October 1961 (NBS Technical Note No. 118) (PB161619). \$.75.

J.R. Johler

No abstract

ON PROPAGATING DISCONTINUITIES IN AN ELECTROMAGNETIC FIELD

EE Abstr. 2182/1962; Inst. Radio Engrs (USA), V. AP-9, No. 4, Pgs 370-7, July 1961.

K.R. Johnson

The propagation of discontinuities of an electromagnetic field is considered for the case of a conducting medium. Conditions relating the values of the discontinuities in the electric and magnetic fields are obtained, and equations governing the transport of the discontinuities through space are derived. Such discontinuity conditions and transport equations are obtained both for the fields and for the n th order partial time derivatives of the fields. Previous derivations have treated the case of a nonconducting medium and have used distribution theory. The present treatment does not use distribution theory.

TRANSFER OF TRANSIENT ELECTROMAGNETIC SURFACE WAVES INTO A LOSSY MEDIUM
J. appl. Phys. (USA), V. 30, No. 10, Pgs 1595-98, October 1959.
J. Keilson, R.V. Row

The propagation of a transient surface wave in the form of an impulse into a lossy medium is examined via a simple two-dimensional plane wave model. The solution found exhibits characteristics of both wave propagation and diffusion. This impulse response is used as a basis for calculating the response to an arbitrary excitation at a point on the surface. For observation times longer than the time duration of the surface disturbance, the form of this solution is equivalent to a moment expansion. The limits imposed on the signalling band width by the losses in the medium are discussed.

IMPULSE ELECTROMAGNETIC FIELDS

Phys. Abstr. 978/1953; Trans. S. African Inst. Engrs, V. 43, Pgs 200-11, July 1952.
R. Kitai

Expressions are developed for the field established by the Hertzian dipole and by the magnetic dipole in terms of dipole moments. The expressions hold when the derivatives of the dipole moments are continuous for all values of time. It is then assumed that the moment M obeys a hyperbolic tangent $M \propto \tanh(kt)$ and an insight into the nature of impulsive field is obtained by considering the condition $k \rightarrow \infty$ when the function becomes a step. General expressions for impulse fields are then formulated, and an example is worked to illustrate some properties of impulse fields. It is found that the "static", "induction" and "radiation" fields have different shapes. Theory also shows that it is meaningless to consider the relative importance of these fields unless a receiver frequency is specified.

THEORY OF TERRESTRIAL ATMOSPHERICS

P.E. Krasnushkin
See Part I, Page 64.

A DIPOLE APPROXIMATION OF THE BACKSCATTERING FROM A CONDUCTOR IN A SEMI-INFINITE DISSIPATIVE MEDIUM

Phys. Abstr. 21976/1963; J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 4, Pgs 433-43, July-August 1963.
M.B. Kraichman

The backscattering of a uniform plane wave by a conductor in a semi-infinite dissipative medium is discussed. The conductor is assumed to act as both an electric and a magnetic dipole with moments

which are obtained from the electric and magnetic polarizabilities of the conductor, respectively. Using these induced moments, expressions are derived for the backscattered electric field at a point on the surface of the dissipative half-space directly above the dipoles. Both harmonic and transient excitation are considered.

STUDY OF ELECTRO-MAGNETIC PROPAGATION OF A TRANSIENT SIGNAL THROUGH SEA WATER

AD 258 631; Engineering and Industrial Experiment Station, College of Engineering, University of Florida, Gainesville, Technical Report 1, 24, p., illus., 1961.

M.J. Larsen, M.H. Latour, M.M. Newman.

The results of an experimental study of the propagation characteristics of sea water for a high-powered electromagnetic transient wave are presented. The methods of the transient wave generation and reception are described. The results consider the non-linear frequency characteristics of the medium as they relate to the attenuation and delay of the propagated wave. The observed transient received signal characteristics as a function of both distance and depth are compared with those calculated for continuous-wave signals in sea water medium.

ON THE PROPAGATION OF THE WAVE FRONT IN A DISPERSIVE MEDIA

M. Marziani

See Section I, Page 71.

PROPAGATION OF ELECTROMAGNETIC STEP FUNCTIONS OVER A CONDUCTING MEDIUM

Phys. Abstr. 17955/1962; J. appl. Phys. (USA), Vol. 33, No. 8, Pgs 2556-64, August 1962.

P.E. Mijnaerends

A theoretical treatment is presented of the behaviour of various components of the electromagnetic field by a horizontal electric dipole, embedded in a homogeneous conducting half-space, and excited by a step-function current. Displacement currents are neglected, thereby limiting the validity of the treatment to frequencies that are not too high, while the results for the transient response are only valid for sufficiently large times after the application of the step function to the dipole. The treatment is based on Laplace transform theory. Besides the electric and magnetic components in the conducting medium, the vertical electric field air $e_{c,z}$ at points at the interface is also examined. Since the expressions obtained are rather involved, numerical results are given only for $e_{c,z}$ and a horizontal magnetic component in the conducting medium $h_{i,x}$. The response of $e_{c,z}$ is a pulse with a rise time proportional to the square of the aerial depth but independent of horizontal distance, and a long trailing edge. The magnetic component $h_{i,x}$ rises slowly to a stationary value; its rise time increases with increasing horizontal distance. It is shown that there is a marked difference in attenuation with depth, and sometimes also with horizontal distance, between transient and sinusoidal signals.

TRANSIENT RESPONSE OF A DIPOLE ANTENNA

Phys. Abstr. 13690/1964; J. Math. Phys. (New York), Vol. 3, No. 3,
Pgs 564-5, May-June 1962.
S.P. Morgan

The transient current in a long dipole aerial excited by a step-function voltage across an infinitesimal centre gap has recently been calculated by Wu (Abstr. 1598 of 1962). A simpler derivation of Wu's result is given using double Fourier transformation.

DIFFRACTION OF ELECTROMAGNETIC WAVES BY AN INHOMOGENEOUS SPHERE

Phys. Abstr. 20151/1962; Geophysics (USA), Vol. 27, No. 4, Pgs 480-92, August 1962.
J.G. Negi

The electromagnetic response of an inhomogeneous conducting sphere (having radial conductivity distribution) embedded in an infinite homogeneous medium is investigated. The effect of linear conductivity variation and magnetic contrast between the two media is discussed in detail and relevant curves are presented. Analytical results are further extended to a more general situation in which this sphere is located in a half-space and the influence of the air-earth boundary is calculated. These results may be applied to geoelectrical interpretation.

REFLEXION UND BRECHUNG VON KUGELWELLEN: EFFEKTE 2. ORDNUNG.

Ann. Phys. (France), V. 41, Pgs 443-466, 1942.
H. Ott

No abstract

TRANSIENT PROCESS IN A CYLINDRICAL CONDUCTOR AFTER AN EXTERNAL MAGNETIC FIELD IS SWITCHED OFF. I.

Phys. Abstr. 2082/1963; Izv. Akad. Nauk SSSR, Ser. geofiz., 1962; No. 6, Pgs 736-43; in Russian. English trans. in Bull. Acad. Sci. USSR, Geophys. Ser. (USA), No. 6, Pgs 478-81, June 1962, publ. Sept. 1962.
G.V. Pris

A parameter characterizing the source of an anomaly is introduced in the field-establishment method, based on a study of the transient secondary magnetic field for $t \rightarrow \infty$. The dependence of the parameter on the cross-sectional shape of a cylindrical conductor is investigated.

DETERMINATION OF THE PARAMETERS OF ORE INCLUSIONS FROM THE TRANSIENT
PROCESS CURVE IN THE METHOD OF FIELD ESTABLISHMENT, II.

Phys. Abstr. 2083/1963; Izv. Akad. Nauk SSSR, Ser. geofiz., 1962, No. 6,
Pgs 744-9; in Russian. English trans. in: Bull. Acad. Sci. USSR,
geophys. Ser. (USA), No. 6, Pgs 482-4 (June 1962, publ. Sept. 1962).
G.V. Pris

Parameters of anomalous objects are introduced in the method of field
establishment (transient-process method), based on a study of the asymptotic
behaviour of the secondary magnetic field at $t \rightarrow 0$ and $t \rightarrow \infty$. Parameters
for the inductive method can also be determined from the curve of the
transient process.

TRANSIENTS IN THE CONDUCTING MEDIA

Inst. Radio Engrs. (USA), V. AP-6, No. 2, Pgs 178-82, April 1958.
P.I. Richards

The exact fields generated by transient electric and magnetic di-
poles in an infinite conducting medium are derived. Specialization to
brief, approximately triangular pulses then brings out the salient
practical features of such signals. The peak signals are attenuated as
 r^{-3} or r^{-4} rather than exponentially, and in practical sense, they travel
very slowly (mean effective velocity about equal to sonic speed for a
range of 1 km in sea water.)

A NOTE ON THE BACK-SCATTERING OF A CIRCULAR DISK.

Proc. Nat. Inst. Sci. India, Part A, V. 26, No. 6, Pgs 609-616.
26th November 1960.
S.R. Seshadri

Asymptotic series are obtained for the back-scattering cross-
sections of an acoustically hard disk, and acoustically soft disk and
a perfectly conducting disk.

THE DIFFRACTION OF ELECTROMAGNETIC WAVES AT RECTANGULAR APERTURES IN
PLANE METAL SCREENS

Z. angew. Phys. (Germany), V. 13, No. 1, Pgs 41-47, January 1961.
H. Severin, K. Körper

An approximation method of calculating the diffraction field
(see eq. 2694 of 1951 Severin) is applied to the case of rectangular
apertures; results are compared with those obtained experimentally.

GENERATION OF AN ELECTROMAGNETIC PULSE BY AN EXPANDING PLASMA IN A CONDUCTING HALF-SPACE

Radio Science Journal of Research NBS/USNC-URSI, Vol. 68D, No. 2, Pgs 147-155, February 1964.
A.P. Stogryn, R.N. Ghose

The problem of the generation of an electromagnetic pulse by an expanding infinitely conducting, spherical plasma under the earth is considered. The solutions consist of the derivation of an appropriate tensor Green's function for the half-space which reduces the problem of determining the electric field at any point in space due to the current density generated by the interaction of the plasma with the earth's static magnetic field to evaluating an integral. The vertical component of the electric field at the earth's surface which is generated by the mechanism is calculated.

SWEEP-FREQUENCY PULSE-TRANSMISSION MEASUREMENTS OVER A 2400 KM PATH

P.G. Sulzer
See Section I, Page 96.

LOW-FREQUENCY SCATTERING BY CYLINDRICAL BODIES

EE Abstr. 2040/1964; Appl. Sci. Res. B. (Netherlands), Vol. 10, Nos. 3-4, Pgs 195-202; 1963.
J. van Bladel

General formulae are derived for the scattered amplitude and scattering cross-section of metallic and dielectric cylinders immersed in a low-frequency field. The shape of the cylinders is left unspecified. The two fundamental polarizations (i.e. either E or H parallel to the axis) are considered.

TRANSIENT ELECTROMAGNETIC PROPAGATION IN A CONDUCTING MEDIUM

Geophysics (USA), V. 16, Pgs 213-221, April 1951.
J.R. Wait

The transient electric fields will be calculated for several types of step function current sources embedded in a conducting medium. These will be developed by the aid of the Laplace Transformation. The types of source elements considered are the electric dipole, the magnetic dipole and the linear grounded current element of finite and infinite length.

TRANSIENT COUPLING IN GROUNDED CIRCUITS
Geophysics, (USA), V. 18, Pgs 138-141, January 1953.
J.R. Wait

Transient coupling between insulated circuits of finite length grounded at their end points in an infinite homogeneous and conducting medium is investigated. The general result is specialized to the case of a typical electrode array as used in electrical resistivity logging in wells or drill holes. A graphical example shows how the voltages build up to their static value due to a suddenly applied current.

A TRANSIENT MAGNETIC DIPOLE SOURCE IN A DISSIPATIVE MEDIUM
J. appl. Phys. (USA), V. 24, Pgs 341-343, March 1953.
J.R. Wait

The solution is given for the electric field of a small current-carrying loop which is immersed in a dissipative medium and is energized by a step-function current. Approximate expressions for the magnetic fields are also derived. The propagation of an electromagnetic pulse in sea water is then discussed.

TRANSIENT FIELDS OF A VERTICAL DIPOLE OVER A HOMOGENEOUS CURVED GROUND
Canad. J. Phys., V. 34, Pgs 27-35, January 1956.
J.R. Wait

Expressions are derived for the transient fields of a short vertical antenna, situated on a smooth spherical conducting earth, and energized by a current which is discontinuous in time. When the antenna current is a linear function of time, the radiation field on a flat perfectly conducting earth is of step-function form. The departure from the step shape of the field is shown to be due to the finite conductivity and dielectric constant of the ground, the induction and static fields of the antenna, and the curvature of the earth.

SHIELDING OF A TRANSIENT ELECTROMAGNETIC DIPOLE FIELD BY A CONDUCTIVE SHEET
Canad. J. Phys., V. 34, Pgs 890-893, August 1956.
J.R. Wait

No abstract.

THE TRANSIENT BEHAVIOUR OF THE ELECTROMAGNETIC GROUND WAVE ON A SPHERICAL EARTH

Inst. Radio Engrs. (USA), Trans., V. AP-5, No. 2, Pgs 198-202, April 1957.
J.R. Wait

Some calculations are presented to show the nature of the transient ground wave radiated from an electric dipole which is situated over a spherical earth. The moment of the dipole is considered to vary with time in a linear manner. It is shown that the departure of the leading edge of the radiation field from a step function form is a consequence of diffraction and loss in the finitely conducting ground.

PROPAGATION OF VERY-LOW-FREQUENCY PULSES TO GREAT DISTANCES

J. Res. Nat. Bur. Stand. (USA), V. 61, No. 3, Pgs 187-203, September 1958.
J.R. Wait

A theoretical study is presented for the propagation of electromagnetic pulses at very low frequencies to large distances. The space between the earth and the ionosphere is represented as a wave guide with sharply bounded and concentric spherical boundaries. The concept of phase and group velocity and its application to the present problem is discussed in some detail. The influence of the propagation medium on the shape of the envelope of a quasi-monochromatic pulse is also considered. Using an alternative approach, the response of an impulsive source is also calculated and is shown to be a damped oscillatory function of time with a quasi-half-period varying in a predictable manner with distance of travel in agreement with the observations of Norinder and Hepburn.

DIFFRACTION OF ELECTROMAGNETIC WAVES BY SMOOTH OBSTACLES FOR GRAZING ANGLES

J. Research (D. Radio Propagation), Nat. Bur. Standards 63D, Pgs 181-197, September-October 1959.
J.R. Wait, A.M. Conda

No abstract

PROPAGATION OF ELECTROMAGNETIC PULSES IN A HOMOGENEOUS CONDUCTING EARTH

Appl. sci. Res. (Netherlands), Section B, V. 8, 1960.
J.R. Wait

A general analysis for the electromagnetic response of conducting media due to pulse excitation is presented. The treatment is based on the Laplace transform theory. First, a survey of the field is made

and the limitations and scope of the previous work are pointed out. The theory of propagation of a plane wave pulse in a conducting and homogeneous medium of infinite extent is then reviewed. The form of these results enable one to evaluate the relative importance of the conductivity and the dielectric constant. It is indicated, for sufficiently large times in the transient response, that displacement currents may be safely neglected for sea water and for most geological media. Under this assumption, the waveform of the electric field in a conducting medium is illustrated for the case where the source is an electric dipole energized for exponential and bell-shaped source functions. The pulse shape of the field components is profoundly modified as they propagate through the medium. It is suggested that this property may be utilized in measuring distances in the earth's crust. The more difficult problem of propagation in non-infinite conducting media is also considered. To account for the presence of the interface in a conducting half-space, (i.e. homogeneous flat ground) a rather involved analytical expression for the transient fields is required. Certain special cases, such as a horizontal-electric dipole at the interface, are illustrated by numerical results. The transient excitation of a wire loop lying on the surface of a homogeneous ground is also considered. Finally, transient coupling between pairs of parallel insulated wires grounded at their end points is treated as an extension of the earlier results.

A NOTE ON THE PROPAGATION OF ELECTROMAGNETIC PULSES OVER THE EARTH'S SURFACE.

Phys. Abstr. 1451/1963; Canad. J. Phys. Vol. 40, No. 9, Pgs 1264-8, September 1962.

J.R. Wait

In considering pulse propagation over a finitely conducting earth it is always assumed that the magnitude of the refractive index is large compared with unity. This assumption, though easily justified for harmonically varying fields for lower and medium frequencies, is not obviously justified for transient problems which require integration over all frequencies. This paper attempts to examine the justification for this assumption by comparing the results from the approximate forms used for finitely conducting media with the known exact solution for the case of lossless media. It is concluded that the Sommerfeld form of the attenuation function is applicable to pulse propagation over a flat earth provided that the dielectric constant is reasonably large compared with unity.

ON THE PROPAGATION OF ELF PULSES IN THE EARTH-IONOSPHERE WAVEGUIDE

Can. J. Phys., 40, Pgs 1360-1369, October 1962.

J.R. Wait

No abstract

ON THE DIFFRACTION OF SPHERICAL RADIO WAVES BY A FINITELY CONDUCTING SPHERICAL EARTH

J. Res. Nat. Bur. Stand. (USA), Vol. 66D, No. 1, Pgs 101-6, January-February 1962; Phys. Abstr. 16036/1962.

L.C. Walters, J.R. Johler

The theory for the diffraction of spherical electromagnetic waves by a finitely conducting spherical earth was developed from Maxwell's equations by Watson (1918) and the intricate computation details were later worked out by van der Pol and Bremmer (1936) as the now classical series of residues. Two aspects of this computation present considerable difficulty, especially at low frequencies: (1) The calculation of the height-gain factor which takes account of an elevated transmitter and/or receiver. (2) The evaluation of the special roots, $\tau = \tau_s$, of Riccati's differential equation:

$$\frac{d\tau}{d\tau} = 25\tau^2 + 1 = 0$$

near the circle of convergence, $\tau^2 = \frac{1}{25}$. These analytic difficulties are avoided with the aid of modern analysis techniques applied to a large scale electronic computer. Hankel functions of the first and second kind of order one-third and two-thirds are calculated by numerical integral methods and then used with iteration to solve Riccati's differential equation. The amplitude and phase of the spherical radiowave diffracted in the vicinity of the earth with various altitudes above the surface of the earth, of both the transmitter and the receiver are then calculated by a summation of the series of residues.

ELECTROMAGNETIC TRANSIENTS IN CONDUCTING MEDIA

EE Abstr. 6709/1960; Inst. Radio Engrs. (USA), Trans., V. AP-8, No. 2, Pgs 229-30, March 1960.

S.H. Zisk

In a recent paper (see Abstr. 4723/1958) Richards derived expressions for the electric and magnetic fields of a short pulse of electric or magnetic dipole moment in a conducting medium. An alternative analysis is given which explains certain unusual results of the original work as arising from dispersion in the conducting medium and from the frequency dependence of the attenuation factor of the fields. The conclusion drawn is that communication by pulses is expected to be inferior to that by low-frequency continuous waves.

SHIELDING OF TRANSIENT ELECTROMAGNETIC SIGNALS BY A THIN CONDUCTING SHEET

J. Res. Nat. Bur. Stand. (USA), V. 64D, Pgs 563-567, 1960.

N.R. Zitron

No abstract.

PART VII

PART VII

MISCELLANEOUS (PLASMA PHYSICS, FUNDAMENTAL THEORIES, ETC.)

CLASSICAL THEORY OF ELECTRICITY AND MAGNETISM

2nd ed. rev. by Richard Becker, il. 1951, \$5.50, Hafner
M. Abraham

THEORIE DER ELEKTRIZITAT

2 vols. V. 1, Einführung in die Maxwellsche Theorie der Elektrizität
12th and 13 eds., \$7.00; V.2, Elektronentheorie, 6th rev. ed. \$6.50;
set \$13.50; Edwards.
M. Abraham, R. Becker

A GENERAL METHOD OF CALCULATING THE CONDUCTIVITY OF HETEROGENEOUS GROUND
EE Abstr. 4617/1953; Ann. Télécomm. (France), V. 8, Pgs 212-24, June
1953.

M. Argirovic

A new analytical method for calculating attenuation factors for
radio wave propagation over heterogeneous ground is given. The method
yields a simple expression for the attenuation factor and a nomogram
procedure for the determination of ground conductivity from field
strength curves. There appears to be satisfactory agreement between
the theoretical calculations and experimental results.

PLASMA PHYSICS AND MAGNETOHYDRODYNAMICS

AD 271 170; An ASTIA Report Bibliography, 135 p., 1350 refs., 1962.
M.F. Aukland

No abstract

BIBLIOGRAPHY ON RADIO FREQUENCY INTERFERENCE

IRE Trans. Radio Freq. Interference (USA), Vol. RF1-4, No. 1, Pgs 1-211,
February 1962; EE Abstr. 8260/1962.
C.E. Blakely, R.N. Bailey, H.H. Jenkins, W.M. Rogers, E.W. Wood, R.F.
Ficcki

A very comprehensive bibliography in two parts, one of which contains
abstracts.

ELECTRIC FIELDS AND WAVES

Handbuch der Physik, V. 16, Springer, 1958, Chap. 4, Pg 519.
H. Bremmer

No abstract

BIBLIOGRAPHY AND COMMENTS ON IMPORTANT RECENT RESEARCH IN THE FIELD OF
VLF AND LF PROPAGATION

Mathematical Note 166, Boeing Physical Research Staff, Mathematics
Service Unit, Seattle, Washington, 22nd March 1957.
R.L. Brock, R.C. McCarty

The feasibility of a reliable long distance communication system operating at the very low frequencies (LF) depends to a great extent on the propagation characteristics of the transmission medium at these frequencies and on the geophysical phenomena associated therewith. There is presented here a bibliography covering the recent (1947 to 1957) research efforts on both the theoretical and experimental levels in this area of study. Summarizing paragraphs are included for the more important papers listed.

BIBLIOGRAPHY ELECTROMAGNETIC PHENOMENA WITH SPECIAL REFERENCE TO ELF
(1-3000 CPS)

SACLANT ASW Research Centre, La Spezia, Italy. Technical Report No. 10,
1st September 1962, 320 pgs, 1,000 references.
L. Brock-Nannestad.

The bibliography covers unclassified literature and is based on information available from the abstract literature, the U.S. Armed Services Technical Information Agency (ASTIA) indexes and bibliographies, company reports, references in published papers, etc. The bibliography covers the period 1952-1962, although a few older references are included. Although the emphasis is on ELF quite a number of papers dealing with the frequency ranges above and below this range are incorporated. Whenever available, abstracts are given.

WAVE PROPAGATION IN A RANDOM MEDIUM

1960. \$7.50. McGraw
L.A. Chernov

LABORATORY INVESTIGATION OF OVERVOLTAGE

Chapter 5 of Overvoltage Research and Geophysical Applications, edited by J.R. Wait, 1959; \$9.00, Pergamon.
L.S. Collett, and Others.

A technique for the laboratory studies of induced polarization in mineralized and non-mineralized rock specimens is discussed. The equipment for both the transient and the frequency variation procedures is described in outline. Some typical results are presented for various metallic and non-metallic minerals.

FIELD THEORY OF GUIDED WAVES

\$16.50. McGraw
R.E. Collin

No abstract

SCATTERING DIAGRAMS IN ELECTROMAGNETIC THEORY

Electromagnetic Theory and Antennas, Proceedings of a Symposium held in Copenhagen, Denmark, June 1962, edited by E.C. Jordan. Pgs 235-251.
G.A. Deschamps

The formalism of quantum mechanics, as described for example by Dirac (1947) suggests a notation convenient also in classical field theories. This notation leads to simple representations by means of diagrams, or graphs, similar to those introduced by Feynman (1949). In this paper both the notation and the associated diagrams are adapted to problems in electromagnetics. They are applied mostly to a review of known results: equivalence principles, formulation of scattering and diffraction problems, Born-Kirchhoff approximations. It will be clear, however, that they provide a systematic method for formulation problems and expressing their solutions. Furthermore, as illustrated by the problem of propagation over a mixed boundary, the method can be used as a tool for finding meaningful approximations.

THE EFFECT OF SOLAR CORPUSCLES IN THE IONOSPHERE

EE Abstr. 4431/1954; Arch. elekt. Ubertragung (Germany), V. 8, Pgs 259-68, June 1954.
W. Dieminger

The paper discusses typical changes occurring in the ionosphere during the penetration of solar corpuscles inside and outside the zone of northern lights. The theory of Chapman-Ferraro by Martyn is extended so as to allow the observed phenomena in the ionosphere and in terrestrial magnetism to be explained in the same basic manner. The essential idea

is here that the corpuscles emitted from the "ring current" transfer the radial field of polarization of this current to the zone of northern lights. The meridional electrical field set up there brings current systems into motion and modifies as a secondary effect the distribution of the charge carriers in the F_2 -layer.

INVESTIGATION OF ELECTROMAGNETIC PHENOMENA INVOLVED IN THE MOTION OF BODIES IN A CONDUCTING FLUID IN A MAGNETIC FIELD

Phys. Abstr. 2115/1963; Zh. eksper. teor. Fiz. (USSR), Vol. 43, No.3(9) Pgs 752-62, September 1962. In Russian. English trans. in Soviet Physics - JETP (USA).

L.I. Dorman, Yu. M. Mikhailov

The motion of a sphere in an incompressible fluid of finite conductivity in an external magnetic field is considered for small magnetic Reynolds numbers and small Stuart numbers. The distribution of the electric and magnetic fields is given under the assumption that the fluid velocity field is potential. The electric field distribution in the boundary layer of the sphere is derived for small Hartman numbers. The electric and magnetic fields produced during the movement of a sphere in mercury were investigated experimentally for Reynolds numbers lying between 5×10^4 and 5×10^5 .

HYDROMAGNETIC THEORY OF GEOMAGNETIC STORMS

A.J. Dressler, E.N. Parker

See Section IV, Page 289.

ELECTROMAGNETIC FIELDS ENERGY AND FORCES

il. 1961, \$7.50, Wiley

R.M. Fano, and Others

ELECTROMAGNETIC THEORY

1954. \$6.75. Oxford U.P.

V.C.A. Ferraro

ELECTRIC FIELDS AND WAVES

V. 16, Encyclopedia of Physics, 1958, Springer.

S. Fluegge, Ed.

BIBLIOGRAPHY ON RECENT ADVANCES IN APPLIED ELECTRO-PHYSICS
AD 269 951; U.S. Army Engineering Research and Development Labs., Fort
Belvoir, Virginia, LTIS Bibliography No. 11, 91 refs., 1961.
J.B. Forlini

No abstract

SOUND PULSES IN A CONDUCTING MEDIUM
Proc. Cambridge Phil. Soc. (GB), V. 55, Pt. 4, Pgs 341-67, October
1959.
F.G. Friedlander

Theoretical treatment of the propagation of small disturbances in
a compressible conducting fluid in a magnetic field.

GRUNDZUGE DER ANGEWANDTEN GEOELEKTRIK
V. Fritsch
See Section III, Page 222.

PROPAGATION ALONG A NARROW SLOT IN A CONDUCTING SCREEN ABOVE A LOSSY
DIELECTRIC
Applied Research Lab., Sylvania Electronics Systems, Waltham 54, Mass.,
ARM No. 268, 24 p., 1961.
J. Galejs

A narrow slot in a conducting screen which separates a lossless
from a lossy dielectric half space, is excited by a current source
which lies in the interface between the two media. The transverse dis-
tribution of the electric field in the slot plane is approximated by the
static solution. The longitudinal distribution of the potential across
the slot is obtained from a Hallen type solution of an integral equation.
The zero and the first order solutions of the integral equation are valid
for slot widths that are much less than the skin depth in the lossy
dielectric. For slots of negligible width the propagation constant
along the slot approaches the propagation constant of a thin wire which
lies in the interface between the two dielectrics. The attenuation of
the fields along the slot is increased with increasing width of the slot.
The input admittance and the magnetic dipole moment of the slot are
calculated with increasing frequency. The efficiency is less than 10^{-6}
for $f = 1$ kc, and remains less than 3×10^{-2} for $f < 10^4$ kc.

PROPAGATION ALONG A WIDE SLOT IN A CONDUCTING SCREEN ABOVE A LOSSY DIELECTRIC HALFSPACE

Applied Research Lab., Sylvania Electronics Systems, Waltham 54, Mass., ARM 274, 18 p., 1961.

J. Galejs

A wide slot in a conducting screen which separates a lossless from a lossy dielectric half space is excited by a current source which lies in the interface between the two media. The electric field in the slot plane is related to the excitation current by an integral equation. After assuming a negligible variation of the electric field in the transverse direction the integral equation can be solved for the longitudinal variation of the transverse electric field by Fourier transforms, provided that the slot width w is much larger than δ the skindepth in the lossy medium. The electric field exhibits the same longitudinal variation in the slot plane as the electric field in a direction transverse to the axis of an infinitely long line current which lies in the interface of the two dielectrics. The first order correction to the field distribution which is due to a finite slot width w is computed with neglected displacement currents of the lossless medium and is shown to be small at distances $x \ll w$. The radiation efficiency of the wide slot ($w > \delta$) is larger than the radiation efficiency of narrow slots ($w < \delta$). Still, the expected efficiency of the wide slots is less than 10^{-3} for frequencies in the VLF range and below, if the ground conductivity is of the order of 10^{-3} mho/meter.

PROPOSAL FOR STANDARD FREQUENCY BROADCAST AT VERY LOW FREQUENCY

Paper No. 41, V. 3. Publications Listing, July 1954-March 1963.

Central Radio Propagation Laboratory, Boulder Laboratory, Nat. Bur. Stands., Boulder, Colorado.

W.D. George.

No abstract

ON THE DEFINITION OF SOME ELECTROMAGNETIC QUANTITIES

Electromagnetic Theory and Antennas, Proceedings of a Symposium held at Copenhagen, Denmark, June 1962, edited by E.C. Jordan, Pgs 997-1007.

Germano Braga Rego

A four-dimensional calculus based on a Clifford algebra is applied to classical electromagnetism. Maxwell's equations are derived from the equation of continuity and the condition that $\text{div } D = \rho$. The displacement vector D is "axial" and transforms like B , and H like E . The orbital gyromagnetic ratio for a point charge is twice that given by the usual definition of magnetic moment. The Poynting vector appears as $\frac{1}{2}(E \times H + c^2 D \times B)$.

THE POLARIZATION OF ELECTROMAGNETIC WAVES AT THE BOUNDARY OF TWO MEDIA
Phys. Abstr. 5476/1962; Rev. Opt. (France), V. 40, No. 11, Pgs 547-54,
November 1961.

O. Gherman

The nature and degree of polarization of the electromagnetic waves reflected and transmitted at the boundary of two media was determined by means of the Stokes' coefficient method. This method is likely to be extended to some other problems in optics.

ELECTRIC AND MAGNETIC FIELDS

EE Abstr. 1483/1964; Electro Technology (USA), Vol. 72, No. 5, Pgs
83-104, November 1963.

A. Glaser

The basic equations and relations between variables in all types of electromagnetic fields are given and discussed in relation to their importance in designing electrical and electronic equipment.

A RECIPROCITY THEOREM FOR NON-PERIODIC FIELDS

EE Abstr. 7609/1960. Inst. Radio Engrs. (USA), Trans., V. AP-8, No. 3,
Pgs 339-42, May 1960.

G. Goubau

By the use of Fourier transforms, the reciprocity theorem for electromagnetic fields emanating from two independent sources can be converted into a form applicable in the time domain. The theorem yields all the results which can be derived from the classical formulation but is more that it applies also in the case where either or both of the sources are moving. (The classical theorem fails in this case as the field of a moving source is never periodic in the entire space). A suitable form of the theorem is derived for application to problems similar to that of signal transmission between a satellite and a ground station.

LONGITUDINAL HALL EFFECT

Phys. Rev. (USA), V. 117, No. 3, Pgs 689-697, February 1960.

L. Grabner

The "Hall field", defined as the electric field which is an odd function of the magnetic field, is split into the conventional transverse (TH) field and a longitudinal (LH) field. Some properties of the LH field contrast with those of the TH field. The LH field is investigated theoretically and experimentally for n-type Ge.

STEADY-STATE ELECTRODYNAMICS OF A CYLINDRICAL BODY IN AXIAL MOTION
EE Abstr. 7979/1963; J. Electronics and Control (GB), Vol. 14, No. 4,
Pgs 459-80, April 1963.
P. Graneau

Coupled circuit theory (CCT) was applied to an electromagnetic system in which a cylindrical conductor moves axially through a filament carrying a forced energizing current. With both this current and the relative velocity being arbitrary functions of time, it results in infinite series expressions for the current induced at any point in the cylinder, the e.m.f. induced in an open circuited, external, sensing filament, the mechanical reaction force between cylinder and energizing filament and the rate of energy exchange. The general equations were further developed for the three specific cases of (i) direct current excitation and constant relative velocity, (ii) direct current excitation and accelerated relative motion and (iii) alternating current excitation and constant relative velocity. It was also shown how to study the effects of varying size and conductivity by employing scaled inductance coefficients. It is argued that the application of Lorentz transformations to the Maxwell-Hertz absolute field theory should, in its experimental consequences, be in full agreement with CCT. The advantage of having two theories available resides in the differences between their respective mechanical models and mathematical formulations. Facts which lie hidden in one of them may be obvious from the other. CCT will probably be preferred when dealing with electromagnetic induction in three-dimensional bodies and perhaps fluid media.

STUDIES OF ELECTROMAGNETIC COMPATIBILITY OF EQUIPMENT AND SYSTEMS
AD 261 048; Moore School of Electrical Engineering, University of
Pennsylvania, Philadelphia, rept. No. 61-11, 72 p., illus. 1961.
F. Haber, D.E. Mode, and Others

The work on simulation of power line corona noise by means of a pulse modulated Gaussian noise was completed. A method for selecting parameters for the simulator is presented. Procedures for inter-comparing noise meter readings obtained on so-called direct-reading peak and quasi-peak detectors are made. In order to make such comparisons, it is necessary to know the nature of the noise source. A detailed discussion of the approach used to analyze and evaluate noise in underwater communications systems is presented. Models are included of the possible sources and means of propagation. It is believed that one of the major factors in such systems is the transfer of electromagnetic energy within the hull to critical positions immediately outside the hull.

PRINCIPLES OF ELECTRICITY AND ELECTROMAGNETISM

2nd ed. 1949. \$9.50 McGraw

G.P. Harnwell

POTENTIAL OPERATOR IN QUASI-STATIC ELECTROMAGNETIC THEORY

EE Abstr. 1484/1964; Proc. Inst. Elect. Engrs (GB), Vol. 110, No. 11, Pgs 2093-2100, November 1963.

M.R. Harris

The algebra of the integral potential (pot) operator, in combination with the usual differential operators, is briefly discussed. The main algebraic results are simple, easily remembered and of interest in themselves. A particularly important result is the operational equation that shows the separation of any vector field into two unique partial fields, one having zero curl and the other zero divergence. The algebra is applied in the transformation of the well-known differential electromagnetic equations into various integral equations, in terms of the total (applied and induced) sources of the field. The transformation process is usually based on the equation of separation mentioned above. It is simple, and its routine nature leaves the mind largely free to concentrate on the physical interpretation of the results. Only quasi-static fields are discussed. It is well known that the concept of sources does not fail in a more general time-varying field, and it is intended to extend the application of pot algebra in this direction in later work. A novel form of infinite operational series is presented, which expresses the total magnetic field explicitly in terms of the inducing field, in a region of varying permeability. The series is known to be convergent in particular cases, but work is still proceeding on a general proof of convergence. The use of pot algebra stresses the close relation between equations that emphasize the field structure of an electromagnetic system and equations that emphasize the corresponding source structure. The ability to visualize the system in both ways is a valuable aid to clear understanding.

RESPONSE OF A LOADED ELECTRIC DIPOLE IN AN IMPERFECTLY CONDUCTING CYLINDER OF FINITE LENGTH

EE Abstr. 6921/1960; J.Res. Nat. Bur. Stand. (USA), V. 64D, No. 3, Pgs 289-93, May-June 1960

C.W. Harrison, Jr., R.W.P. King

Analytical relationships are developed which permit calculation of the power in the load impedance of an electric probe, symmetrically located within an imperfectly conducting cylinder of small radius compared to the wavelength, in terms of the electric field incident upon the cylinder.

THERMAL NOISE IN DISSIPATIVE MEDIA

Res. Lab. of Elec. Mass. Inst. of Tech. Cambridge. (J. appl. Phys. V. 32, Pgs 493-500, March 1961).

H.A. Haus

To account for the spontaneous thermal fluctuations in a general dissipative medium, a current-source term may be introduced into Maxwell's equations. The dyadic correlation function of the source term is evaluated for a uniform medium at uniform temperature in which the driving field E and driving-current density J are related by differential equations in time and space variables. In those cases in which a simple tensor relation exists between the Fourier components of E and J at a particular frequency, the result is generalized to uniform media. A similar generalization is achieved only under some restrictive assumptions for media characterized by differential equations in the space variables. The results obtained may be applied to the computation of thermal noise radiated from a medium at non-uniform temperature, and can serve as an aid toward understanding of noise mechanisms. The source is also evaluated for a thin plasma sheet with the result derived from the general theory.

THE LAW OF INDUCTION AND ITS APPLICATION TO MOVING CONDUCTING LOOPS

EE Abstr. 10878/1963; Acta. tech. (Czechoslovakia), Vol. 7, No. 4, Pgs 319-34, 1962. In German.

B. Heller

Points out the obscurities in published views on this subject and clarifies the situation, taking the usual Maxwell equation as starting-point. Specific examples are discussed, such as the experiments of Hering and Cullwick, and unipolar induction. The main conclusion is that the induction law is quite adequate for dealing with phenomena in conductors whether moving or at rest, and that the introduction of an additional e.m.f. is unnecessary.

RELIABILITY OF ATMOSPHERIC RADIO PREDICTIONS

EE Abstr. 6106/1962; J. Res. Nat. Bur. Stand. (USA), V. 65D, No. 6, Pgs 565-74, November-December 1961.

J.R. Herman

Measured radio noise values are compared with the corresponding predicted values of the International Radio Consultative Committee (C.C.I.R. 1957) at four noise measuring stations. Five frequencies between 0.013 and 10.0 Mc are considered. The stations selected for this study include Balboa, Panama, near two major radio noise centres, and Byrd Station, Antarctica, remote from atmospheric radio noise sources. It is found that the predicted and measured noise levels are in good agreement, except at some places and times, where large discrepancies occur. Most of the disagreements are found at places where the predictions are based on extrapolations of data measured at other stations. Reasons for the disagreements are discussed.

THE PHASE STRUCTURE OF THE FIELD AND VELOCITY OF MEDIUM RANGE RADIOWAVE DISTRIBUTION OVER THE SEA SURFACE DURING TURBULENCE

Ukrayin. fiz. Zh. (USSR), V. 3, No. 6, Pgs 712-20, 1958.

V.L. Herman

The unevenness of the sea surface during turbulence leads to a change in the phase structure of the field and the phase and "medium" velocities of radiowave propagation. This is physically connected with changes in the boundary field value due to the resulting non-uniformities. The integral equation of Feinberg for a medium with effective parameters is necessary for the mathematical investigation of this effect. The attenuation function obtained on solving this equation is given. The attenuation function obtained on solving this equation is given. The characteristic length $\Lambda = \lambda^2/h^2 (hL^{-1})^2$, which depends on the squares of the average height and steepness of the sea waves h^2 , $(hL^{-1})^2$ and the radio-wavelength λ , and not on the conductivity and dielectric constant of the real medium. The values and arg are tabulated. The value of the relative change of phase may vary from several per cent to fractions of 1 per cent in the medium wavelength range, depending on h and λ . Since the phase change $\delta\varphi$ theoretically varies with the distance, the phase measurements, carried out simultaneously with the field amplitude measurement, permits the experimental checking of the theory. The value of Λ , defined by the experimental value of amplitude Φ , should approximately agree with the characteristic length Λ determined by phase measurements. This condition should be satisfied during turbulence of various radio wavelengths. It is expedient, here, to measure $\varphi(u)$ experimentally. The relative change in phase and "average" velocity of radiowave propagation over the sea during the turbulence should reveal a qualitatively distinct correlation which does not practically depend on the distance (on the assumption of uniformity of sea turbulence along its path). The possible error in determining the phase and "average" velocity, due to turbulence of the sea, decreases with an increase in wavelength and a reduction in the average height and steepness of the waves.

MEASUREMENT OF THE SELECTIVITY OF EXTREMELY LOW-FREQUENCY SELECTIVE NETWORKS

EE Abstr. 2093/1959; J. Inst. Elect. Commun. Engrs Japan, V. 41, No. 11, Pgs 1120-6, November 1958.

M. Higashiguchi

Phase characteristics instead of amplitude characteristics are used in two methods of measuring the centre frequency f_0 and the selectivity Q of resonant networks for extremely low frequencies. In the first method, a suppressed-carrier a.m. wave is applied to the network and the output waveform is observed on a c.r.o. When adjustments are made so as to obtain an output waveform exactly similar to the applied waveform, f_0 is approximately equal to the carrier frequency and Q can be calculated from the envelope delay, f_0 and the modulation frequency. In

the second method, a sinusoidal waveform generator is constructed by forming a loop with the network to be tested, an amplitude comparator and a phase shifter. The oscillation frequency of this loop is measured. The oscillation frequency of zero phase shift then gives the network centre frequency f_0 and Q is calculated from the variation of the oscillation frequency corresponding to a known phase shift.

REFLECTION OF WAVES FROM VARYING MEDIA

Phys. Abstr. 7805/1953; Quart. appl. Math. (USA), V. 11, Pgs 9-31, April 1953.
C.O. Hines

Formulae are found for the coefficient of reflection from varying media of a type encountered in physics. These are applied approximately for some general classes of media, and exactly for some specific cases. Many media which would normally be expected to be highly reflecting are shown to be completely transparent to certain waves at least and, in some cases, to a whole spectrum of waves. The results are considered both for electromagnetic (or other classical) waves and for mass waves.

ENERGY EQUATIONS IN THE ELECTROMAGNETIC FIELD

EE Abstr. 7973/1963; Elektrotech u. Maschinenbau (EuM) (Austria), Vol. 80, No. 7, Pgs 153-160, 1st April 1963. In German.
H. Hoffmann

The classical equations of Maxwell can be interpreted in terms of electric and magnetic quantities ("Quantity theory") as well as in terms of electric charges and magnetized elementary currents ("Elementary current theory"), all three theories leading to energy density equations involving Poyntings radiant vector.

ON THE EFFECT OF A MAGNETIC FIELD UPON EXTREMELY LOW FREQUENCY (ELF) WAVE PACKETS

Phys. Abstr. 12713/1960; Astrophys. Norveg. (Norway), V. 6, No. 12, Pgs 131-45, January 1960.
O. Holter

An expression on a form analogous to the Appleton-Hartree formula for the refractive index is evaluated when the plasma has different components. At extremely low frequencies the best approximation to the exact formula is the Q.T.-approximation, and not the Q.L.-approximation as in the Appleton-Hartree theory. When it is possible to calculate the path of the extraordinary wave-packets in the Q.T.-approximations, it results that the path coincides with the magnetic lines of force. Thus, the more the region where this approximation is valid increases (by lowering the frequency of the wave), the more the packets are guided along the lines of force. No such guiding is present in the ordinary mode. The theory may be applied to whistler propagation.

DIFFRACTION BY A UNIDIRECTIONALLY CONDUCTING HALF-PLANE
Canad. J. Phys., V. 38, No. 2, Pgs 168-175, February 1960.
R.A. Hurd

A solution is obtained by transform methods for diffraction of plane electromagnetic waves.

PRESENCE AND ABSENCE OF THE SOLID ANGLE IN SOME CLASSICAL RELATIONSHIPS IN ELECTROMAGNETISM
EE Abstr. 1482/1964; Atti Accad. Sci. Torino I (Italy), Vol. 97, No. 4a, Pgs 685-98, 1962-63. In Italian.
F. Iachello

The question whether the steradian enters into the definitions and therefore dimensions of certain electromagnetic quantities is discussed by reference to the examples of self and mutual induction, scalar potential and vector potential, which are treated in detail. It is shown that the introduction of the steradian is a consequence of the physical impossibility of zero length sections of conductors, and of point electrical charges.

INTEGRAL EQUATION METHODS IN POTENTIAL THEORY. I.
EE Abstr. 14178/1963; Proc. Roy. Soc. A. (GB), Vol. 275, Pgs 23-32, 20th August 1963.
M.A. Jawson

A short study of Fredholm integral equations related to potential theory, with a view to preparing the ground for their exploitation in the numerical solution of difficult boundary-value problems. Attention is drawn to the advantages of Fredholm's first equation and of Green's boundary formula. The latter plays a fundamental and hitherto unrecognized role in the integral equation formula of biharmonic problems.

ELECTROMAGNETIC WAVES AND RADIATING SYSTEMS
1950. \$15.00; text. ed. \$11.25. Prentice-Hall
E.C. Jordan

ELECTROMAGNETIC THEORY AND ANTENNAS
Phys. Abstr. 12308/1963; Oxford, Pergamon Press, 1963.
E.C. Jordan, editor.

Proceedings of a symposium held at Copenhagen from 25th - 30th June, 1962, sponsored by the International Scientific Radio Union, the Technical University of Denmark, the Danish Academy of Technical Sciences, and the

Danish National Committee of the International Scientific Radio Union. 126 papers were presented at the symposium and most of them are published in the proceedings, some of them in summary form, under the following headings:

Scattering and diffraction theory; Anisotropic and stratified media; Random media and partial coherence; Surface waves, leaky waves and mode propagation; Antenna theory and radiating elements; Antenna arrays and data processing.

Abstracts of some of the papers will be found in succeeding issues of Physics Abstracts.

EQUATIONS GOVERNING THE PROPAGATION OF SECOND-ORDER CORRELATIONS IN NON-STATIONARY ELECTROMAGNETIC FIELDS

Phys. Abstr. 9683/1962; Nuovo Cimento (Italy), V. 23, No. 2, Pgs 328-38, 16th January 1962.

Y. Kano

The main results derived by Wolf and Roman relating to the propagation of second order correlations in electromagnetic fields are generalized to the case of a non-stationary field containing currents and charges. The basic differential equations relating the correlations are derived. They fall into two groups, one of which contains only differential equations of the first order, but involves certain parameters that seem difficult to be determined experimentally. When these quantities are eliminated a second set of equations is obtained. Equations of this set are of higher order, but they contain only the electric and the magnetic correlation tensors and a tensor characterizing the correlation in the electric currents.

A COMPACT MULTIPLIER PUTS THE HALL EFFECT TO WORK

Control Engng (USA), November 1955.

G.L. Keister

No abstract

ELECTRICAL RESISTIVITY STUDIES ON THE ATHABASCA GLACIER, ALBERTA, CANADA.

J. Res. Nat. Bur. Stand. (USA), Vol. 64D, No. 5, Pgs 439-48, September-October 1960.

G.V. Keller, F.C. Frischknecht

The use of electrical methods for measuring ice thickness and properties on the Athabasca Glacier, Alberta, Canada, has been studied by the U.S. Geological Survey. Two methods for measuring resistivity were tried: one, a conventional resistivity method in which current was introduced galvanically into the glacier through electrodes, and the

other an electromagnetic method in which a wire loop on the ice was used to induce current flow. Results of the galvanic measurements showed large variations in the resistivity of the ice; in a surface layer several tens of feet thick the resistivity is between 0.3 and 1.0 megohm-meters, and under this layer, the resistivity of the ice is more than 10 megohm-meters. The resistivity of the surface ice is determined by its water content rather than by molecular resonance loss. The ice had no effect on the mutual coupling measurements in the frequency range from 100 to 10,000 cycles per second. As a consequence, the electromagnetic data could be simply interpreted in terms of ice thickness and bedrock resistivity.

ELECTRICAL PROPERTIES IN THE DEEP CRUST

IEEE Trans. Antennas and Propagation, (USA), Vol. AP-11, No. 3, Pgs 344-57, May 1963. EE Abstr. 283/1964.
G.V. Keller

Resistivities in the earth's crust have been evaluated by direct observation using dipole-dipole resistivity soundings and magneto-telluric resistivity methods, supplemented by laboratory measurements of the electrical properties of appropriate rock types at elevated temperatures. Assuming a three-layer crustal model, the field observations indicate an attenuation of one to ten dB per km in the resistant middle layer. It is pointed out, however, that the resistivities in this zone are biased toward the lower side. Higher resistivities are expected on the basis of the laboratory experiments and if they occur to any significant extent, lower transmission losses would be obtained than are predicted by the field measurements.

ON THE FLOW OF ELECTRIC CURRENT IN SEMI-INFINITE STRATIFIED MEDIA

Proc. Roy. Soc. (GB), V. 139A, No. A-838, February 1933.
L.B. King

No abstract

INTERNATIONAL CONFERENCE ON THE IONOSPHERE, LONDON, JULY 1962.

Phys. Abstr. 24029/1962; Brit. J. appl. Phys., Vol. 13, No. 10, Pg 493, October 1962.
J.W. King

Reports a conference organized by the Institute of Physics and the Physical Society at which more than 70 papers were read under the four main headings of: Ionospheric constitution and ionizing radiations; Geomagnetism and the ionosphere; Irregularities and drifts in the ionosphere; The Mathematics of wave propagation through the ionosphere.

GESCHWINDIGKEITSMESSUNG MIT HILFE DES ELEKTROMAGNETISCHEN DOPPLER-EFFEKTES

Arch. tech. Messen (Germany), V. 143-4, No. 293, June 1960.

B. Koch

No abstract

REVIEW OF HALL PROBES

Phys. Abstr. 18970/1961; Monatsber. Deutschen Akad. Wiss Berlin (Germany), V. 1, No. 7-10, Pgs 473-8, 1959.

F. Kohout, I. Weiss

Gives a general review of the construction and uses of Hall probes for various experimental purposes.

THE POYNTING'S VECTOR AND THE VELOCITY OF THE ENERGY PROPAGATION

Electromagnetic Theory and Antennas, Proceedings of a Symposium held at Copenhagen, Denmark, June 1962, edited by E.C. Jordan. Pgs 991-996.

Venče Koželj

We are accustomed to speak about propagation of electromagnetic energy, whenever we have in space the electric and the magnetic fields simultaneously. We described the area-density of the power, determined by the traveling energy, using the Poynting's vector:

$$S = E \times H = W_i V_i$$

which we have put equal to the product of the volume density of the energy W_i and the velocity V_i . In the literature one can find a variety of velocities, with which the energy should propagate; the above-mentioned product can of course be resolved in an infinite multitude of factor pairs. This article tries to find the factor pair which is physically proven. To this goal it proceeds on the ways of the classical continual electrodynamics and of the relativistic theory.

ON THE WAVE-GUIDING PROPERTIES OF HETEROGENOUS MEDIA

Zhotekh. Fiz. (USSR), V. 18, Pgs 431-446, 1948.

P.E. Krasnushkin

No abstract

ELECTROMAGNETISM

1953. \$12.00. McGraw

J.D. Kraus.

EINFUHRUNG IN DIE THEORETISCHE ELEKTROTECHNIK
1959. Springer
K. Kupfmüller

CLASSICAL THEORY OF FIELDS

il. tr. by M. Hamermesh. 1951. \$2.50; Addison-Wesley.
L. Landau, E. Lifshitz

MAXIMUM QUANTITY OF INFORMATION CARRIED BY ELECTROMAGNETIC FIELDS

EE Abstr. 1107/1964; Dokl. Akad. Nauk. SSSR, Vol. 149, No. 6,
Pgs 1299-1302, 21st April 1963. In Russian. English trans. in:
Soviet Physics-Doklady, U.S.A.
D.S. Lëbedev, L.B. Levetin

A discussion of the information-carrying capacity of electromagnetic radiation based upon quantum and thermodynamical considerations. Expressions are obtained which agree well with previous results.

LEAKAGE OF ELECTROMAGNETIC INTERFERENCE ALONG STATIONARY CONDUCTORS
PASSING THROUGH CONDUCTING WALLS

EE Abstr. 7774/1963; IEEE Trans. Radio Freq. Interference (USA), Vol.
RFI-5, No. 1, Pgs 14-22, March 1963.
P.P. Lombardini, J. Goldhirsh

A mechanism by which electromagnetic energy at quasistatic frequencies may leak out of seemingly shielded compartments via conducts such as external shields of cables, pipes, shafts, bolts, etc. protruding from the interior of the compartment is investigated both theoretically and experimentally. The mechanism involved may be illustrated by considering a conductor, such as a shaft passing through a hole in a conducting wall, and contacting the wall at a finite number of contact regions. These regions represent a short circuit to the TEM mode, however higher modes may pass along the guide whose walls may be represented by the actual regions of contact and the inner and outer coaxial conductors. Attenuated transmission may thus occur at frequencies below the cut-off frequency of the higher modes. As verification of the above hypothesis an impedance relationship representing the shunt impedance that the contact regions offer at below cut-off frequencies (in particular $f = 15$ kc/s), was developed and checked experimentally for continuous pressure and soldered contacts. The experimental data show relatively close comparison with the theoretical model.

HIGHLY SENSITIVE SPECTRAL ANALYZER OF LOW-FREQUENCY ELECTRICAL NOISE
Instrum. exper. Tech. (USA),
A.N. Malakhov

No abstract

GUIDED WAVE CONCEPT IN ELECTROMAGNETIC THEORY
EE Abstr. 1786/1953; Inst. Radio Engrs (USA), Trans., V. AP, No. 3,
Pgs 231-9, August 1952.
N. Marcuvitz

Some applications are given of the guided wave concept to the solution of electromagnetic problems in waveguide regions. Such problems are reformulated from a network point of view which is particularly suitable for the calculation of the electromagnetic field produced by prescribed current sources and of diffraction problems where the sources, being induced, are initially unknown. The former case is illustrated by known Sommerfeld-type problems of the field of a dipole above dielectric structures and is treated in network terms. An example of the diffraction problem given is the plane-wave scattering by two displaced semi-infinite planes, which is solved in terms of a network equivalent to a Fourier transform procedure using Schiwinger's application of the Wiener-Hopf technique.

ELECTROMAGNETIC FIELD
il. 1952; \$2.00; Dover.
M. Mason, W. Weaver.

BEUGUNGSERSCHEINUNGEN AN KORPERN VON ELLIPSOIDISCHER GESTALT.
Ann. Phys. (Germany), V. 83, Pgs 609-734, 1927.
F. M \ddot{u} glich

No abstract

THE GRADIENT OF THE CHARGE DENSITY AND THE ROTATION OF THE CURRENT DENSITY AS QUANTITIES FOR THE ANALYSIS OF STEADY FIELDS
EE Abstr. 9503/1963; Elektrotech Z. (ETZ) A (Germany), Vol. 84, No. 10, Pgs 325-31, 20th May 1963. In German.
K. M \ddot{u} ller-Ltbeck

It is not the intention to replace known methods for the calculation of electric and magnetic fields by new ones, rather to give a new insight into the context of the vector quantities involved. Starting from the known equations of the vector analysis, new multi-integral expressions are stated for the electric and magnetic field strengths: for the former,

as a function of rotation of the current density. It is due to the non-uniform distribution of charge density in space that the electric field is set up and due to the variation of the current density across the direction of the current that the magnetic field is set up, and not simply to the existence of a charge density with respect to current density itself. The investigation also includes the case of an alternating field.

INDUSTRIAL EQUIPMENT SPECTRUM SIGNATURES

EE Abstr. 7776/1963; IEEE Trans. Radio Freq. Interference (USA), Vol. RFI-5, No. 1, Pgs 30-42, March 1963.

H.A. Myers

Presents a survey of the radiation characteristics (spectrum signatures) of electrical and electronic equipment such as rectifiers, welders, power lines, switching devices, ignition systems, induction heaters, and electric motors. Several equipment signatures were compiled from reports on interferences. The reports indicated that some industrial activities radiate strongly enough to cause interference at ranges up to a few miles and that most of the energy is concentrated in the low-frequency portion of the spectrum. The equipment was measured at very low frequencies at the Douglas Aircraft Co., Santa Monica, Calif., using Stoddart Aircraft Radio Co. receivers. Graphs of the measurements show strong and unique signatures in the slf and ulf (30-3000 c/s) band.

REMARKS ON THE MEASUREMENT OF HALL-EFFECT IN FERROMAGNETS

Z. Naturforsch. (Germany), V. 13a. Pgs 113-116, 1958.

Influence of misalignment of the magnetic field. Serious errors possible.

ELECTRIC AND MAGNETIC INFLUENCES ON THE GROWTH OF LIVING THINGS

New Scientist (Letters), V. 10, No. 238, Pg 596, June 1961.

Discusses the work of Dr. H. Konig, of the Munich Electrophysical Institute on the effect of static electric and magnetic fields on living tissues.

SYMPOSIUM ON THE THEORY OF ELECTROMAGNETIC WAVES

\$8.50. Interscience

New York University, Institute of Mathematical Sciences.

No abstract.

COHERENCE PROPERTIES OF ELECTROMAGNETIC RADIATION

Phys. Abstr. 16048/1961; Phys. Today (USA), V. 14, No. 6, Pgs 28-34,
June 1961.

E.L. O'Neill, L.C. Bradley

Report of a conference held in June 1960 at the University of Rochester and sponsored by the U.S. Air Force, the University of Rochester and the Optical Society of America. The purpose of the conference was to bring together optical and atomic physicists from this country and abroad to discuss problems of common interest dealing with the question of coherence throughout the electromagnetic spectrum.

ELECTROMAGNETIC THEORY

2 Vols. 1960. Dover.

A. O'Rahilly

CLASSICAL ELECTRICITY AND MAGNETISM

1955. \$10.75. Addison-Wesley.

W.K.H. Panofsky, M. Phillips.

EFFECT OF HYDROMAGNETIC WAVES IN A DIPOLE FIELD ON THE LONGITUDINAL INVARIANT

Phys. Abstr. 21087/1961; J. geophys. Res. (USA), V. 66, No. 3, Pgs 693-708, March 1961.

E.N. Parker

Hydromagnetic wave violation of the longitudinal invariant of a particle trapped in a mirror magnetic field is investigated quantitatively. It is shown that the passage of hydromagnetic waves across the region of mirroring leads to a diffusion of the individual-particle mirror points. If the relative wave amplitude $\Delta B/B$ is maintained throughout the mirror field, particles released in the field will soon diffuse out through the mirror and be lost. Application to thermonuclear devices is obvious. Confining attention principally to the charged particles trapped in the geomagnetic field, it is shown that high-energy (10^5 eV) electrons in the outer Van Allen radiation zone are caused to diffuse along the lines of force with a characteristic time of 4 months by hydromagnetic waves of 1 cps and an amplitude of 10^{-4} G.

DIFFRACTION IN A NON-UNIFORM FIELD

EE Abstr. 2401/1961; Radiotekhnika i Elektronika (USSR), V. 4, No. 3, Pgs 384-7, March 1959.

V.P. Peresada

A general method for obtaining an approximate solution of the problem

of diffraction by perfectly conducting bodies in a field in which surfaces of the same phase and amplitude are not in the same plane is given, based on Kirchhoff's approximation method in vector form. The particular case of diffraction by a rectangular plate situated above the earth is considered.

THE DIFFRACTION OF ELECTROMAGNETIC WAVES BY DIELECTRIC OR SEMICONDUCTING SHEETS

EE Abstr. 2402/1961; Radiotekhnika i Elektronika (USSR), V. 4, No. 6, Pgs 911-19, June 1959.

A.A. Pistl'kors, V.W. Kaplum, L.V. Knyazeva

The effect of dielectric sheets of finite dimensions on the field of a plane wave is studied theoretically using Kirchhoff's method and expressions are derived for the diffracted field. The results are extended to include semi-conducting sheets. Diffraction from a half-plane and from a sheet of finite width are considered as special cases. The results are verified experimentally.

THE SOMMERFELD-RUNGE LAW AND GEOMETRIC OPTICS IN FOUR DIMENSIONS

Symposium on Electromagnetic Theory and Antennas, Copenhagen, 25th June to 30th June 1962.

H. Pöeverlein

No abstract

ON THE GROUP VELOCITY

Phys. Abstr. 8444/1954; Acad. Sci. (France), V. 238, Pgs 1289-91, 22nd March 1954.

P.C.R. Poincelot

It is shown that when a signal in the form of a step function propagates in a dispersive medium whose refractive index n is given by $n = \sqrt{1 - (a^2/\omega^2)}$, the steady-state regime is established at infinity immediately.

ON VARIOUS EXPRESSIONS FOR ELECTROMAGNETIC ENERGY

Phys. Abstr. 654/1964; C.R. Acad. Sci. (France), Vol. 256, No. 26, Pgs 5522-4, 24th June 1963. In French.

P. Poincelot

An expression for the density of electromagnetic energy is derived without making any assumptions about the relations between the inductions and the fields. It is pointed out that the tensors of Maxwell and Minkowski for the electromagnetic energy density in a vacuum are inapplicable to material substances in the absence of assumptions about the relations between the fields and the inductions.

EXCEPTIONAL CASES OF ELECTROMAGNETIC INTERPRETATION PROBLEMS

Phys. Abstr. 5228/1953; Proc. Roy. Soc. (GB), V. 216A, Pgs 434-5, February 1953.

A.T. Price, L.B. Slichter

This note points out that the method proposed by Slichter for determining the variation of the electrical properties of the earth with depth by electromagnetic induction, will fail for certain special distributions of the exciting magnetic field, and examines mathematically why this is so.

ON THE DEFINITION OF SOME ELECTROMAGNETIC QUANTITIES

Symposium on Electromagnetic Theory and Antennas, Copenhagen, 25th June to 30th June 1962.

G.B. Rego

This summary presents some results that point to the modification of commonly accepted properties and definitions of some electromagnetic quantities. These results are easily obtained through the use of a four-dimensional calculus, based on a Clifford algebra, a brief account of which is given in the Appendix.

FOUNDATIONS OF ELECTROMAGNETIC THEORY

il. 1960. \$9.75. Addison-Wesley.

J.R. Reitz

THE EFFECT OF A VERTICAL MAGNETIC FIELD ON THE PROPAGATION OF GRAVITY WAVES ALONG THE PLANE SURFACE OF A SEMI-INFINITE VISCOUS, ELECTRICALLY CONDUCTING FLUID

Phys. Abstr. 13661/1962; Astrophys. J. (USA), Vol. 135, No. 2, Pgs 552-92, March 1962.

P.H. Roberts, A.D. Boardman

The basic equations and boundary conditions governing the effect of vertical magnetic and gravitational fields on small amplitude perturbations of the free equilibrium surface of a viscous, electrically conducting fluid are presented. Normal modes are examined. A dispersion relationship is derived which relates the complex "frequency" n of the normal mode to the Alfvén velocity, V , the viscosity, ν , the magnetic diffusivity, \wedge , and the horizontal wave-number, k . This dispersion relationship is solved in nine extreme cases. In six of these the magnetic field is too weak to modify substantially the familiar gravity-wave solution holding in the absence of a magnetic field. The influence of the field is so strong in the remaining three cases that they have no parallel in the zero-field case. One of these holds for any k if the magnetic field is sufficiently strong. In this case $n = -gV^{-1}(\lambda/\nu)^{1/2}$, i.e. the effect of the magnetic field is so great that the disturbance is attenuated aperiodically as the Alfvén wave

radiates energy away from the free surface. Another interesting feature demonstrated is the existence (if V is sufficiently large) of a band of wave numbers k for which no normal-mode solution exists. It is nevertheless demonstrated that the associated initial-value problem can be solved for such values of k . In addition to the nine extreme cases mentioned above, three special cases are solved for all k for particular values of V , namely, $\nabla = \wedge$, $\nabla = 0$, and $\wedge = 0$.

HIGHER ORDER CONSERVATION LAWS IN THE THEORY OF STATIONARY ELECTRO-MAGNETIC FIELDS

AD 261 322; Boston University, Boston, Mass., Sci. Rept. No. 2, 12 p., 1961.

P. Roman

By imitating well-known techniques to obtain the energy-equation in Maxwell's theory, eight independent higher order conservation laws are found for the various second order correlation functions associated with stationary random electromagnetic fields. Two further conservation laws are deduced which involve the physically so significant energy coherence tensor and the flow coherence tensor.

UNIQUENESS PROOF FOR THE ELECTROMAGNETIC BOUNDARY VALUE PROBLEM

Phys. Abstr. 13673/1964; Acta. phys. Polon. (Poland), Vol. 21, No. 4, Pgs 415-22, 1962. In German.

A. Rubinowicz

Presents a proof for an electromagnetic field harmonically periodic in time.

ELECTROMAGNETIC WAVES

il. 1943. \$10.50. Van Nostrand.

S.A. Schelkunoff

UBER DIE TOTALREFLEXION IN DER AKUSTIK UND OPTIK (AUF GRUND EXPERIMENTELLER ERGEBNISSE DER SPRENGSEISMIK)

Ann. Phys. (Germany), V. 19, Pgs 891-912, 1934.

O.V. Schmidt

No abstract

UBER DIE AUSBREITUNG LANGER ELEKTRISCHER WELLEN IN MAGNETISIERTEN PLASMEN UND IHREN DURCH PLASMASCHICHTEN

Z. angew. Phys. (Germany), V. 10, No. 9, 1958.

W.O. Schumann

No abstract

ON WAVE PROPAGATION IN A PLASMA BETWEEN TWO INFINITE CONDUCTING PLANES
IN THE DIRECTION OF AN APPLIED EXTERNAL MAGNETIC FIELD
Z. angew. Physik, Vol. 8, No. 10, pp. 482-5, October 1956. In German.
W.O. Schumann

Results previously obtained for an infinite field are extended to a finite one. In a plasma between two conducting planes there are, in general, three frequency ranges in which the propagation constant is imaginary. If the plasma moves in the direction of an applied magnetic field, the excitation of electromagnetic waves in these ranges appears possible.

JOINT COMMISSION ON RADIO-METEOROLOGY. INTERNATIONAL COUNCIL OF
SCIENTIFIC UNIONS. PROCEEDINGS OF THE SECOND MEETING, BRUSSELS.
16TH-18TH AUGUST 1951.
Phys. Abstr. 1278/1953; Secrétariat Général de l'U.R.S.I., 42
rue des Minimes, Brussels, 83 p., 1952.

After an introductory summary of the topics discussed, 9 papers are given in full: Meteorological processes controlling the refractive index of the atmosphere. P.A. Sheppard (9-17) (Abstr. 1289/1953). Thunderstorms. The electric field variations radiated from lightning discharges. H. Norinder (17-38) (Abstr. 1294/1953). On the sources of atmospherics. R. Bureau (41-4) (Abstr. 1298/1953). Note on the relation between the meteorological situation and location of sferics. A Perlat (44-52) (Abstr. 1299/1953). Present status of research on radio-meteorology in Japan. H. Hatakeyama (52-6) (Abstr. 1300/1953). Precipitation echoes. J.S. Marshall (56-66) (Abstr. 1287/1953). Radar observations of natural rain. E.G. Bowen (66-9) (Abstr. 1288/1953). Attenuation of microwaves by atmospheric gases and by rainfall. L.J. Anderson (70-3) (Abstr. 1301/1953). Statistical fluctuations in the atmosphere. W.E. Gordon (74-7) (Abstr. 1302/1953). A paper on Sferics by J. Lugeon, is reported in summary form only. Brief "remarks" by P.A. Sheppard on atmospheric turbulence are also reported.

INTRODUCTION TO ELECTROMAGNETIC FIELDS
1958. \$9.00; answers, \$0.50, McGraw
S. Seely.

No abstract.

A NOTE ON IMPEDANCE BOUNDARY CONDITIONS

Phys. Abstr. 13692/1962; Canad. J. Phys., Vol. 40, No. 5, Pgs 663-5, May 1962.

T.B.A. Senior

A brief account is given of the significance and usefulness of impedance boundary conditions in the solution of diffraction problems.

AN APPROXIMATE SOLUTION OF A PROBLEM CONCERNING THE MOTION OF A CONDUCTING PLASMA

Dokl. Akad. Nauk. SSSR (USSR), V. 130, No. 6, Pgs 1248-1251, 21st February 1960.

G.A. Skuridin, K.P. Stanyukovich

A new method for the asymptotic integration of linear differential equations with partial derivatives of the hyperbolic type has been applied to the integration of equations of plasma oscillations.

ELECTROMAGNETIC THEORY

il. 1941. \$12.00. McGraw.

J.A. Stratton

OPERATORS FOR WAVE EQUATIONS IN GENERAL LINEAR MEDIA

IRE Trans. Antennas and Propagation (USA), Vol. AP-9, No. 5, Pgs 501-2, September 1961. EE Abstr. 4907/1963.

I. Sugai

Presents some linear vector and scalar operators for electromagnetic waves in stationary, isotropic, linear media.

EARTH CONDUCTION EFFECTS IN TRANSMISSION SYSTEMS

il. 1949. \$9.00. Van Nostrand

E.D. Sunde

INTEGRAL EQUATION METHODS IN POTENTIAL THEORY, II.

EE Abstr. 14179/1963; Proc. Roy. Soc. A. (GB), Vol. 275, Pgs 33-46, 20th August 1963.

G.T. Symm

The boundary integral equations of potential theory can be solved to a tolerable accuracy without undue labour by digital computer techniques, and the computed data generate numerical values of the potential field wherever required. Tests were made with a representative selection of two-dimensional problems, some of which were not amenable to any other treatment.

MAGNETIC DIPOLE MODELS

Phys. Abstr. 20087/1962; Amer. J. Phys., Vol. 30, No. 9, Pgs 650-2, September 1962.

B.D.H. Tellegen

A recent book (Electronic fields, energy, and forces. R.M. Fano, L.J. Chu and R.B. Adler. New York: John Wiley (1960)) rejects the amperian-current model of a magnetic dipole and accepts the magnetic charge model, because the first model would lead to inconsistencies in the interpretation of Poynting's theorem. It is shown that the inconsistencies are only apparent. The choice between the two models should be based on measurement of the force on a magnetic dipole, which, in non-stationary cases, is different for the two models.

OBSERVATIONS OF HYDROMAGNETIC EMISSIONS

J. Geophys. Res. (USA), V. 66, No. 6, Pg 1651, June 1961.

L.R. Tepley

No abstract

THE AMPLITUDE DISTRIBUTION AND FALSE ALARM RATE OF NOISE AFTER POST-DETECTION FILTERING

EE Abstr. 2704/1961; Proc. Inst. Radio Engrs. (USA), V. 49, No. 2, Pgs 479-84, February 1961.

S. Thaler, S.A. Meltzer

A digital computer was used to simulate the passage of white, Gaussian noise through a narrow-band filter, followed by a detector and a post-detection filter was obtained for several different detectors. In addition, the variation of false alarm rates with detector law, post-detection filtering; time constants, and threshold setting was investigated. Not only the numerical results but also the approach, and the new detectors described are of interest.

EXPERIMENTAL STUDY OF THE MOTIONAL ELECTROMOTIVE FORCE

Phys. Abstr. 13656/1962; Amer. J. Phys., Vol. 30, No. 6, Pgs 411-15, June 1962.

J.W. Then

Experiments are described that develop a pure motional electromotive force detected with a sensitive galvanometer. Old questions are re-examined by an original experimental approach as follows: What are the conditions of relative motion between magnetic field and conductor for developing a motional electro-motive force? Unipolar induction is considered when a uniform or symmetrical magnetic field is concerned and

special attention is given to the rotation of non-uniform magnetic fields. The results of the latter differ markedly from the former. Concepts of macrostructure and microstructure of magnetic fields are considered briefly as applied to the experiments described. References are made to theoretical treatments to clarify the issues, but discussions are kept to the experimental approach with a qualitative rather than quantitative treatment.

DETERMINATION OF THE ELECTRICAL CHARACTERISTICS OF THE DEEP STRATA OF THE EARTH'S CRUST

AD 70 673; An English translation of Dokl. Akad. Nauk. SSSR (USSR), V. 73, No. 2, Pgs 295-297, 1950, by E.R. Hope, DRB, Canada.
A.N. Tikhnov

No abstract

ELECTROMAGNETIC WAVES

Phys. Today (USA), V. 13, No. 7, July 1960.
V. Twersky

No abstract

DEVELOPMENT OF THE FORMULAE OF ELECTROMAGNETISM IN THE M.K.S. SYSTEM
Proc. Inst. Elect. Engrs. (GB), V. 107, No. 34, July 1960.
P. Vigoreux

The use of metres, kilogrammes, amperes, etc. instead of centimetres, grammes, deca-amperes (the C.G.S. unit of current), etc., need not change the method of teaching electricity and magnetism, for it does not interfere with the notions of magnetic poles and point charges of electricity. A logical method of developing the theory from conventional experiments on the forces between magnets, between magnets and current-carrying loops, and between electric charges, is to proceed from magnetic poles to magnetic shells and from these to loops of current, and then bring in the definition of the ampere to evaluate the magnetic constant; consideration of the forces between electric charges follows and, together with identification of rate of change of charge and electric current, leads to the law of induction, to Maxwell's equations, and to wave propagation, which, in conjunction with the known velocity of light, gives the value of the electric constant. The theory is then extended to material media.

STEADY-STATE TRANSFORMS

Proc. Inst. Radio Engrs. (USA), V. 48, Pg 2039, 1960.
D.L. Waidelich

No abstract.

ELECTROMAGNETIC RADIATION IN THE EARTH (A THEORETICAL INVESTIGATION)
Univ. of Toronto, Pgs 1-69, 1950.
J.R. Wait

No abstract

▲ CONDUCTING SPHERE IN A TIME VARYING MAGNETIC FIELD
Geophysics (USA), V. 16, Pgs 666-672, October 1951.
J.R. Wait

The secondary magnetic fields are evaluated for the case of a conducting sphere in a relatively poorly conducting medium under the influence of a time varying magnetic field. The sinusoidal and step responses are both considered. The responses so calculated are thought to be useful in a geophysical prospecting method which utilizes the transient behaviour of induced eddy currents in a highly conducting ore zone.

REFLECTION OF ELECTROMAGNETIC WAVES OBLIQUELY FROM AN INHOMOGENEOUS MEDIUM
J. appl. Phys. (USA), V. 23, Pgs 1403-1404, December 1952.
J.R. Wait

No abstract

A CONDUCTING PERMEABLE SPHERE IN THE PRESENCE OF A COIL CARRYING AN OSCILLATING CURRENT
Canad. J. Phys. V. 31, Pgs 670-678, May 1953.
J.R. Wait

The analysis is carried out for the problem of a current-carrying coil in the neighbourhood of a spherical body whose conductivity and magnetic permeability differ from the surroundings. The case is considered in detail where the frequency is low enough so that the primary field of the coil can be derived from a magnetic scalar potential. The secondary magnetic fields due to the sphere are then derived. The "in-phase" and "quadrature" components of the secondary field are discussed numerically and illustrated by graphs. The results have application to electrical prospecting.

AN APPROXIMATE METHOD OF OBTAINING THE TRANSIENT RESPONSE FROM THE
FREQUENCY RESPONSE

Canad. J. Tech., V. 31, Pgs 127-131, June 1953.

J.R. Wait

A novel approximate method is described for the calculation of the transient response of a system from the steady-state frequency response data. This method is particularly well suited to situations where the real part of the frequency function, when plotted on a log-frequency base, is approximated by a series of straight line segments.

ON THE SCATTERING OF SPHERICAL WAVES BY A CYLINDRICAL OBJECT

Appl. sci. Res. (Netherlands), V.4, Section B, Pgs 464-468, 1955.

J.R. Wait

The connection between plane wave and spherical wave scattering from an infinitely cylindrical object is investigated. If the distance of the source and the observer from the axis of the cylinder are denoted by ρ_0 and ρ , respectively, the ratio of the scattered field to that for plane excitation $[\rho_0 / (\rho_0 + \rho)]^{\frac{1}{2}}$.

RADIATION FROM AN ELECTRIC DIPOLE IN THE PRESENCE OF A CORRUGATED
CYLINDER

Appl. sci. Res. (Netherlands), Section B, V. 6, Pgs 117-123, 1955.

J.R. Wait

A solution is outlined for the problem of an electric dipole which is located outside and parallel to the axis of a circular cylinder to infinite length. The corrugated surface of the cylinder is assumed to be described by an anisotropic boundary impedance which specifies the ratios of the tangential electric and magnetic fields. It is shown that, in general, the radiated field is elliptically polarized.

REFLECTION OF A TRANSIENT ELECTROMAGNETIC WAVE AT A CONDUCTING SURFACE

J. geophys. Res. (USA), V. 60, No. 1, Pgs 97-103, March 1955.

J.R. Wait, C. Froese

A solution is given for the reflection of a transient electromagnetic plane wave at oblique incidence from the plane interface of a dissipative medium. The inversion of the Laplace transforms can only be carried out in closed form in special cases. Series solutions are developed for the general case and the numerical results are presented in graphical form. Brief mention is made of the possible application of this solution to the reflection of a radio atmospheric at a sharply bounded ionosphere.

SCATTERING OF ELECTROMAGNETIC WAVES FROM A "LOSSY" STRIP ON A CONDUCTING PLANE

Canad. J. Phys., V. 33, Pgs 383-390, April 1955.

J.R. Wait

One method for solving boundary value problems involving imperfectly conducting media is to assume, for a first approximation, that the surface currents are the same as if the media were perfectly conducting. Using this type of approximation, the problem of a line source of current situated over a plane surface, with a simple type of mixed boundary condition, is solved. For purposes of comparison the situation of an imperfectly conducting or "lossy" strip on an otherwise perfectly conducting plane surface is treated by an exact method employing elliptic wave functions. The calculations of the scattered fields of the strip by the two methods indicate the extent of the validity of the initial assumption in the approximate procedure.

RADIATION PATTERN OF AN ANTENNA MOUNTED ON A SURFACE OF LARGE RADIUS OF CURVATURE

Proc. Inst. Radio Engrs (USA), V. 44, No. 5 (Letter), May 1956.

J.R. Wait

No abstract

CURRENTS EXCITED ON A CONDUCTING SURFACE OF LARGE RADIUS OF CURVATURE

Inst. Radio Engrs (USA), Trans., V. MTT-4, No. 3, Pgs 144-145, July 1956.

J.R. Wait

The nature of the electromagnetic field of an antenna in the vicinity of a surface of large radius of curvature is discussed. Assuming a spherical surface, the solution for a dipole source in the form of the Watson residue series is transformed to a more rapidly converging series which is preferable at short distances. Using this result, the numerical data is presented in graphical form for the currents induced on the spherical surface. The curves are applicable to both a stub and slot antenna mounted on the conducting surface.

INFLUENCE OF A RIDGE ON THE LOW-FREQUENCY GROUND WAVE

J. Res. Nat. Bur. Stand. (USA), V. 58, No. 1, Res. Paper 2727, Pgs 1-5, January 1957.

J.R. Wait

The problem of a plane wave incident on a semi-elliptical boss on an otherwise perfectly conducting flat ground plane is considered. A

solution in terms of elliptic wave functions is obtained. Numerical values of the field on the near and far side of this idealized ridge are given for a base width of about two-thirds of a wavelength and various ellipticity ratios.

THE PATTERN OF A SLOT-ARRAY ANTENNA ON A FINITE IMPERFECT GROUND PLANE
Communication presented at the Congress International Circuits and Antennas Hyperfrequencies, Paris, October 1957.
J.R. Wait, A. Conda

The radiation from a slot aperture on a perfectly conducting half-plane is discussed in some detail. The extension to end-fire arrays of slots is also treated. Numerical computations are carried out for radiation patterns. It is shown that in general, the main beam is tilted up and away from the edge of the half-plane. The situation where the half-plane is lying on the surface of a homogeneous flat earth is also considered. The results have application in the design of flush-mounted antennas of the end-fire type where, because of practical limitations, the ground plane is of finite extent and may be located on the surface of a "lossy" plane.

THE EFFECTIVE ELECTRICAL CONSTANTS OF SOIL AT LOW FREQUENCIES
Proc. Inst. Radio Engrs. (USA), V. 45, No. 10, 1 p., October 1957.
J.R. Wait

No abstract

EXCITATION OF SURFACE WAVES ON CONDUCTING STRATIFIED DIELECTRIC-CLAD,
AND CORRUGATED SURFACES
J. Res. NVS, V. 59, No. 6, Pgs 365-377, December 1957.
J.R. Wait

An expression for the field of an electric dipole located over a flat surface with a specified impedance Z is derived from the formal integral solution by a modified saddle-point method. Using the value of Z appropriate for a homogeneous conducting ground, the general expressions reduce to those given by Norton. In this case the phase of Z lies between 0 and 45° . When the phase exceeds 45° , as it may for a stratified ground, the radiated wave of the dipole becomes partially trapped to the interface. This effect is most pronounced for an inductive surface where the phase of Z is 90° , in which case the energy of the wave is confined within a small distance from the surface. Such inductive surfaces are a metallic plane with a thin dielectric film or a corrugated surface. This unifying treatment provides a link between the surface waves of Zenneck, Sommerfeld, Norton, and Goubau, and indicates that the phase angle of Z controls the extent to which these waves may exist for a dipole excitation.

A LOW-FREQUENCY ANNULAR-SLOT ANTENNA

J. Res. Nat. Bur. Stand. (USA), V. 60, No. 1, Pgs 59-64, January 1958.
J.R. Wait

The radiation characteristics of an annular slot cut in an ideally conducting ground plane are discussed. The voltage impressed between the concentric edges is assumed to be constant around the slot. The annular slot is backed by a hemispherical cavity which has imperfectly conducting walls. For a specified voltage, the power radiated in the upper half-space and the power absorbed by the hemispherical cavity are calculated. It is indicated that the power absorbed can be reduced greatly by lining the walls of the cavity with a wire mesh. A flush-mounted antenna of this type at low frequencies may have certain practical advantages over the more conventional monopole.

DISCUSSIONS ON ρ A THEORETICAL STUDY OF INDUCED ELECTRICAL POLARIZATION
Geophysics (USA), V. XXIII, No. 1, Pgs 144-153, January 1958.

J.R. Wait, R.H. Frische, H.V. Buttlar

No abstract

FURTHER STUDIES OF THE INFLUENCE OF RIDGE ON THE LOW-FREQUENCY GROUND
WAVE

J. Res. Nat. Bur. Stand. (USA), V. 61, No. 1, Pgs 57-60, July 1958.
J.R. Wait, A. Murphy.

Computations are presented in graphical form for the perturbation of a plane wave by a semicylindrical boss on an otherwise flat ground plane of perfect conductivity. The height of the ridge is comparable to the wavelength. This is an extension of earlier work on the semi-elliptical boss.

A PHENOMENOLOGICAL THEORY OF INDUCED ELECTRICAL POLARIZATION

Canad. J. Phys. V. 36, Pgs 1634-1644, 1958.

J.R. Wait

A brief theoretical derivation is presented for the effective conductivity and dielectric constant of a homogeneous medium loaded with a uniform distribution of spherical conducting particles. To account for the effect of induced polarization, the particles are taken to have a concentric membrane or film which has a blocking action to the current flow into the particle. The characteristics of this phenomenological model are very similar to the experimentally **observed features of induced polarization in a block of compacted andesite particles which contains a dissemination of small metal par-**

ticles and is partially saturated with a weak electrolyte. The theory is then extended to a two-layer medium where the lower region is polarizable. The results explain, at least in a qualitative way, the observed features of induced electrical polarization in rocks, soils, and clay.

A PHENOMENOLOGICAL THEORY OF OVER-VOLTAGE FOR METALLIC PARTICLES
Chapter 3 of Overvoltage Research and Geophysical Applications, il.
1959. \$9.00. Pergamon, edited by J.R. Wait.
J.R. Wait

A brief theoretical derivation is presented for the effective conductivity and dielectric constant of a homogeneous medium loaded with a uniform distribution of spherical conducting particles. To account for the effect of inducted polarization, the particles are taken to have concentric membrane or film which has a blocking action to the current flow into the particles.

THE VARIABLE FREQUENCY METHOD
Chapter 4 of Overvoltage Research and Geophysical Applications, il.
1959. \$9.00. Pergamon, edited by J.R. Wait
J.R. Wait

It has been found that the complex conductivity of rocks is a function of frequency. These dispersion or over-voltage effects, which are very pronounced in mineralized media, can be attributed mainly to interfacial polarization at the boundaries of the metallic ore particles and the electrolyte in the pores of the host rock. In the first part of this paper, the variation of the magnitude and the phase of the conductivity for mineralized and non-mineralized samples is reported for frequencies in the range from 0.1 to 10^5 cps. The mathematical relation between a frequency dependent conductivity and the transient build up on the field for a step function current is then derived. The interrelation is demonstrated by an actual example which is verified experimentally for a mineralized sample. In the second part, electromagnetic propagation and inter-wire coupling effects are discussed briefly from the standpoint of their masking effect on the overvoltage measurement when a four electrode array is employed. In the third part, results from a preliminary field trial of the frequency variation method carried out in the summer of 1950 in the vicinity of Jerome, Arizona, are described.

CRITERIA FROM THE TRANSIENT DECAY CURVES

Chapter 6a of Overvoltage Research and Geophysical Applications, il.
1959. \$9.00. Pergamon, edited by J.R. Wait.
J.R. Wait, L.S. Collett

In this chapter, the progress in the analysis of induced polarization decay curves on rock specimens is described. The curves analyzed are those taken by Collett with the standard accepted technique including the electroosmosis treatment described in Chapter 5. Particular attention is paid to the examination of the curve shape. For this purpose the first, second and third derivatives are evaluated and shown plotted against the magnitude of the response in each case. Several other interesting properties of the decay curves are also investigated. The descriptions in the text of this chapter are brief since most of the information is listed on the illustrations.

ELECTROMAGNETIC RADIATION FROM CYLINDRICAL STRUCTURES

1959. \$8.00, Pergamon.
J.R. Wait

A comprehensive and self-contained account of the theory of electromagnetic sources on and near cylindrical surfaces is presented. While none of the forms considered duplicates the shape of the actual bodies such as aircraft and missiles, the derived results do provide considerable insight into the behaviour of flush-mounted and stub-type microwave antennas in actual systems. In each section, the salient features of the analytical results are presented in graphical form. An exhaustive and up-to-date review of the relevant literature in the field is given. This part of the work was sponsored by Commission VI of the International Scientific Radio Union. The contents include: Axial dipole within a corner reflector and slots on wedges; The fields of axial dipoles in the presence of a circular conducting cylinder; Slots on a cylindrically-tipped wedge; Transverse half-wave slots on isolated cylinders; Conductance of axial slots on infinite cylinders and wedges; Residue series presentation for the fields of an axial slot; Fields of the axially slotted cylinder in terms of Fock functions; Residue series representation for circumferential slots on cylinders; Fields of current distributions in wedge regions; Radial electric dipoles in cylindrical wedge regions; Field of a slot on an elliptic cylinder and Calculated radiation characteristics of slots in metal sheets.

GUIDING OF ELECTROMAGNETIC WAVES BY UNIFORMLY ROUGH SURFACES
Inst. Radio Engrs. (USA) Trans., V. AP-7, S154-162, December 1959.
(Special Supplement).
J.R. Wait

A simple derivation is given for the reflection of electromagnetic waves from a perfectly-conducting plane surface which has a uniform distribution of hemispherical bosses whose electrical constants are arbitrary. The spacing between the centres of the bosses is taken to be small, which is the justification for neglecting the incoherent radiation. An approximate boundary condition is developed which must be satisfied in an average sense by the tangential fields on the reference plane. The excitation of surface waves on the rough surface is then discussed. It is indicated that to a first order, a rough surface of the kind described here possesses an inductive surface reactance and will support a trapped wave. The effect of finite conductivity of the bosses is to damp exponentially this trapped wave.

PREFACE TO THE SURFACE WAVE PAPERS
Inst. Radio Engrs. (USA), V. AP-7, S132, December 1959 (Special Supplement).
J.R. Wait

No abstract

ON THE DIFFRACTION OF ELECTROMAGNETIC PULSES BY CURVED CONDUCTING SURFACES
Canad. J. Phys., V. 37, Pgs 1384-1396, 1959.
J.R. Wait, A.M. Conda

Starting with the known steady-state solutions for diffraction by a perfectly conducting convex surface, the corresponding transient responses are derived using Fourier-Laplace inversion. Explicit results are given for an incident wave which varies with time as a step function.

PROCEEDINGS OF THE 1960 CONFERENCE ON THE PROPAGATION OF ELF RADIO WAVES
J.R. Wait, editor.
See Section I, Page 109.

RADIATION FROM A SLOT ON A LARGE CORRUGATED CYLINDER

In Electromagnetic Wave Propagation, edited by M. Desirant, J.L. Michiels, Academic Press, 1960.

J.R. Wait, A.M. Conda

The radiation fields are computed for an axial slot on a cylinder whose surface is regularly corrugated. The mathematical idealization is a magnetic line source on a cylindrical surface whose boundary impedance is specified. Special attention is given to surfaces whose radii of curvature are large compared to the wavelength.

A CONFERENCE ON THE PROPAGATION OF ELF ELECTROMAGNETIC WAVES

Proc. Inst. Radio Engrs (USA), V. 46, July 1960.

J.R. Wait

No abstract

THE ELECTROMAGNETIC FIELDS OF A DIPOLE IN THE PRESENCE OF A THIN PLASMA SHEET

Appl. Sci. Res. (Netherlands), V. 8, Section B, Pgs 397-417.

J.R. Wait

The problem of electric and magnetic dipoles located near a thin planar slab or sheet of ionized material is considered. A constant and uniform magnetic field is impressed on the slab. Under the assumption that the thickness of the slab is very small, expressions for the resultant fields are obtained. As a result of the anisotropy of the sheet it is indicated that the fields are elliptically polarized in general. On carrying out a saddle-point evaluation of the integrals in the formal solution it is shown that the far fields may be split into "radiation" and "surface wave" components. The dependence of the radiations pattern and the surface wave characteristics on electron density, collision frequency and the impressed magnetic field is illustrated.

ON THE CALCULATION OF AFMAG ANOMALIES

Geophysics (USA), V. 25, Pgs 1290-1293, December 1960.

J.R. Wait

No abstract.

RESONANCE CHARACTERISTICS OF A CORRUGATED CYLINDER EXCITED BY A
MAGNETIC DIPOLE

Inst. Radio Engrs. (USA), Trans., V. AP-9, No. 4, Pgs 330-3, July 1961.
J.R. Wait, A.M. Conda

Radiation from an axial magnetic-current element in the presence of a corrugated cylinder is considered. It is indicated that the power radiated in a given mode depends on the surface reactance, the circumference of the cylinder and the elevation angle. For certain values of the parameters, particular modes are strongly excited in a manner corresponding to the resonance condition of the circumferential (or spiral) surface waves.

SOME BOUNDARY VALUE PROBLEMS INVOLVING PLASMA MEDIA

J. Res. Nat. Bur. Stand. (USA), V. 65B, No. 2, April-June, 1961.
J.R. Wait

A plasma consisting of a neutral mixture of electrons, ions and molecules, in the presence of a constant magnetic field H_0 , possesses a dielectric constant which is in the form of a tensor. Exact solutions of boundary value problems involving such media are obtained for two dimensional configurations. Explicit results are given for the reflection coefficients of stratified plasma in planar and cylindrical geometry.

INTRODUCTION TO THE VLF PAPERS

Proc. Inst. Radio Engrs (USA), V. 50, No. 7, Pgs 1624-47, July 1962.
J.R. Wait

This paper is a self-contained exposition of the conventional theory of propagation of VLF radio waves. The model is a spherical earth surrounded by a concentric ionosphere. Although the model is highly idealized, the theory is still quite involved. The complexities arise from the long wavelengths inherent in such problems. In Section I the elementary geometrical or hop theory for VLF is considered. This includes a discussion of ionospheric reflection coefficients and the influence of multiple reflections. The validity of the model is established by a comparison with experimental data. In Section II, the diffractive corrections near the caustics of the ray systems are obtained. These provide a means to extend the theory to points near and beyond the horizon point for the individual hops or rays. In Section III, the waveguide mode theory is expounded. A number of approximations and simplifications are introduced in order to illustrate principles. References to more detailed analyses which use higher order approximations are given. Finally, in Section IV, the influence of a stratified ionosphere is treated by using a two-

layer model. The material in this paper was included in the Summer (1961) Lecture Course on Radio Propagation given at the Boulder Laboratories of the National Bureau of Standards, and in early graduate courses, at the University of Colorado.

MEASURED ELECTRICAL PROPERTIES OF SNOW AND GLACIAL ICE

Phys. Abstr. 12131/1960; J. Res. Nat. Bur. Stand. (USA), V. 64D, No. 4, Pgs 357-63, July-August 1960.
A.D. Watt, E.L. Maxwell

The electrical properties of snow and glacial ice near 0°C have been observed over the frequency range from 20 cps to 200 kc. In general, the conductivity of snow and glacial ice is found to be much higher than that for pure ice. This is particularly so at frequencies below 2 kc. The magnitude of the complex conductivity for glacial ice appears to increase with temperature at frequencies below 200 cps and to decrease with temperature above this frequency.

EFFECTS OF NATURAL NOISE ON SYSTEMS

In Horner, F. Monograph on radio noise of terrestrial origin, 109-115; Discussion, 14-15, Amsterdam and New York, Elsevier Publishing Co., 1962.
A.D. Watt

No abstract

ELECTROMAGNETIC FIELDS: THEORY AND APPLICATIONS
V.I. Mapping of Fields. 1950. \$10.00. Wiley.
E. Weber.

No abstract

DERIVATION OF THE SPEED OF ELECTROMAGNETIC WAVES IN TERMS OF DIELECTRIC CONSTANT, MAGNETIC PERMEABILITY, AND RATIO OF CHARGE UNITS
EE Abstr. 625/1960; Amer. J. Phys., No. 2, Pgs 126-8, February 1960, V.28.
F.G. Werner, D.R. Brill

An elementary derivation of the expression for the propagation speed of a change in the electromagnetic field in terms of the dielectric constant, the magnetic permeability, and the ratio of magnetic to static units of charge is given. The only knowledge of electrodynamics required is familiarity with the expressions for the electrostatic charge on a parallel plate condenser, the magnetic field in a long solenoid, and the induced e.m.f. in a loop. Also easily found are expressions for the characteristic impedance of the medium (or the

vacuum) and displacement current. These are introduced in a rather directly conceivable physical manner. No use is made of calculus or vector analysis proper. No swiftly moving bodies are considered. Units are kept general so that reduction to any particular unit system is easy.

UNIVERSAL SKIN-EFFECT CHART FOR CONDUCTING MATERIALS
Electronics (USA), V. 25, Pgs 152-154, November 1952.
H.A. Wheeler

Formulas and a chart are given for finding the depth of penetration of current in some metals and solutions (including sea water) and in ground, at frequencies from 1 cps to 1,000 kMc.

ELECTROMAGNETIC WAVES
4th ed. 1950. \$1.50. Wiley.
F.G.W. White

No abstract

A SUMMARY OF LITERATURE PERTAINING TO VLF AND ELF PROPAGATION
Stanford Research Inst., Project No. 3311, July 1962.
A.L. Whitson, W.T. Sperry, F.H. Smith

A bibliography of literature pertaining to VLF and ELF propagation is presented. Authors' abstracts are given whenever available. The survey includes theory, measurements, the transmission medium (ground constants and lower ionosphere), atmospheric noise, and extra-terrestrial VLF and ELF phenomena (whistlers, hiss, etc.).

HIGH SPEED FREQUENCY SHIFT KEYING OF LF AND VLF RADIO CIRCUITS
Inst. Radio Engrs (USA), Trans. V, CS-5, Pg 29, December 1957.
H.G. Wolff

No abstract

THE VOLTAGE APPEARING BETWEEN PROBES APPLIED TO A FLAT CIRCULAR DISK
CARRYING A RADIAL ALTERNATING CURRENT
EE Abstr. 3930/1960; Arch. Elektrotech. (Germany), V. 44, No. 7,
Pgs 395-8, 1959.
H.H. Wolff

Reference is made to the similarity between the formula obtained and those given in preceding abstract for magnetic flux due to a straight conductor.

THE INTERPRETATION OF ELECTROMAGNETIC REFLECTION DATA IN GEOPHYSICAL EXPLORATION. I. GENERAL THEORY
Phys. Abstr. 3761/1953; Geophysics (USA), V. 17, Pgs 89-106, January 1952.
W.J. Yost

It is shown that any variable current method of electrical exploration must be interpreted in terms of a semi-infinite conducting medium underlying a semi-infinite insulator. The complete theoretical treatment for a homogeneous conductor is outlined, and the details of the solution for low frequencies are presented. Secondly, the insulating (air) region is shown to have an influence on the electromagnetic fields within the conductor. Specific results for two cases of most practical interest are presented in graphical form. These are compared with experimental data obtained from a laboratory scaled model composed of metallic plates.

THE INTERPRETATION OF ELECTROMAGNETIC REFLECTION DATA IN GEOPHYSICAL EXPLORATION. II. METALLIC MODEL EXPERIMENTS.
Geophysics (USA), V. 17, Pgs 806-26, October 1952.
W.J. Yost, and Others

A metallic model of a horizontally stratified section of the earth's crust has been constructed to provide information of considerable value in the interpretation of geophysical data. An experimental check of the theory given in Part I has been made for the case of a semi-infinite conducting medium underlying a semi-infinite insulator. Discontinuities in electrical conductivity within such a medium have been shown to reflect electromagnetic pulses back to the surface. An example is given of the use of a non-concentric loop arrangement for geophysical profiling of a limited reflector, such as a salt dome. Finally, data are given to show the agreement between model signals and field results obtained from a known resistivity contrast in the earth.

A GENERAL THEOREM FOR THE ELECTROMAGNETIC FIELD GENERATED BY A MOVING CHARGE
Phys. Abstr. 9682/1962; Atti Accad. Sci. Torino (Italy), V. 96, No. 1, Pgs 71-9, 1961-1962.
G. Zin

No abstract

DETERMINATION OF ELECTROMAGNETIC RELATIONS BY MEANS OF AN ELECTRO-
MAGNETIC CO-ORDINATION VECTOR

Phys. Abstr. 13654/1962; C.R. Acad. Sci. (France), Vol. 254, No. 20,
Pgs 3511-13, 14th May 1962; In French.
M.P. Zlatev

A vector is defined which the author calls the "electromagnetic co-ordination". By using classical principles and the laws of electrostatics, the basic formulae of electromagnetism are deduced from the definition. A formula is also deduced for a co-efficient of mutual dynamic potential ("potential mutuel dynamique"), analogous to the Neumann formula for mutual inductance.

INTRODUCTION TO PARTIALLY COHERENT ELECTROMAGNETIC WAVES

Electromagnetic Theory and Antennas, Proceedings of a Symposium held at Copenhagen, Denmark, June 1962, edited by E.C. Jordan, Pgs 773-783.
Francis J. Zucker

The theory of partially coherent electromagnetic waves was born of a marriage between Maxwell's equations and the statistics of stationary ensembles. While its language closely resembles that of conventional statistical communication theory, partial coherence covers the space domain in addition to the time domain, and is thus richer in physics. This paper is an introduction to partial coherence language, and to the papers on the subject that follow it; the fitness of this language for describing a wide range of the stochastic aspects of electromagnetic fields is shown.

ELECTROMAGNETIC RADIATION FIELDS

Phys. Abstr. 4225/1953; 1953. Springer.
H. Zuhrt

Part A deals with the theory of radiation fields, in particular with the various methods of solution of Maxwell's equations. Part B describes the field around conducting wires and inside waveguides. Part C deals with radiation from the main types of aeri-als: in particular cylindrical linear aeri-als are treated in detail with original contributions. Part D treats problems of wave propagation especially in the atmosphere. The book appears up to date and contains various topics that cannot be found in other treatises. The bibliography is mainly confined to German and American contributions.

UNDERSEA WARFARE

AD 264 000; An ASTIA Report Bibliography, 1102 pgs., 1961.
Hq. Armed Services Technical Information Agency, Arlington Hall Station,
Arlington, 12, Va.,

No abstract

CATALOGUE OF DISTURBANCES IN IONOSPHERE, GEOMAGNETIC FIELD, FIELD
INTENSITY, FIELD INTENSITY OF RADIO WAVE, COSMIC RAY, SOLAR PHENOMENA
AND OTHER RELATED PHENOMENA.

Phys. Abstr. 4634/1962; Rep. Ionosphere Space Res., Japan, V. 14, No. 4,
Pgs 463-84, December 1960.

Catalogue No. 38. Results are given of simultaneous observations
of the disturbances during the period 30th April to 1st May 1960.

CATALOGUE OF DISTURBANCES IN IONSOPHERE, GEOMAGNETIC FIELD, FIELD
INTENSITY OF RADIO WAVE, COSMIC RAY, SOLAR PHENOMENA AND OTHER RELATED
PHENOMENA

Phys. Abstr. 4635/1962; Rep. Ionosphere Space Res. Janpan, V. 15, No. 1,
Pgs 107-69, March 1961.

Catalogue No. 39. Results are given for the period 29th August to
7th September 1960.

LISTING OF PUBLISHED VLF SYMPOSIUM PAPERS

J. Res. Nat. Bur. Stand. (USA), V. 64, No. 4, July-August 1960.

A symposium on the Propagation of Very-Low-Frequency Radio Waves
was held at the Central Radio Propagation Laboratory of the National
Bureau of Standards, Boulder, Colorado, on 23rd to 25th January 1957.
At that time, preprints of the papers were available which were supplied
to the participants. Since then a large number of requests have been
received for additional copies. Since these have not been available
for some time, it is felt that the following list of open literature
references is of value. These comprise the bulk of the symposium papers
in their original or modified form.

PART VIII

PART VIII

ASW APPLICATIONS

TESTS OF UNDERWATER REMOTE CONTROL SYSTEM
U.S. Coast Guard, Washington, D.C.
See Section III, Page 217.

AIR-TO-UNDERSEA COMMUNICATION-ELECTROMAGNETIC FIELDS IN THE TWO MEDIA,
CAUSED BY VERTICAL AND HORIZONTAL ELECTRIC DIPOLES IN AIR
S.H. Durrani
See Section I, Page 32.

AIR-TO-UNDERSEA COMMUNICATION WITH ELECTRIC DIPOLES
S.H. Durrani
See Section I, Page 33.

SUBMERGED VLF RECEPTION. A STUDY OF VARIOUS LOOP COUPLING METHODS.
S.V. Fratianni
See Section II, Page 146.

UNDERWATER ELECTROMAGNETIC DETECTOR
G.D. Gillett
See Section III, Page 228.

THE HALL COMPASS
EE Abstr. 8551/1963; Proc. Nat. Electronics Conf. (USA), Vol. 18,
Pgs 753-62, 1962.
E.A. Keller

Unmanned remotely operation oceanographic instruments and detection devices in Undersea Warfare require azimuth references for vector-type variables under investigation. Solid state compasses and especially the Hall Compass are particularly well suited to withstand the rough environment in the sea. Design and performance data are described.

A NOTE ON THE DETECTION OF UNDERSEA CRAFT BY MEANS OF LOW FREQUENCY RADIATION FROM AIRCRAFT
W.R. McKinley
See Section I, Page 72.

THE THEORY OF RADIO COMMUNICATION BETWEEN SUBMERGED SUBMARINES

R.K. Moore

See Section I, Page 74.

SUBMARINE COMMUNICATIONS BY ELECTROMAGNETIC MEANS

R.K. Moore, W.L. Anderson & Others

See Section II, Page 170.

THE OMEGA LONG-RANGE NAVIGATION SYSTEM

Navy Electronics Lab.

See Section I, Page 75.

THE SUBMERGED RECEPTION OF RADIO FREQUENCY SIGNALS

O. Norgorden

See Section I, Page 77.

ATTENUATION OF MAGNETIC DISTURBANCES IN THE SEA

S.J. Raff

See Section II, Page 176.

SUBMARINE COMMUNICATION ANTENNA SYSTEMS

R.W. Turner

See Section II, Page 185.

A D D E N D U M

ADDENDUM

AN "IDK" INSTRUMENT FOR MEASURING STATISTICAL CHARACTERISTICS OF RANDOM VOLTAGES

Phys. Abstr. 16388/1964; Pribery Tekh. Eksper (USSR), 1960, No. 4, Pgs 77-81 (July-Aug). In Russian. English trans. in: Instrum, Exper, Tech. (USA), No. 4, Pgs 599-604 (1960; publ.Feb. 1961).
M.S. Aleksandrov

This article gives a schematic diagram and a description of an instrument for measuring the unidimensional integral and differential probability distribution law, the two-dimensional integral probability distribution law for one or two random voltages at the same or different instants, coefficients of mutual or autocorrelation, and probability distribution moments. The instrument is intended for the study of amplifier noise, attenuation of signals in radio relay communication lines, radio interference, interference in wire communication lines, etc.

RADIO COMMUNICATIONS VIA ROCK STRATA

EE Abstr. 5255/1964; IEEE Trans. Commun. System. (USA), Vol. CS-11, No.2, 159-69 (June 1963).
L.A. Ames, J.T. de Bettencourt, J.W. Frazier, A.S. Orange

The communications potential of radio wave propagation through rock strata in the earth's crust is discussed. Included are geological and geophysical considerations pertinent to communications system design. Expressions are given for radio wave attenuation and wavelength, performance factors of bare and insulated linear aeriels, and transmission loss between aeriels immersed in dissipative media. Results of their application to a short transmission path is illustrated. Practical considerations in the design of communication circuits are discussed.

SOME REMARKS ON THE WATSON TRANSFORMATION AND MODE THEORY

EE Abstr. 7892/1964; J.Res.Nat.Bur.Stand. (USA), Vol. 68D, No.1, Pgs 59-66, (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves, Boulder, 1963).
L.A. Berry

The Watson transformation, which is the basis of vlf mode theory, is reviewed. It is shown that the disappearance on the line integral ("continuous spectrum") depends only on the properties of the earth (for a homogeneous ionosphere). Thus, the integral is interpreted just as in the classical groundwave case, i.e. it represents the waves which have re-entered the air after travelling through the earth. The limitations of the second-order Debye approximations have been discussed vaguely before. Actual calculation in specific cases shows that the attenuation rate of the first mode is in error by 60% at 16.6 kc/s, 25% at 10 kc/s, and 15% at 8 kc/s when the Debye approximations are used for all wave functions. It is not possible to deduce effective parameters for the homogeneous ionosphere from consideration of the attenuation rate alone. It is suggested that simul-

taneous consideration of attenuation rate and phase velocity will remove ambiguity and an example calculation is given for 10.2 kc/s. The resulting model ionosphere is at a height of 65 km with $(\omega_p f \sim 1.2(10^5))$.

ATTENUATION CHARACTERISTICS OF RADIO-ATMOSPHERICS

EE Abstr. 6574/1964; J. Atmos. Terrest. Phys. (GB), Vol. 26, No. 2, Pgs 263-71 (February 1964).

H. Bhattacharya, Manoranjan Rao.

The amplitude-frequency spectra and the distances of origin of radio-atmospherics were obtained from an analysis of the observed waveform patterns. Amplitudes, relative to the amplitude at 10 kc/s, for different frequencies over a range from 3 to 15 kc/s were then plotted against the distances of origin. For frequencies below the reference frequency of 10 kc/s it was found that the initial decrease of the relative field intensity is followed by a gradual increase after about 1200 km. On the other hand, for frequencies greater than the reference frequency, the relative field intensity was found to increase rapidly after the initial decrease and subsequently to decrease gradually with distance. The marked difference in the nature of these curves for distances greater than 1200 km was attributed to ionospheric reflections. It was shown that if the received waveform pattern shows a succession of reflected impulses, then for a large distance and for large orders of reflection, higher frequencies are heavily attenuated. Due to this heavy attenuation of higher frequencies, a sinusoidal waveform of a very low frequency is expected at large distances and for large orders of reflection. The appearance of a low frequency component of 3.3 kc/s observed by Tantry and Srivastava (1958) may then be explained.

DIURNAL CHANGES AND TRANSMISSION TIME IN THE ARCTIC PROPAGATION OF VLF WAVES

EE Abstr. 6567/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 2, Pgs 205-10, (February 1964).

W.T. Blackband

The diurnal variation of the transmission time for the signal from a distant vlf transmitter results from the solar illumination of the lower ionosphere. For a path crossing the Arctic regions there will be no diurnal change for that part of the path which is illuminated by the mid-night sun. It is shown that for a path crossing the Arctic Circle the diurnal change curve is of the normal trapezium shape at the equinoxes but that it takes on different forms at midsummer and mid-winter. An analysis of experimental curves shows that they are of the form predicted. A simple rule for computing the change-over on Arctic path is shown to agree well with the experimental data available.

MAGNETIC TAPE RECORDING AND REPRODUCING OF ATMOSPHERIC NOISE WITH A WIDE DYNAMIC RANGE

EE Abstr. 7904/1964; Rev. Sci. Instrum (USA), Vol. 35, No. 3, Pgs 377-80, March 1964.

E.C. Bolton

To properly evaluate the performance of radio systems in the presence

of atmospheric noise, it is necessary to be able to reproduce atmospheric noise of various known amplitude distributions whenever necessary. However, conventional tape recording techniques cannot be used because of the large dynamic range of atmospheric noise. This paper describes a tape recording and reproducing system which has been developed that can record and reproduce atmospheric noise with a dynamic range of 90 dB. The frequency range is 1 to 25 kc/s with a one-half octave bandwidth and, by using frequency conversion, frequency from 25 to 500 kc/s may be recorded with a maximum bandwidth of 10 kc/s.

AN EXPLANATION OF TRIGGERED VERY-LOW-FREQUENCY EMISSIONS

Phys. Abstr. 7853/1964; J. Geophys. Res. (USA), Vol. 68, No. 15, Pgs 4626/8 (1 Aug. 1963).

N. Brice

The proposed mechanism is that the relative phases of particles gyrating about the lines of force of the earth's field are adjusted by the triggering wave so that the particles can radiate coherently. More particles are influenced by the induced radiation, and the process becomes self-sustaining.

ELECTROMAGNETIC MODELLING STUDIES OF LITHOSPHERIC PROPAGATION

EE Abstr. 5256/1964; IEEE Trans. Geosci. Electronics (USA), Vol. GE-1, No.1, Pgs 17-23, (December 1963).

G.L. Brown, A.F. Gangi

The propagation of radio waves through the lithosphere between buried transmitting and receiving sites is a communication technique of great interest at the moment due to the physical hardness of invulnerability of such a communication system to nuclear blasts. Theoretical studies and laboratory experiments were performed to investigate the propagation of electromagnetic waves in a low-conductivity lithospheric duct (granitic basement layer). The real earth situation was approximated by a low conductivity layer with uniform properties located between two regions of high conductivity (the upper crust of the earth and the earth's mantle). Models were also used to investigate the effects of geological discontinuities and inhomogeneities on the electric field strength. Different models were constructed using scaling factors of the order of 10^3 . Aluminium plates were used in the first model to represent the mantle and the upper crust. The low conductivity layer was modelled by a salt water solution. In the second model the upper crust was modelled by a carbon sheet instead of an aluminium sheet. The conductivity of the carbon sheet accurately modelled the value of conductivity assumed for the upper crust of the earth. Excellent agreement was obtained between theoretical and experimental results for c.w. propagation. This agreement demonstrates the validity of the laboratory modelling techniques and lends confidence to the experimental results obtained for the effects of inhomogeneities in the duct.

PROPAGATION OF VLF WAVES OVER DISTANCES BETWEEN 1000 AND 3000 KM
EE Abstr. 7884/1964; J.Res.Nat.Bur.Stand. (USA), Vol.68D, No.1, Pgs 15-16 (Jan.1964). (Ionospheric Propagation of VLF Radio Waves, Boulder, 1963).
B. Burgess

In this summary paper it is not possible to enter into a discussion of a theoretical interpretation of the above data, but, in essence, the mode theory as developed by Wait can give a picture which agrees with the outlined experimental results. The behaviour of signal strength and phase over the paths discussed when inspected in detail, puts the mode theory to a stringent test and the simple model of an upper ionospheric boundary in the form of a step seems no longer to suffice. The explanation of the experimental results should lead to a more realistic model of the D-region for use in vlf propagation work.

SOME EXPERIMENTAL RESULTS CONCERNING NON-RECIPROCAL EAST-WEST VLF WAVE PROPAGATION

EE Abstr. 7885/1964; J.Res.Nat.Bur.Stand. (USA), Vol.68D, No.1, Pgs 17-18, (Jan.1964). (Ionospheric Propagation of VLF Radio Waves, Boulder, 1963).
B. Burgess

There is a strong evidence that the results presented are due to non-reciprocity in the east-west, west-east propagation of vlf waves. The range of propagation phenomena exist at least to within 10,000 km of the transmitter.

PROPAGATION OF VLF WAVES UNDER DISTURBED CONDITIONS

EE Abstr. 7897/1964; J.Res.Nat.Bur.Stand. (USA), Vol.68D, No.1, Pgs 103+4, (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves, Boulder, 1963).
B. Burgess

No abstract.

EXTREMELY LOW-FREQUENCY RADIO PROPAGATION IN AN INHOMOGENEOUS IONOSPHERE

Phys.Abstr. 5830/1964; Nature (GB), Vol. 199, 581-2 (10 Aug. 1963).
R. Burman, R.N. Gould

Exact solution of the wave equation in the zero-order mode for waves propagating in the earth-ionosphere waveguide are determined for a linear refractive index profile. The results indicate that the attenuation of e.l.f. waves may increase as frequency decreases at the lower frequencies - a result in agreement with some experimental measurements.

ELECTROMAGNETIC FIELDS IN A SPHERICAL CAVITY EMBEDDED IN A DISSIPATIVE MEDIUM.

EE Abstr. 7348/1964; IEEE Trans. Antennas & Propagation (USA), Vol. AP-12, No. 1, Pgs 110-18, January 1964.
C.M. Butler, J. Van Bladel

Time-harmonic and transient electromagnetic fields in spherical cavities whose walls are made of any material characterized by (σ, μ, ϵ) are investigated. For time-harmonic fields the wave equation is solved exactly in both the cavity and wall regions when the excitation is an electric dipole located

at the cavity centre. Numerical information based on these exact solutions shows the influence of the wall parameters upon the fields and provides a basis for studying the applicability and validity of several often used approximations. From the time-harmonic solutions, the Laplace transforms of the field equations are determined. These transforms are very complex and therefore are inverted numerically. Numerical results describing the magnetic field due to a particular dipole current, $i_d(t) = (1 - e^{-dt})$, are presented for several cases of interest.

NATURAL ELECTROMAGNETIC FIELD FLUCTUATIONS IN THE 3.0 - TO 0.02 - C/S RANGE

Phys. Abstr. 7941/1964; Proc. Inst. Elect. Electronics Engrs (USA), Vol. 51, No. 10, 1337-42, October 1963.
W.H. Campbell

Using large loop aerials the ultra-low-frequency research group at the National Bureau of Standards has studied the upper atmospheric phenomena of geomagnetic micropulsations. Data taken at a number of world stations on both direct reading chart and magnetic tape indicate a division into three contributing phenomena for the frequency range of 3.0 to 0.02 c/s. Very regular oscillations of 2.0 to 0.2 c/s are a strange pulsation phenomenon most likely of outer atmospheric origin but apparently unrelated to solar-terrestrial disturbances. Sudden bursts of large amplitude field fluctuations spread throughout the frequency range are closely related to high latitude particle precipitation, enhanced ionospheric absorption, and auroral luminosity; these fluctuations seem to be of ionospheric origin. Regular oscillations between 0.2 and 0.03 c/s appearing over broad sections of the earth with related phase on days of high solar-terrestrial activity are presently the best candidate for magnetohydrodynamic interpretation. During the International Quiet Sun Year (IQSY) a configuration of world stations will be operated along a latitudinal line covering about 180° at three sites in the boreal auroral zone, along a longitudinal line near 75° to 80° W longitude with conjugate stations corresponding to L shell values of about 6.5 and 4, and at an equatorial site.

ROCKET OBSERVATIONS OF VERY LOW FREQUENCY RADIO NOISE AT NIGHT

EE Abstr. 5286/1964; Planet. Space Sci. (GB), Vol. 12, No. 1, Pgs 11-16 (Jan. 1964).
D.G. Cartwright

Diffuse whistlers, with sometimes a single echo, were observed during a night-time rocket flight; none were observed on the ground at the same time. The whistlers were not ducted, but were loosely guided along the magnetic field. From the modulation of the whistlers and their echoes by the spinning vehicle, it is concluded that the wave normal angles were not within the limits required for penetration of the ionosphere. A band of hiss, centred at about 2.8 kc/s, 2 kc/s wide, and deeply modulated by spin, was also observed at the rocket but not on the ground. It is suggested that, even at night, many more vlf phenomena can be observed above the ionosphere than on the ground.

STEPPED STRUCTURE OF THE SUNRISE EFFECT IN ATMOSPHERICS ACTIVITY ON
27 KC/S

EE Abstr. 5258/1964; Indian J. Pure Appl. Phys., Vol. 2, No. 1,
Pgs 30-2, (Jan. 1964).

M.W. Chiplonkar, P.R. Marwadi, R.N. Karekar

Some additional peculiarities in the diurnal variation in the atmospherics activity on 27 kc/s with special reference to sunrise effect, not noticed by earlier workers, are reported. On many occasions a stepped structure instead of a single fall was observed in the records, with two and sometimes even three steps preceding the fall. The number of steps is less in summer than in winter. A qualitative correlation, namely that the ionospheric absorption at sunrise increases with the number of steps observed in the records was indicated.

IONOSPHERIC PROPAGATION OF ATMOSPHERICS

Phys. Abstr. 7904/1964; Indian J. Meteorol. Geophys. Vol. 14, No. 3,
Pgs 343-52 (July 1963)

M.W. Chiplonkar, M.S. Hattiangadi

Numerous waveforms of atmospherics in the frequency region 50 c/s to 300 kc/s have been observed during the period April 1957 to December 1958. A large number of these show a multi-hop propagation and the results of measurements of these waveforms are analysed and presented. It is found that the height of the reflecting layer varied from about 55 km to about 120 km but most frequently lies between 80 and 90 km. The frequency distribution curve of height is skew and has a tendency to show Gaussian distribution around two values, 60 and 90 km. Similarly the distance of the source of atmospherics varied from about 200 to 2000 km. The frequency distribution curve in this case shows principal peaks at about 750 and 1750 km with subsidiary peaks on either side of these. This trend is also shown by the individual monthly histograms for distances. Further, when separate histograms were drawn for distances which were associated with a height of 60 km and those that were associated with a height of 90 km it was found that the two principal peaks at 750 and 1700 km were prominently shown by the 90 km group alone and only the first peak was shown by the 60 km group, thus indicating a preponderant role of the upper layer. This statistical distribution of distances has been interpreted qualitatively with the help of a Hologworth interference pattern of field strength. When heights of the reflecting layers are plotted against the corresponding source distances, it is seen that the height increases rapidly at first and then gradually reaches a limiting value around 95 km. However, other evidence shows that there exist two reflecting layers, one at about 60 km and the other at about 90 km. The reflection coefficient of the ionosphere varied from 0.4 to 0.9 or more. Occasionally even smaller values down to 0.25 were also observed. The reflection coefficient is higher in winter than in summer.

GEOMETRICAL OPTICS CONVERGENCE COEFFICIENT FOR THE WHISTLER CASE
Phys. Abstr. 17905/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D,
No. 2, Pgs 211-14 (Feb. 1964).
J.H.Crary

In a previous report (1961) the field strength, direction of arrival and apparent polarization of whistler signals was calculated by the use of ray theory (or geometrical optics). The convergence coefficient is a factor in the ray theory equations which expresses the net convergence or divergence of the rays caused by reflection from the curved earth and ionosphere. Intuitive reasoning led to the assumption of unity for this coefficient in the whistler case, where there are an equal number of reflections from the concave ionosphere and convex earth. This is contrasted with the convergence coefficient for the case of ground-to-ground transmission; this coefficient contains singularities at critical distances. The derivation and evaluation of the expression for the coefficient for the whistler case confirms the accuracy of the assumption of unity; this greatly simplifies whistler calculations.

PERIODIC FADING OF VLF SIGNALS RECEIVED OVER LONG PATHS DURING SUNRISE AND SUNSET

EE Abstr. 7888/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 1, Pgs 27-34 (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves, Boulder, 1963).
D.D. Crombie

Data on the periodic changes in amplitude and phase of vlf signals received over long vlf paths is examined. It is concluded that the variations are due to multimode propagation in the night-time portion of the path.

A STUDY OF WHISTLING ATMOSPHERICS. IV. COMPARISON OF OBSERVATIONS AT WIDELY SPACED STATIONS

EE Abstr. 7902/1964; Austral. J. Phys., Vol. 17, No. 1, Pgs 75-87, (March 1964).
J. Crouchley

For Pt III, see Abstr. 6435 of 1963. Whistlers observed at stations separated from one another by up to 3000 km are examined statistically and by comparing simultaneous whistlers. It is shown that whistlers are not commonly observed further than 1000 km away from their "ionospheric source", i.e. the limited region through which they emerge from the ionosphere, and that a lightning stroke may produce whistlers with different dispersions at stations with a separation of this order of magnitude. Ionospheric sources are most common around (geomagnetic) latitude $44-46^{\circ}$ in winter and around latitude $50-52^{\circ}$ in summer (southern hemisphere). It is suggested that this change is related to changes in the electron density of the ionosphere.

A STUDY OF WHISTLING ATMOSPHERICS V. DISPERSION

EE Abstr. 7903/1964; Austral J. Phys. Vol. 17, No. 1, Pgs 88-105,
(March 1964).

J. Crouchley

The dispersion characteristics of whistlers recorded at Brisbane, Adelaide, and Hobart, mainly during the IGY are examined. The dispersion recorded at each station shows a wide range of values. Diurnal ($10-15 \text{ s}^2$) and annual variations ($20-25 \text{ s}^2$) are observed and correlations between dispersion and F_2 critical frequency and dispersion and magnetic disturbance are discussed. No association between dispersion and sunspot number was detected. The position of the "ionospheric sources" of the whistlers is of prime importance as dispersion varies with geomagnetic latitude. Much of the variation in dispersion observed by individual stations is believed to be due to their being able to "see" ionospheric sources up to 10° away.

SOME PARTICULAR OBSERVATIONS ON DIURNAL PHASE VARIATIONS OF VLF TRANSMISSIONS RECEIVED IN PARIS

EE Abstr. 7887/1964; J. Res. Nat.*Bur. Stand. (USA), Vol. 68D, No. 1, Pgs 21-25 (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves, Boulder, 1963).

B. Decaux, A. Gabry.

Observations made in Paris, France, of the phase of various frequency stabilized v.l.f. transmitters are reported. Descriptions are given of the seasonal dependence of the diurnal phase shift on an arctic path, effects following solar flares, effects of two solar eclipses, and observation following the high-altitude nuclear explosion of 9th July 1962.

EFFECT OF MAGNETIC ANOMALIES ON VERY LOW FREQUENCY DISCRETE EMISSIONS
Phys. Abstr. 13803/1964; Austral J. Phys., Vol. 16, No. 4, Pgs 588-92, December 1963.

R.L. Dowden

A theory accounting for "distorted" r.l.f. emissions is given. The analysis shows that such emission may be explained in terms of magnetic anomalies in a predominantly dipole magnetic field. It is shown that the emissions are remarkably sensitive to small field anomalies, contrary to the effect of such anomalies in whistlers.

EXPERIMENTAL RESEARCH ON THE GEOMAGNETIC GUIDANCE OF DECAMETRIC WAVES
EE Abstr. 5253/1964; Ann. Telecomm. (France), Vol. 18, No. 9-10, Pgs 177-84 (Sept.-Oct. 1963). In French.

F. du Castel

Reports observations at a latitude of 50° of long distance

(22,000 km) echoes in the decametre band. It seems that the radiation is guided by ionized layers along the direction of the terrestrial magnetic field. The order of magnitude of the changes of ionization density necessary for guidance is of the order of 5×10^2 electrons/cm³ for a layer of thickness 1000 m. It seems that these ionized layers may exist at certain latitudes.

LONG-TERM VARIATION OF IONOSPHERIC REFLECTION HEIGHTS FOR VLF RADIO WAVES

EE Abstr. 7876/1964; J. Atmos. Terrest. Phys. (GB), Vol. 26, No. 3, Pgs 51-65 (March 1964).

A. Egeland, W. Riedler

The field strength at Kiruna from GBR Rugby at 16 kc/s was monitored from January 1959 to July 1963. From the day/night ratio of signal strengths it was concluded that the reflection height increased perhaps 5 to 10 km as solar activity waned. A maximum strength was observed in 1960, two years after sunspot maximum, Strengths are higher in summer than in winter. Effects were noted of high altitude nuclear explosions.

THE VLF RADIO EMISSIONS FROM THE EARTH'S OUTER ATMOSPHERE

Phys. Abstr. 7895/1964; Proc. Instn. Radio Engrs Australia, Vol. 24, No. 2, Pgs 204-7 (Feb.1963).

G.R.A. Ellis

Electromagnetic waves in the frequency band from 2-20 kc/s are generated by streams of electrons travelling through the distant outer atmosphere of the earth. They may be recorded with very simple equipment and provide information about the disturbances which occur in these regions following particle outbursts from the sun. The properties of these vlf emissions are described and details of suitable receivers are given.

ON THE CORRELATION OF METEORS WITH MICROPULSATIONS

Phys. Abstr. 10773/1964; J. Geophys. Res. (USA), Vol. 68, No. 21, Pgs 5937-45 (1 Nov. 1963).

C.D. Ellyett, B.J. Fraser

Night-time geomagnetic micropulsations were observed in the 1.5 c/s frequency band down to a limiting sensitivity of 0.05 my. These results were compared with all-sky and localized radar meteor rates obtained at the same site to investigate the magnetic effects produced by meteors. The variation of meteor rates for each hour, plotted through a succession of nights, is not significantly related to the corresponding micropulsation activity. Individual meteor

occurrence has been examined by recording on the same chart as the micropulsation activity. Most individual meteors do not have any associated micropulsation activity, but the number of coincidences is greater than random, and it remains possible that some of the larger meteors do produce magnetic effects.

THE PRINCIPLES OF A RESONANCE-FLUORESCENCE MAGNETOMETER

Phys. Abstr. 8887/1964; Monatster, Deutschen Akad. Wiss. Berlin (Germany), Vol. 5, No. 3, Pgs 145-51 (1963). In German.
G. Fanselau, W. Lindner

The effect of a magnetic field on the degree of depolarization of the fluorescence radiation of atoms is shown to form the basis of a method of magnetic measurement which is directionally dependent. The basic effect is free from hysteresis and the device avoids some disadvantages of other methods, while being comparable with them in sensitivity. Fundamental principles, including the part played by the lifetime of the excited atomic state, are discussed, and a practical arrangement and experimental tests are outlined.

INVESTIGATIONS OF SPHERICS

A Series of Progress Reports on Project T-506/NBS, U.S. Nat. Bur. Stands., et seq.
E.F. Fierman

These reports deal with the study of the propagation of characteristics of the very low frequency electromagnetic radiation from lightning discharges.

ON THE ESTABLISHMENT OF AN ELECTROMAGNETIC FIELD

EE Abstr. 5722/1964; Izv. Akad. Nauk SSSR. Ser Geofiz., 1963, No. 7, Pgs 1076-80. In Russian. English trans. in: Bull. Acad. Sci. USSR, Geophys. Ser. (USA), No. 7, Pgs 656-8, (July 1963).
P.P. Frolov

The process of establishing an electromagnetic field is used widely in geophysical prospecting. The interpretation of the field observations requires the use of master curves calculated for a diversity of geoelectric cross sections and final states. A method of calculating the entire curve of field establishment is presented for an arbitrary geoelectric cross section using an electronic computer. This method enables one to compute master curves with a given degree of accuracy and can be used to calculate the establishment of both electric and magnetic fields.

PROPAGATION OF ELF WAVES BELOW AN INHOMOGENEOUS ANISOTROPIC IONOSPHERE
EE Abstr. 6560/1964; IEEE Trans. Antennas and Propagation (USA), Vol.
AP-12, No. 1, Pgs 74-83 (Jan. 1964).
J. Galejs, R.V. Row

The ionospheric anisotropy is considered with horizontal magnetic field either for transverse (East-West or West-East) or for longitudinal (South-North) propagation. For transverse propagation in a vertically stratified medium the differential equations of the various field components are uncoupled and a closed form solution is given for identical exponential height variation of the components of tensor conductivity. For arbitrary height variation of the tensor conductivity numerical solutions are obtained after expressing the surface impedance below the ionosphere in terms of a Riccati-type differential equation. The West-East direction of propagation exhibits a lower attenuation constant than the East-West direction for $f < 1000$ c/s. This is contrary to the expectations based on a model of a homogeneous anisotropic ionosphere. For longitudinal propagation the differential equations of the various field components are coupled with the coupling, being particularly strong above the D region. The differential equations are simplified by assuming no coupling in the lower ionosphere and strong coupling above a pre-selected altitude y_1 . For exponential height variation of the tensor conductivity components the closed form solution differs negligibly from the isotropic case. For arbitrary height variation of the tensor conductivity numerical solutions are obtained similarly as for the transverse propagation. Over most of the frequency range the attenuation figures for South-North propagation are intermediate between the corresponding figures for West-East and East-West propagation.

CAPACITOR TYPE BICONICAL ANTENNAS

EE Abstr. 6518/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 2,
Pgs 165-72, (February 1964).
J. Galejs

The biconical aerial analysis performed by C.T. Tai (Abstr. 831 of 1950) is extended to top-loaded and half-buried aerial structures which may have spherical cores of lossy dielectric. After computing the terminal admittance of the aerial, its input admittance is obtained by transmission line considerations. The numerical calculations emphasize aeriels of dimensions which are small relative to the wavelength. Wide angle aeriels of solid cones exhibit smaller radiation power factors (or products of available bandwidth and efficiency) than top-loaded aeriels of small angle. The hemispherical aerial, located above a perfectly conducting ground plane, exhibits a larger radiation power factor than the corresponding half-buried aerial of the same total volume.

PROPAGATION OF ELF WAVES BELOW AN INHOMOGENEOUS ANISOTROPIC IONOSPHERE
EE Abstr. 7897/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 1,
Pgs 103-4 (January 1964). (Ionospheric Propagation of VLF Radio Waves,
Boulder, 1963).

J. Galejs, R.V. Row

No abstract.

AN EXPERIMENTAL STUDY OF THE PHASE STABILITY OF VLF SIGNALS
EE Abstr. 7886/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 1,
Pgs 19-20 (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves,
Boulder, 1963).

D.E. Hampton

No abstract

FIELD INTENSITY MEASUREMENTS AT 10.2 kc/s OVER RECIPROCAL PATHS
EE Abstr. 7883/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 1,
Pgs 11-14 (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves,
Boulder, 1963).

J.C. Hanselman, C.J. Casselman, M.L. Tibbals, J.E. Bickel

Experimental data at 10.2 kc/s are presented which demonstrate non-reciprocity in attenuation rates for propagation in the east-west directions, and that reciprocity exists in the north-south direction along a magnetic meridian. The experimental evidence recorded for propagation paths of 3820, 7830, and 8450 kilometers, compares well with theoretical attenuation rates of 10 kc/s given by J.R. Wait and K. Spies.

A MECHANISM FOR THE PRODUCTION OF CERTAIN TYPES OF VERY-LOW-FREQUENCY EMISSIONS

EE Abstr. 4017/1964; J. Geophys. Res. (USA), Vol. 68, No. 21, Pgs 5925-35,
(1st Nov. 1963).

S.F. Hansen

It has been shown that some types of vlf emissions (hooks, risers, and falling tones) may be the result of cyclotron emission by energetic electrons trapped in the earth's magnetic field. Observational evidence suggests that a relatively intense electromagnetic whistle-mode wave may be necessary to trigger each such emission. An interaction mechanism is proposed by which certain electrons may couple with a wave already propagating along the same line of force. A gyroresonance is established which organizes the electrons so that cyclotron radiation can be coherent. A change in phase relationship occurs for those electrons that have a longitudinal velocity component such that the Doppler-shifted frequency of the whistler wave seen by the electron is equal or nearly equal to the electron gyro-

frequency. This condition is met by electrons moving in a direction opposite to the whistler wave and is satisfied only over a certain fraction of the line of force. Observations also show instances of a sudden change in slope of the rising tail of a hook or other vlf emission at the crossing of the spectrums of the emission and a whistler. This change is interpreted as the effect of the encounter of a whistler with the electron stream that changes both energy and pitch angle of the emitting electrons.

RADIATION AND RECEPTION WITH BURIED AND SUBMERGED ANTENNAS
EE Abstr. 9065/1964; Electromagnetic Theory and Antennas Symposium, Copenhagen, 1962 (see Abstr. 4902 of 1963), Pgs 1173-8.
R.C. Hansen

A brief outline of the propagation theory coupled with physical explanation. The various approximate solutions and their ranges of applicability are given but the theory is not developed into practical examples. Aerial gain evaluation methods are suggested and "merit factors" quoted for three types.

INDUCED ELECTRIC FIELDS IN COAXIAL GEOMETRY
EE Abstr. 5469/1964; J. Appl. Phys. (USA), Vol. 35, No. 3, Pt. 1, Pgs 508-11 (March 1964).
P.J. Hart

Although electromagnetic theory has been known for a century, and Biot's (also called Ampere's) formula in its simple form, $dH = (1/4\pi) (Idl \sin\theta/r^2)$, is often used, the corresponding relationship, $dE = -(1/4\pi) \oint dl \sin\theta/r^2$, for the electric field induced in space by a filament of time-varying magnetic flux, seems not to have been recognized or used to any great extent. The discussion here presented, using the example afforded by coaxial conductors, illustrates some aspects of how this latter relationship may be used to solve for induced electric fields, including those for coaxial systems of both finite and infinite length with hollow or solid centre conductors. The magnetically induced electric field fringes outward near the shorted end of a coaxial system, and a method is shown for finding the radial positions of a given line of electric force when coaxial conductors of different dimensions are connected together.

REMARKS ON THE MEASURABILITY OF ELECTROMAGNETIC FIELDS
Phys. Abstr. 2416/1958; Nuovo Cimento (Italy), V. 7, No. 5, Pgs 677-84, 1st March 1958.
G. Heber

Indeterminancy relations are derived, which express the facts, that only 4-dimensional averages of electromagnetic fields are measurable

and that also an average cannot be measured with unlimited accuracy simultaneously with the position of the averaging region in space-time continuum. Essentially in showing this is the use of test-bodies, which obey Heisenberg's indeterminacy relations and possess a finite extension, finite mass and finite electric charge.

WHISTLER-TRIGGERED PERIODIC VERY-LOW-FREQUENCY EMISSIONS

Phys. Abstr. 7855/1964; J. Geophys. Res. (USA), Vol. 68, No. 19, Pgs 5387-95 (1 Oct. 1963).

R.A. Helliwell

From new experimental data on the relationship between whistlers and periodic vlf emissions (vlf ionospheric noise) it is found that both the dispersive and non-dispersive types of periodic noise are of common origin. In the cases examined, a sequence of emissions is initiated, or "triggered", by a whistler, and the period between emissions is the same as the whistler-mode echoing period at some frequency within the range of the emission. To explain these results it is proposed that the generation, or triggering, of the emissions is controlled by packets of electromagnetic waves echoing in the whistler mode. In this triggering hypothesis it is supposed that the wave packets act to organize temporarily the particles in existing streams of charge so that their radiation is coherent. The resultant temporary increase in total radiation is seen on the ground as a short burst of noise. An earlier explanation of non-dispersive periodic noise based on a postulated small bunch of particles that oscillates between its mirror points in the earth's magnetic field is found to be incompatible with the data.

UBER DIE MESSUNG KLEINSTER MAGNETISCHER FELDER MIT HALLGENERATOREN

Siemens (Germany), V. 31, No. 8, August 1957.

H.V. Hieronymus, H. Weiss

No abstract

HIGH RESOLUTION AND THE MEASUREMENT OF WEAK FIELDS BY NMR

CR Acad. Sci. (France), V. 248, Pgs 218-220, 1959.

G. Hochstrasser, G. Béné, R. Extermann

Variation of the earth's magnetic field with time can be measured to about 10^{-6} Gauss.

A COMPARISON OF MEASUREMENTS MADE WITH TWO NMR MAGNETOMETERS OF DIFFERENT TYPES: THE SOLAR ECLIPSE OF 15TH FEBRUARY 1961.

Phys. Abstr. 2316/1964; Arch. Sci. (Switzerland), Vol. 14, Special No. 280-6, (September 1961). In French. (Ampere Colloquium, Leipzig, 1961 - see Abstr. 23198 of 1963).

G. Hochstrasser, A. Erbeia

Slight changes in the usual diurnal variation of the earth's magnetic field on this day are ascribed to the eclipse of the sun.

INSTRUMENTATION FOR RECORDING AND ANALYSIS OF AUDIO AND SUB-AUDIO NOISE

EE Abstr. 787/1959; Inst. Radio Engrs. (USA), V. 6, Pt 5, Pgs 176-82, 1958.

D.D. Howard

Describes a technique, employing magnetic recording, for the analytical study of noise received from a radar tracking system where a complex target like an aircraft is involved. Amplitude or frequency modulation is employed for the original recording of the noise and frequency multiplication, to expand the noise spectrum, in the analysing equipment. For spectral power distribution analysis a 40 in. recorded loop is scanned by a 4 cps bandwidth analyser while a voltage analyser is used for determining the amplitude distribution. The derivation of probability distribution curves from the analyses is discussed.

A DEVELOPMENT OF THE USE OF THE ELECTROLYTIC TANK FOR FIELD STUDIES

EE Abstr. 7590/1962; Nature (GB), Vol. 193, 468, 3rd February 1962.

J. Hudson

A technique is briefly described for establishing a field which satisfies Poisson's equation in a conducting sheet analogue by the use of eddy currents generated within an electrolyte by a probe and 1 kc/s source of supply.

AN EXPERIMENTAL STUDY OF THE INSULATED DIPOLE ANTENNA IMMERSSED IN A CONDUCTING MEDIUM

EE Abstr. 5233/1964; IEEE Trans Antennas and Propagation (USA), Vol. AP-11, No. 5, Pgs 518-32 (September 1963).

K. Iizuka

The driving-point admittance and the amplitude and phase distributions of the current referred to the driving-point were measured for an insulated cylindrical aerial immersed in a conducting medium. The ratio $\sigma/\omega\epsilon_r\epsilon_0$ of the conducting medium was varied from $\sigma/\omega\epsilon_r\epsilon_0 = 0.036$ to 8.8, a range which includes a variety of media such as poor

insulators, the ionosphere, plasmas, dry earth, wet earth, lake water and sea water. The aerial height βh in radians was varied from $\beta h = 0.1$ through $\beta h = 2\pi$ at intervals of 0.1. The thickness of the insulator was varied from $b/a = 1.25$ to $b/a = 12.0$ where a is the radius of the aerial and b the radius of the insulator. Measurements were also made of the admittance, current and phase distributions along an insulated aerial with a conductive top load, that is, one whose tip is in direct contact with the conducting medium. It is found that when the tip of the aerial is in direct contact with the conducting medium, the current increases almost linearly as the end of the aerial is approached. This is quite unlike the decaying sinusoidal distribution on the completely insulated aerial. In a general sense, the experimental results are in fair agreement with an approximate theoretical expression for the admittance of an insulated aerial immersed in a highly conducting solution. The approximate theory is based on the driving-point admittance of a coaxial line whose outer conductor is imperfectly conducting and infinite in extent.

AN EXPERIMENTAL INVESTIGATION ON THE BEHAVIOUR OF THE DIPOLE ANTENNA NEAR THE INTERFACE BETWEEN THE CONDUCTING MEDIUM AND FREE SPACE
 EE Abstr. 6521/1964; IEEE Trans Antennas and Propagation (USA), Vol. AP-12, No. 1, Pgs 27-35 (January 1964).
 K. Iizuka

An experimental study was made of the driving-point admittance and the relative amplitude and phase distributions of the current for a dipole aerial near and parallel to the interface between the conducting medium and free space. (The aerial was always located in the conducting medium, unless otherwise specified.) The depth d of the aerial from the interface was varied from $d/\lambda = 4.4$ to 0. The loss tangent $\sigma/\omega\epsilon_r\epsilon_0$ of the conducting medium was varied from 0.036 to 8.8, a range which includes a variety of media such as poor insulators, the ionosphere, plasmas, dry earth, wet earth, lake water, and sea water. The aerial height βh in radians was varied from $\beta h = 0.1$ through 2π . Comparisons were made, wherever possible between the characteristics of the dipole aerial in the half space and in a space completely filled with the dissipative medium. The driving-point admittances in the limiting case $d \rightarrow \infty$ are in good agreement with the available theories by King and Harrison (see Abstr. 6921 of 1960) and Wu (J. Math. Phys. New York (USA), Vol. 2, No. 41, 550-75 (July-August 1961), which have already been verified experimentally by Iizuka and King (see Abstr. 13439 of 1962). Since all measured results are given in terms of dimensionless parameters such as $\beta h, d/\lambda, \sigma/\omega\epsilon_r\epsilon_0$, and $1/\sqrt{\epsilon_r}$, they may be applied to any combination of conductivity, frequency, dielectric constant, and distance of the aerial from the interface.

AN EXPERIMENTAL STUDY OF THE INSULATED DIPOLE ANTENNA IMMERSSED IN A CONDUCTING MEDIUM

EE Abstr. 9067/1964; Electromagnetic Theory and Antennas Symposium, Copenhagen, 1962. (see Abstr. 4902/1963), Pgs 1179-82.

K. Iizuka

Gives the experimental results of an investigation into driving-point admittance of an aerial buried or submerged in a lossy medium (earth, sea, plasma, etc.) and the effect of variations of insulation thickness and of end contact with the medium. The determination of optimum dimensions is demonstrated. Current distribution observed is mentioned.

A MODEL OF GEOMAGNETIC MICROPULSATIONS WITH LONG PERIODS

Phys. Abstr. 10772/1964; Canad. J. Phys., Vol. 42, No. 1, Pgs 200-7, (January 1964).

J.A. Jacobs, T. Watanabe

A physical process whereby a hydromagnetic oscillation of a magnetic line of force passing through the auroral zones gives rise to a system of ionospheric currents is described. Geomagnetic micropulsations, at least in middle and lower latitudes, are claimed to be due to ionospheric currents thus produced. Observational evidence in support of this viewpoint for micropulsations in the daylight hemisphere is provided by the solar eclipse effect that the intensity of micropulsations is weakened in the eclipsed zone. The phase relationship between micropulsations in the north-south component and oscillations in the received frequency of a radio wave which is emitted from a station with a stable frequency of the order of several to tens of megacycles, and is propagated through the ionosphere, is correctly interpreted by the above theory.

CONCERNING LIMITATIONS AND FURTHER CORRECTIONS TO GEOMETRIC-OPTICAL THEORY FOR LF, VLF PROPAGATION BETWEEN THE IONOSPHERE AND THE GROUND.

EE Abstr. 7893/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No.1, Pgs 67-78 (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves, Boulder, 1963).

J.R. Jöhler

Considerable use has been made of the geometric-optical propagation theory to describe long wavelength terrestrial radio waves between the ionosphere and the ground by Bremmer (1949), Wait and Murphy (1957), Wait (1961), Wait and Conda (1961), and Jöhler (Abstr. 6099, 10102 of 1962). The physical interpretation of pulse signals propagated around the terrestrial sphere as an application of the theory has been described by Jöhler (1962, 1963a, 1963b). Indeed, the use of the Loran-C radio navigation-timing system to study the propagation of l.f. ionospheric waves has given further impetus to such a study. The geometric series from which the geometric-optical ray limit is derived like the full wave residue series or the series of

zonal harmonics (Johler and Berry, (Abstr. 4391 of 1963)) is rigorous. However, the comparatively gross approximations usually employed in the geometric-optical ray limit are worthy of careful scrutiny at this time since the rigorous residue series methods have been worked out in some detail for large scale computers (Johler and Berry, 1962, 1963). It is apparent from the rigorous theory that the geometric-optical rays do not merely diffract around the curvature of the terrestrial sphere but at considerable distance beyond the geometric-optical horizon are built up to stronger fields by additional ionospheric reflections of the nature of a detached mode of propagation not ordinarily taken into account by the saddle point method of the ray limit.

ELASTIC, ELECTROMAGNETIC, AND OTHER WAVES IN A RANDOM MEDIUM

Phys. Abstr. 16016/1964; J. Math. Phys., New York (USA), Vol. 5, No. 4, Pgs 537-47, (April 1964).

F.C. Karal, Jr., J.B. Keller

Propagation of any type of wave in a random medium is analyzed on the assumption that the medium differs slightly from a homogeneous medium. An equation satisfied by the average wave is deduced which is correct through terms of order ϵ^2 , where ϵ measures the deviation of the medium from homogeneity. From this equation, the propagation constant of the medium is determined. The general formulation applies to any type of linear differential or integral equation with random coefficients. It is applied to time-harmonic waves satisfying the reduced wave equation, to the equations of elasticity and to Maxwell's equations. The propagation constant for the average or coherent wave is complex even for a non-dissipative medium, because the coherent wave is continually scattered by the inhomogeneities and converted into the incoherent wave. The propagation velocity of the average wave is also diminished by the inhomogeneities. This propagation constant depends upon certain trigonometric integrals of the auto- and cross-correlation functions of the coefficients in the original equations, i.e. of the various coefficients characterizing the medium. To illustrate the results, media with particular random variations are considered and the propagation constants are determined for them.

GEOMAGNETIC PULSATIONS AND THE EXOSPHERE

EE Abstr. 6572/1964; Sci. Engng Rev. Doshisha Univ. (Japan), Vol. 4, No. 2, Pgs 83-95, (Nov. 1963). In Japanese.

T. Kitamura

Frequency-time analysis of geomagnetic giant pulsations (P_g 's) is made on the basis of IGY data, and the following four types are found: (1) A type having an increasing frequency with time (called here ascending tone). (2) A type having a decreasing frequency with time (descending tone). (3) A type having a constant frequency with time. (4) A type having an irregular frequency with time. A phenomenon like a beat having regularly varying amplitudes with time is often found. By examining in

more detail its frequency character as above from this point of view, it is seen that the first half shows the ascending tone character and the latter half the descending tone, or vice versa. On the other hand, if the occurrence frequency of P_g 's is plotted against local time, two maxima are found: one is in the morning (0900 LT) and the other in the evening (1900 LT). The ascending type P_g 's tend to occur more often in the morning, the descending ones more frequently in the evening. In order to interpret these phenomena (1) dispersion mechanism, (2) doppler mechanism, (3) variable frequency mechanism, (4) cavity mechanism are considered, and it is found that the cavity mechanism is most reliable.

LINEAR PHASE SHIFTER WITH UNRESTRICTED RANGE

EE Abstr. 3510/1964; Instrum. Pract. (GB), Vol. 17, No. 12, Pgs 1320-3 (Dec. 1963).

H. Koppe, L. Everts

This phase shifter comprises a symmetrical twin-T bridge for which it is stated that an unrestricted virtually linear phase shift will be attained, with constant network attenuation, when small sections of both shunt and one arm series resistors are varied around balance according to appropriate sinusoidal functions. The mathematical theory is given of the device for both resistive and capacitive phase shift control. Because ganged sine-potentiometers may be applied to give a full range of control, an explanation of the operation of such potentiometers is given.

SELECTIVE LOW-FREQUENCY AMPLIFIER WITH A NARROW RECTANGULAR FREQUENCY CHARACTERISTIC

Phys. Abstr. 16403/1964; Priboiy Tekh. Eksper (USSR), 1960, No. 2, 74-6, (March-April). In Russian. English trans. in: Instrum. Exper. Tech. (USA), No. 2, 257-60 (Dec. 1960).

E.V. Kuchis

A low-frequency, narrow-band amplifier is described, which ensures a constant amplification factor flat to 3% in a frequency band 1 c/s wide. The center frequency of the amplifier is 20 c/s. The amplification factor $K = 5 \times 10^6$.

AN EFFECTIVE METHOD FOR ELECTRICAL COMPENSATION OF THE PRIMARY FIELD IN THE AIRBORNE INDUCTION METHOD

EE Abstr. 8532/1964; Izv. Akad. Nauk SSSR, Ser. Geofiz., 1963, No. 10, 929-31 (Oct. 1963; publ. Jan. 1964).

S.L. Kuzovkin

Present methods of compensating the primary field signal have disadvantages when applied under practical conditions. The method

described consists of measuring both field components and then equating the module of the two signals and adding them electronically. A signal is thus derived which is a measure of the secondary field component. Several advantages of the method are discussed.

INDUCTION PICKUPS FOR MEASURING WEAK MAGNETIC AUDIO-FREQUENCY FIELDS

Phys. Abstr. 16612/1964; Izv. Akad. Nauk SSSR. Ser. Geofiz., 1963, No. 11, 1684-90. In Russian. English trans. in: Bull. Acad. Sci. (USSR), Geophys. Ser. (USA), No. 11, 1017-21 (Nov. 1963; publ. Feb. 1964).

D.G. Levchenko, A.F. Kotyuk

In induction methods of surface and airborne electromagnetic prospecting little attention has been paid to the reduction in size and weight of apparatus whilst maintaining sensitivity and stability. The deciding factor would appear to be the choice of a suitable ferrite core. The relevant theory is given and the selection of material and the optimum shape are discussed.

THE ASSIGNMENT OF WAVE FUNCTIONS TO ENERGY DENSITIES AND PROBABILITY DENSITIES

Phys. Abstr. 5020/1964; Nuovo Cimento (Italy), Vol. 30, No. 5, 1291-7, (1 Dec. 1963).

J.S. Lomont, H.E. Moses

In many problems involving wave propagation, the squares of the absolute values of the wave functions rather than the wave functions themselves are the physically observable quantities. These quantities are interpreted as energy densities in the case of electromagnetic radiation, for example, and as probability densities in quantum mechanics. The objective of the present paper is to give a theorem involving Fourier integrals which indicates a set of physical measurements of energy densities and probability densities in one-dimensional problems which lead to an essentially unique determination of the wave functions. For use in quantum mechanics, the measurements which are required can be expressed as the mean values of certain operators constructed from the position and momentum operators. These are also given.

COMMENTS ON "RADIATION FIELDS FROM A HORIZONTAL ELECTRIC DIPOLE IN A SEMI-INFINITE CONDUCTING MEDIUM"

EE Abstr. 3985/1964; IEEE Trans Antennas & Propagation (USA), Vol. AP-11, No. 3, 372-3, (May 1963).

R.S. MacMillan, W.V. Rusch, A.W. Biggs, J.D. Belenski

In reply to a communication by Biggs and Belenski (ibid., Vol. AP-10, 358-62 (July 1962)) the authors draw attention to a conductivity survey carried out in 1956 in three different areas namely, the Mojave Desert,

the Peninsula Range province and a section of the Sierra Nevada mountains. In the first area conductivity was unexpectedly high (max. 0.0147 mhos/m) considering the low rainfall (< 2 in) and was attributed to capillary forces acting through rock fractures. In the other two regions of relatively unfractured granite the conductivity was between 0.000477 and 0.000196 mhos/m. They also give details of experiments carried out with a pure skywave as proposed by Biggs and Belenski. In a further reply Biggs and Belenski give additional information about the radiation from dipoles both at and below the earth's surface. These are results of experiments being currently carried out by the Boeing Company which permits the use of low transmitter power with high resolution for skywave sounding. A block schematic of the arrangement is given.

PHYSICS OF LIGHTNING

Phys. Abstr. 17900/1964; London: English Universities Press (1963)
xv + 176 pp.
D.J. Malan

Brief summary of the various types of thundercloud and lightning discharge. A description of lightning cameras is followed by a detailed examination of the mechanism and characteristics of an earth discharge and the methods of measurement and the amplitudes and wave shapes of electric field changes. A description of the generation and distribution of cloud charges leads to a presentation of modern theories of the mechanism of charge generation. Factual data are given on the magnitudes and wave shapes of lightning currents. The electromagnetic radiation from earth discharges, "sferics" and whistlers are dealt with. Brief reference is made to the protective effect of lightning conductors, flash counters and direction finding. An account is given of the different effects of the lightning discharge, its optical spectrum and frictional static charges. The book covers theoretical and experimental aspects and is well illustrated, but the bibliography is largely confined to references to text books and Codes of Practice on Lightning Protection in the English language.

SUB-AUDIO FREQUENCY (1 TO 50 CPS) GEOMAGNETIC FLUCTUATIONS AT DENVER, COLORADO

Abstract in Proceeding of the 1960 Conference on the Propagation of ELF Radio Waves, Nat. Bur. Stands. (USA), Boulder Labs., Technical Note No. 61, 1960.
E. Maple.

Magnetic-tape recording of three components of the geomagnetic fluctuations in the 1 to 50 cps range was begun at five field stations under IGY Project 3.10. The present progress report is based principally on six months of data from the Denver station. At playback, the recorded waveforms are filtered, rectified, and integrated to yield

values of average magnetic-field strength in six frequency bands. A single value is obtained for the first fifteen minutes of each hour for each frequency band of each component. At the middle latitude station of Denver, almost all of the fluctuations throughout the 1 to 50 cps range are judged to be all of thunderstorm origin during most of the six-month interval. The wave-guide mode propagation theory is applicable down to frequencies of about 10 cps, the minimum attenuation being reached at about 20 cps. Below 10 cps, the attenuation again increases; at still lower frequencies, the induction component of the field of the lightning discharge, rather than the radiation component, becomes the controlling factor. At frequencies below about 4 cps, there are occasional fluctuations which appear to be geomagnetic in the sense that they are related to the K indices. During winter, fluctuation levels at these frequencies are often near or below the instrument noise level. Meteor-shower effects in this frequency range are discussed in a separate paper.

THE NEAR ELECTROMAGNETIC FIELD

EE Abstr. 6512/1964; Electro-Technology (USA), Vol. 73, No. 1, Pgs 55-73 (January 1964).

C.L. Marquardt

An analysis of the electromagnetic field at points relatively close to a transmitting aerial (that is, in the region where the induction field component is significant). The near fields produced by a vertical electric or magnetic dipole over a plane boundary, such as water or flat terrain, are considered in detail.

ELECTRON BEAM MAGNETOMETERS

Phys. Abstr. 13415/1959; J. Res. Nat. Bur. Stand. (USA), V. 63C, No. 1, Pgs 69-75, July-September 1959.

L. Marton and Others

A theoretical investigation of the electron optics of an electron beam deflection method for detecting small magnetic fields is presented. It is shown that remarkably high sensitivity can be reached. A laboratory model of such a magnetometer was constructed and it was demonstrated that the theoretical estimate of sensitivity, 3×10^{-5} A/Oe, could be attained in practice. A discussion of the possible improvements which could extend the sensitivity of the device is also given.

GENERAL CHARACTERISTICS OF pc-TYPE PULSATIONS

Phys. Abstr. 10770/1964; Austral. J. Phys., Vol. 16, No.4, Pgs 507-13, December 1963.

R.W.E. McNicol, J.S. Mainstone

An analysis of geomagnetic micropulsations of the p.c. type, i.e. continuous pulsations detectable for several hours at a time, recorded at Brisbane (35°S geomagnetic latitude) from May to October 1962 has shown that the frequency spectrum was usually spread over several octaves even when the waveform shown on the chart records was quasi-sinusoidal. The greatest spread was around midday, being from about 0.02 to 0.08 c/s on days of mild magnetic activity ($K_p = 3$). Generally p.c. occurred most strongly between about 0600 and 2000 LMT but on occasions were recorded throughout the whole 24 hours. A striking feature was the sudden change in activity which frequently took place within an interval of a few minutes. Good correlation was obtained between both the amplitude and the highest frequency in the p.c. spectrum, and K_p .

MEASUREMENT OF THE PARAMETERS OF AN ELLIPTICALLY POLARIZED FIELD IN INDUCTIVE ELECTRIC PROSPECTING

EE Abstr. 5720/1964; Izv. Akad. Nauk SSSR. Ser. Geofiz., 1963, No. 7, 1050-63. In Russian. English trans. in: Bull. Acad. Sci. USSR, Geophys. Ser. (USA), No. 7, 641-8, July 1963.

L. Ya. Mizyuk, V.M. Podzhari

Consideration is given to certain of the properties of an elliptically polarized low frequency electromagnetic field and to the parameters that are measured in the inductive method. Mathematical expression is given to the relationship between the parameters of the ellipse of polarization and the signals arising in the receiving elements. An analysis is made of block diagrams for the construction of apparatus suitable for the measurement of the parameters of an elliptically polarized field in electric prospecting on the ground and from the air.

ADJUSTING DOUBLE-FREQUENCY SATURATED MAGNETIC PROBES

Phys. Abstr. 16614/1964; Pribery Tekh. Eksper (USSR), 1960, No. 4, Pgs 147-8 (July-August). In Russian. English trans in: Instrum. Exper. Tech. (USA), No. 4, 671 et seq. (1960; publ. Feb. 1961).

N.I. Mocheshnikov, V.F. Ivanov, V.V. Petrenko

A simple method of calculating or compensating for the "unbalanced e.m.f." of saturated magnetic probes is described, which is accurate up to the limit of geomagnetic variations that occur during the measurements.

SOME DIFFERENT TYPES OF WHISTLERS IN RELATION TO SIMULTANEOUS THUNDER-STORM ACTIVITY

Phys. Abstr. 7851/1964; Ark. Geofys (Sweden), Vol. 4, Paper 14, Pgs 333-43 (1963).

H. Norinder, E. Knudsen

It was found that the same thunderstorm region produced usual as well as unusual and mixed variational forms of whistlers. The production of the different types proved to be independent of the geographical positions of the active thunderstorm regions. By the aid of different characteristics of lightning discharges it was not possible to draw conclusions as to why different types of whistlers were produced. The reason must be sought in some other geophysical phenomena, and only further systematic experimental investigations will give an answer to this question.

DELAY-LINE SPEED-UP DEVICES FOR ANALYSIS OF RANDOM VIBRATION DATA
EE Abstr. 8482/1964; Proc. Inst. Electronics Engrs (USA), Vol. 52,
No. 2, 219-20, February 1964.

A.G. Ratz

In the spectral analysis of low frequency random vibration or acoustic signal, sampled signals are fed into a recirculating delay line so as to have the effect of multiplying all frequencies by as much as 10^5 times. The proposed system is useful if the analyser bandwidth is $\ll 1$ c/s or if the random signals have very low frequency components, but has limitations for higher frequency data. It is suggested that statistical errors be reduced by repeating the analysis on successive samples and using a digital computer to analyse the result.

OPTICALLY PUMPED NUCLEAR MAGNETOMETER

EE Abstr. 3230/1964; Rev. Sci. Instrum (USA), Vol. 34, No. 12, 1363-6 (Dec. 1963).

L.D. Schearer, F.D. Colegrove, G.K. Walters

A continuous recording total earth's field magnetometer has been demonstrated which utilizes optical pumping in He^3 and the resultant polarization of the nuclear spins. The device operates as a "self-oscillator" at the Larmor frequency of the ground state atoms. The oscillator has a "Q" of 10^4 in a 0.5-G field. The sensitivity of the instrument to fluctuations in the magnetic field is presently several microgauss. The characteristics and operating principles of the instrument are described. The application of the device to the measurement of the absolute value of the total external magnetic field is discussed.

ON THE INTEGRATED FIELD INTENSITY OF ATMOSPHERICS

Phys. Abstr. 17901/1964; J. Atmos. Terrest. Phys. (GB), Vol. 26, No. 3, 367-74 (March 1964).

K. Sao

For the purpose of continuous observations of atmospherics the integrated field intensity is usually measured. However, in the case of the evaluation of the attenuation coefficient for the v.l.f. radio wave propagation by the use of the integrated field intensity of atmospherics, a method using statistics must be used because of the properties of Gaussian noise in the continuous and random atmospherics. The author derives the expression of the integrated field intensity of atmospherics on the basis of statistics. After that, employing the expression, the attenuation coefficient at a frequency of 27 kc/s and the variation of it at SEA conditions (sudden enhancement of atmospherics) are evaluated.

ESTIMATED CAPABILITY OF A TYPE OF INDUCTIVE PROSPECTING BY AIRPLANE

EE Abstr. 5721/1964; Izv. Akad. Nauk SSSR, Ser. Geofiz, 1963, No. 7, Pgs 1064-71. In Russian. English trans. in: Bull. Acad. Sci. USSR, Geophys. Ser. (USA), No. 7, 649-55 (July 1963).

Yu. B. Shaub

A one-airplane inductive method of prospecting without a towed "bird" is considered. Anomalies are calculated for a spherical ore body, a thin steep-dipping bed, and a homogeneous conducting half-space (geologic resistivity mapping).

A RECORDING PROTON PRECESSION MAGNETOMETER

EE Abstr. 4556/1964; Indian J. Pure Appl. Phys., Vol. 2, No. 1,
Pgs 23-8, January 1964.
J.S. Shirke

A proton precession magnetometer, designed and constructed for the measurement of the total magnetic field, is described. The sensing of the field is done once in 20 sec., and there is provision for stepping up the speed during interesting events. An overall accuracy of better than 1 gamma in the total field is achieved. The output is available in digital form for monitoring as well as for simultaneous recording on a triplex recording meter. The diurnal variation of the field is clearly seen in the records. The instrument is being used for studying selected interesting geomagnetic events.

THE ELECTROMAGNETIC FIELD OF A LOOP CARRYING AN ALTERNATING CURRENT ABOVE A CONDUCTING LAYER

Phys. Abstr. 14863/1964; Zh. Tekh. Fiz. (USSR), Vol. 34, No. 1, 131-41 (Jan. 1964). In Russian. English trans. in: Soviet Physics-Technical Physics (USA), Vol. 9, No. 1 (July 1964).
V.P. Shmelev, Yu. M. Shkarlet

The electromagnetic field is investigated in the quasi-stationary approximation for a current with a frequency ω in a loop situated above a layer of finite thickness and conductivity σ_1 . It is found that the field decays asymptotically with power $(\omega\mu_0)^{-\frac{1}{2}}$. The results are expressed in complete elliptic integrals. For the case $\omega = 0$ the static magnetic field is expressed by a convergent series.

IDENTITY OF SOLUTIONS FOR A HORIZONTAL ELECTRIC DIPOLE IN A CONDUCTING HALF-SPACE

EE Abstr. 9071/1964; Proc. Inst. Elect. Electronics Engrs (USA), Vol. 52, No. 2, 190-1, (February 1964).
W.B. Sisco, B.W. Porter

Expressions developed by Norton in 1936, Banos and Wesley in 1954 and Wait in 1961 are shown to be identical in the far field, i.e. at a large range and on the conducting surface.

SYMPOSIUM ON THE IONOSPHERIC PROPAGATION OF VLF RADIO WAVES

EE Abstr. 6565/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 1, iv + 136 pp. Jan. 1964.

Covers the Proceedings of the Symposium held at the Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, Colorado, on the 12th, 13th and 14th August 1963. There are 22 papers which are devoted

subjects of current importance in terrestrial vlf propagation and the effects of the ionosphere. In particular, the following are included: (a) mode theory; (b) theory of formation and physical characteristics of the lower ionosphere; and (c) observations of vlf propagation under normal and disturbed conditions. Abstracts of the papers will be found in this and subsequent issues of Electrical Engineering Abstracts.

RUBIDIUM VAPOUR MAGNETOMETER

Phys. Abstr. 5739/1964; Z. InstrumKde (Germany), Vol. 71, No. 10, 283-6 (October 1963). In German.
W.A. Stolz

This magnetometer employs optical pumping, and is described in more detail with emphasis placed on the theory of optical pumping.

WHISTLERS OF EXCEPTIONALLY SMALL DISPERSION OBSERVED AT KYOTO

EE Abstr. 6575/1964; J. Atmos. Terrest. Phys. (GB), Vol. 26, No. 1, 137-9, (Jan. 1964).
H. Tokuda

Reports observations made at Kyoto in late January 1963, in which whistlers recorded possessed dispersions as low as 10, comparing with usual values between 20 and 40. Observations were made under good signal-to-noise conditions, and a particular whistler is discussed. Three possibilities which are considered to interpret the phenomena are given.

A HIGH-SENSITIVITY MAGNETOMETER FOR RECORDING SHORT-PERIOD OSCILLATIONS OF THE EARTH'S MAGNETIC FIELD IN THE FREQUENCY RANGE 0.1-10 CPS AND SOME RESULTS OF MAGNETOTELLURIC SOUNDINGS IN THE REGION OF THE "BOROK" GEOPHYSICAL STATION

EE Abstr. 5761/1964; Izv. Akad. Nauk. SSSR. Ser. Geofis., 1963, No. 7, Pgs 1081-6. In Russian. English trans. in: Bull. Acad. Sci. USSR, Geophys. Ser. (USA), No. 7, 59-62 (July 1963).
Véi Tsin-Yun (Wei Ts'ing-Yñh).

No abstract

LIGHTNING STROKE CURRENT MEASUREMENT BY MEANS OF THE FRAME AERIAL METHOD

EE Abstr. 4505/1964; Bull. Electrotech. Lab. (Japan), Vol. 27, No.8, 569-78 (July 1963). In Japanese.
S. Tsurumi, K. Kinoshita, K. Yamamori

The measurements were carried out in Gumma Prefecture in 1961 and at the Electrotechnical Laboratory in Tokyo in 1962. In order to

avoid the disturbance due to the elevation of the earth potential, a symmetrical measuring circuit was adopted and the apparatus was sufficiently shielded to suppress the electromagnetic induction. The integrating time constant of the aerial circuit was 1 msec. It was possible to measure the lightning stroke current within a radius of 10 km. The number of records was 16 in 1961 and 70 in 1962. The results of the records are as follows: 60% of the lightning current amplitudes lie between 16 to 30 kA; 90% of the lightning strokes are of negative polarity; 70% of the wave fronts lie between 2 to 4 μ sec; 50% of the wave tails lies between 30 to 60 μ sec. These results are similar to previous work.

ON THE QUANTITIES CHARACTERIZING THE BUILD-UP OF A FIELD

Phys. Abstr. 16623/1964; Izv. Akad. Nauk SSSR, Ser. Geofiz., 1963, No. 11, 1691-3. In Russian. English trans in: Bull Acad. Sci. (USSR), Geophys. Ser. (USA), No. 11, 1022-3 (November 1963; publ. Feb. 1964).
L.L. Van'Yan

At present there is no standard set of quantities to describe the process of establishing an electromagnetic field. The paper considers the two basic parameters of electrical prospecting applicable to field build-up; the apparent resistance and the effective distance.

THE ELECTROMAGNETIC FIELD OF A HARMONIC DIPOLE GROUNDED AT THE SURFACE OF A MULTI-LAYERED ANISOTROPIC MEDIUM

Phys. Abstr. 16661/1964; Izv. Akad. Nauk SSSR, Ser. Geofiz, 1963, No. 8, 1222-3; In Russian. English trans in: Bull. Acad. Sci. USSR, Geophys. Ser. (USA), No. 8, 740-1, (Aug. 1963; publ. Dec. 1963).
L.L. Van'Yan

Analytic expressions are derived for the electric field of a harmonic dipole located on the surface of an anisotropic medium made up of an arbitrary number of layers, and applied to the particular cases of very low and very high frequencies.

DIURNAL PHASE VARIATIONS OF VLF WAVES AT MEDIUM DISTANCES

EE Abstr. 6568/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 2, Pgs 225-38 (Feb. 1964).
H. Volland

Methods of phase measurements at vlf are briefly described. Some results of diurnal phase measurements, sunrise effects, and solar flare effects at medium distances and northern geographic latitudes are summarized. Two inhomogeneous and anisotropic models are used for the interpretation of the measurements: the first corresponding to the day-time ionosphere and the second corresponding to the night-time ionosphere. The models are related to homogeneous models with sharp boundaries and effective parameters of conductivity, dielectric

constant and equivalent height. The diurnal phase lag, depending on distance, and the sunrise effects at 1000 km and 2000 km are interpreted by these models. Two critical distances exist where the nighttime phase gains a phase advantage of 350° relative to the daytime phase. An electron profile of the daytime lower ionosphere is deduced from measured daytime variations of equivalent height. The strength of ionizing solar radiation during a solar flare and the effective attachment coefficient of the lower ionosphere are derived from measured variations of the equivalent height during a solar flare.

REVIEW OF MODE THEORY OF RADIO PROPAGATION IN TERRESTRIAL WAVEGUIDES
EE Abstr. 3991/1964; Rev. Geophys. (USA), Vol. 1, No. 4, 481-505
(Nov. 1963).
J.R. Wait

An expository review of the theory of guided waves that occur in the earth's atmosphere. The authors introduce the subject by treating the problem of radio propagation around the surface of an airless spherical earth. This leads readily to the classical solutions of van der Pol and Bremmer and the more recent work of Fock in the USSR. The influence of a troposphere with a smooth profile of refractive index is then considered. This analysis, which follows the recent work of Armand, confirms that a monotonically varying or smooth profile will not change the basic structure of the diffraction field. The modifications resulting from the presence of a tropospheric duct are developed by using a parabolic profile of refractive index in the manner suggested by Fock, Weinstein, and Belkina. It is shown that the dominant modes in this system have low attenuation. The second and major part of the paper is devoted to the theory of the mode propagation of vlf radio waves. Here the effective waveguide is the space formed by the earth's surface and the lower edge of the ionosphere. The mode solution is developed as a natural generalization of the classical airless-earth theory. It is shown, for frequencies less than about 10 kc/s, that the field may be described in terms of flat-earth modes analogous to those in a straight ~~rectangular~~ microwave guide. At higher frequencies, however, the earth curvature plays a major role and the character and excitation of the modes are changed drastically. Complications resulting from the anisotropy of the ionosphere are also considered. A critical discussion of the recent work on the subject is given. 136 references.

REFLECTION OF VLF RADIO WAVES FROM AN INHOMOGENEOUS IONOSPHERE. III.
EXPONENTIAL MODEL WITH HYPERBOLIC TRANSITION
EE Abstr. 4010/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 67D, No. 6,
747-52 (Nov.-Dec. 1963).
J.R. Wait, L.C. Walters

For Pt. II see Abstr. 1265 of 1964. An exponential conductivity profile is perturbed in such a manner that the conductivity is increased

for all heights above a certain level. A hyperbolic tangent transition is employed in order to avoid discontinuities in the conductivity versus height profile.

OBLIQUE PROPAGATION OF GROUNDWAVES ACROSS A COASTLINE. III.
EE Abstr. 5259/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 3,
291-5 (March 1964).
J.R. Wait.

This paper, which is a continuation of two earlier papers of the same title (Abstr. 15861-2 of 1963) contains numerical results for the field anomaly near a coastline when the surface impedance changes in a linear manner between land and sea. The earlier results for an abrupt boundary are recovered as the width of the transition region is reduced to zero. In general, it is found that the characteristics of the transition region will not produce significant modifications of the transmitted field. However, the magnitude of the reflected field is greatly reduced as the width of the transition zone is increased beyond about one-quarter wavelength.

SOME REMARKS ON MODE AND RAY THEORIES OF VLF RADIO PROPAGATION
EE Abstr. 7894/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 1,
79-80 (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves,
Boulder, 1963).
J.R. Wait

Some of the assumptions used in treatment of the mode theory of vlf radio propagation are discussed briefly. The connections with geometrical-optical theories are also pointed out.

TWO-DIMENSIONAL TREATMENT OF MODE THEORY OF THE PROPAGATION OF VLF
RADIO WAVES
EE Abstr. 7895/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 1,
Pgs 81-93 (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves,
Boulder, 1963).
J.R. Wait

This paper is partly of a tutorial nature. The intended purpose is to exploit the essential two-dimensional nature of wave propagation in the earth-ionosphere waveguide. It is shown that, without resorting to erudite arguments in the complex plane, the usual working formulae of vlf mode theory may be derived directly from orthogonality considerations. Furthermore, the physical insight gained by the present development immediately suggests how the formulae may be generalized to an earth-ionosphere waveguide of non-uniform width.

ON THE THEORY OF SCHUMANN RESONANCES IN THE EARTH-IONOSPHERE CAVITY
EE Abstr. 9074/1964; Canad. J. Phys., Vol. 42, No. 4, Pgs 575-82,
April 1964.
J.R. Wait

The concept that the concentric region between the earth and the ionosphere acts as a cavity resonator was proposed by Schumann over a decade ago. It is the purpose of this paper to review the theory of these cavity resonances. Some of the assumptions used in current work on the subject are also discussed. An alternative derivation is presented which appears to be more general than any given heretofore.

SPECTRUM OF BARKHAUSEN NOISE FOR PERIODIC MAGNETISATION OF FERRO-MAGNETIC MATERIALS IN BULK
Phys. Abstr. 4683/1964; Proc. Instn. Elect. Engrs (GB), Vol. 111, No. 2, 387-92, Feb. 1964.
K.G. Warren, K.B. Reed

A technique was developed to isolate the Barkhausen noise resulting from the cyclic magnetization of transformer cores; spectral and total noise measurements were made for silicon-iron, nickel-iron, and ferrite samples. The results are analysed in the light of theoretical work, which hitherto lacked adequate experimental evidence, and an empirical formula is developed relating the spectral-power density and the magnetizing frequency. The total noise obtained by the integration of this formula agrees closely with the measured value. Some consideration is given to the structure of the noise when treated as a succession of voltage impulses randomly dispersed about periodic positions within a framework of fixed zeros. These zeros coincide with the instants of reversal of the magnetizing field.

COMPARISON OF OBSERVED VLF ATTENUATION RATES AND EXCITATION FACTORS WITH THEORY
EE Abstr. 7882/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 1, 1-9 (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves, Boulder, 1963).
A.D. Watt, R.D. Croghan

The properties of VLF propagating modes are briefly reviewed and simplified equations are presented which can be employed in calculating the fields produced. Experimentally determined excitation factors are compared with theoretical curves obtained by Wait and found to agree rather closely. Attenuation rates are shown as a function of frequency and are found to agree rather closely with calculated values using a proposed simplified perturbation solution for attenuation rates based on reflection coefficients at the ground and ionosphere. When employing values of ionospheric reflections coefficients recently presented by Wait and Walters,

the nonreciprocal effects in attenuation rate are found both theoretically and experimentally to be much greater in the 10 kc/s region than in the 20 to 30 kc/s region. Finally, experimental field strength versus distance data are compared with mode calculations and found to compare well all the way from 1 megameter out to and including fields at the antipode (20 megameters).

MEASUREMENTS OF NOISE POWER WITH THE SQUARE LAW DIELECTRIC DIODE
EE Abstr. 5711/1964; J. Sci. Instrum (GB), Vol. 41, No. 3, 169-71,
(March 1964).
P. Webb, G.T. Wright

Space charge limited current in solids ideally follows a square-law dependence on applied voltage. Deviations from this law are caused by carrier diffusion at low voltages and by field dependence of carrier mobility at high voltages. Between these extremes is a useful range of three to four decades of current available from zero to ultra-high frequencies. Experimental measurements of power in the random voltage waveform of noise fluctuations are shown and illustrate the linear relation between noise power and diode current.

VLF PROPAGATION UNDER THE IONOSPHERE IN THE LOWEST MODE OF HORIZONTAL POLARIZATION

Phys. Abstr. 16669/1964; J. Res. Nat. Bur. Stand. (USA), Vol. 68D, No. 1, 105-13 (Jan. 1964). (Ionospheric Propagation of VLF Radio Waves, Boulder, 1963).
H.A. Wheeler

In the lower part of the vlf band, around 4 kc/s, it appears that the lowest rate of attenuation is obtainable by horizontal polarization in the TE-01 mode. This offers a substantial advantage relative to vertical polarization in the usual TM-01 mode and the simple TM-00 or TEM mode. Some types of aeriels are found to be suitable for the TE-01 mode, namely, a horizontal wire above ground or a vertical loop, either one located in a plane perpendicular to the direction of transmission. A theoretical study is summarized, leading to the conclusion that this mode offers some unique features and is suitable for transmission to distances of the order of 4,000 km.

ELECTROMAGNETIC LEVITATOR

EE Abstr. 3177/1964; Amer. J. Phys., Vol. 31, No. 12, 925-9, Dec. 1963.
H.E. White, H. Weltin

Describes the construction of an electromagnetic levitator whose small size makes possible the use of easily obtainable surplus capacitors, and puts the levitator within the skill and the budget of a modest physics department shop.

AN INEXPENSIVE OPTICAL-LEVER AMPLIFIER FOR STUDYING THE BROWNIAN MOTION OF A GALVANOMETER

Phys. Abstr. 5369/1964; Amer. J. Phys., Vol. 31, No. 12, 922-5, (Dec. 1963).

K.S. White

A simple optical-lever amplifier constructed from components normally available in a university physics department is described. The design was based on one by Jones (1952), but was modified so that it could be built by a final-year undergraduate. The amplifier was used to study the Brownian motion of a galvanometer. The value of Boltzmann's constant k was found to be $(1.46 \pm 0.1) \times 10^{-23} \text{ J}^\circ\text{K}^{-1}$, the accepted value being $1.38 \times 10^{-23} \text{ J}^\circ\text{K}^{-1}$.

A NEW APPROACH TO THE SPECTRUM ANALYSIS OF NON-STATIONARY SIGNALS
EE Abstr. 6448/1964; IEEE Trans. Applic. Industr. (USA), No. 69, 322-7 (Nov. 1963).

W.W. Wierwille

The problem of the measurement of the power spectrum of a random waveform non-stationary signal is considered and the power spectrum is defined by an expression which is the accurate description of the power spectrum of a non-stationary ensemble of signals. The errors in the detection process due to finite filter bandwidth and finite smoothing time are considered and the time uncertainty and frequency resolution estimated. The design of a practical non-stationary spectrum analyser is sketched and an experimental method of obtaining its constants described.

CHARGE DENSITY RESPONSE IN A LOSSY MEDIUM

EE Abstr. 3467/1964; IEEE Trans. Antennas & Propagation (USA), Vol. AP-11, No. 3, 372 (May 1963).

R.H. Williams

In linear time-invariant isotropic media the current density J can be separated into two terms, a source term J_0 and σE the conduction current response term to the impressed source J_0 . Similarly the charge density ρ can be separated into a source term and a response term. In this case in the sinusoidal steady state the total

charge density ρ is $\rho c/I - J \frac{\sigma}{\omega \epsilon}$ and the step function response is

$\rho = e^{-(\sigma/\epsilon)t}$. The working out of the solutions from Maxwell's equations is given.

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