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NRL Report 4657

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VERY - LOW - FREQUENCY INTERCEPT SYSTEM
(Unclassified Title)

Kenneth G. Snyder

Countermeasures Branch
Radio Division

DECLASSIFIED by NRL Contract
Declassification Team
Date: 16 MAR 2017
Reviewer's name(s): [redacted]
Declassification authority: NAVY DECLASS GUIDE/NAVY DECLASS MANUAL, 11DEC2012
DS SERIES

November 16,1955

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ABSTRACT

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An investigation of a new type of instantaneous broadband very-low-frequency intercept system to monitor the 5 to 20 kc radio-frequency band has been conducted, and experimental equipment has been developed to demonstrate its feasibility. The system permits continuous coverage of the frequency range, and provides for visual detection and bearing determination of signals regardless of their method of modulation or length of transmission. It utilizes the familiar principles of the dual matched-channel direction finder with a cathode-ray-tube presentation. However, instead of employing the conventional, continuously tunable narrow-band circuits, this equipment uses wide-band, low-time-constant amplifiers preceded by bandpass filters of various bandwidths and center frequencies. Signal separation within the band is accomplished visually by noting the difference in angle and length of trace of the signals in the cathode-ray-tube presentation. The operational sensitivity of the wide-band intercept system is comparable to that of the narrow-band very-low-frequency communication receivers now in use by the Navy. As many as five discrete signals, differing in field strength by as much as 60 db, have been detected and their individual bearings resolved at one time.

PROBLEM STATUS

This is an interim report; work on this problem is continuing.

AUTHORIZATION

NRL Problem R06-13
Project No. NR 686-130

Manuscript submitted October 18, 1955

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VERY-LOW-FREQUENCY INTERCEPT SYSTEM
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INTRODUCTION

In the intercept field of electronic countermeasures, much progress has been made in the high-frequency region, up to and including the microwave range. However, little attention has been given to the frequency band below 20 kc except for studies on atmospherics (1). It is conceivable that such frequencies might be employed by a potential enemy for purposes and in a manner now unknown. In considering this problem, it was believed that systems utilizing techniques suitable to the spectrum below 20 kc should be investigated.

The basic requirements of a very-low-frequency intercept system are that it be capable of

(1) instantaneous detection of any type of signal regardless of its location in the band of frequencies being monitored,

(2) handling all forms of modulation and lengths of transmission,

(3) determining the direction of the source of all signals instantaneously, and

(4) operation through high levels of interference and atmospherics.

Requirement (1) precludes the use of conventional manually tuned receivers. Panoramic receivers were similarly discarded because of the sideband difficulties at the frequencies in question. Requirement (3) predicates the use of instantaneous direction-finder techniques, that is, crossed loops and instantaneous cathode-ray-tube presentation. Requirement (4) indicates the need for low-time-constant circuits.

Dual matched-channel direction-finder techniques with cathode-ray-tube presentation are well known and demonstrated in the art, and they presented no particular problem. The problem that did present itself was that of providing instantaneous coverage of wide bands of low frequencies in a way that would permit the disclosure of any new signal which may appear as well as the determination of the direction of its source. The approach to this problem was to investigate the feasibility of departing from the conventional tuned-circuit techniques of receiver design, and to try wide-band low-time-constant amplifiers, preceded and protected by bandpass filters of various bandwidths and center frequencies, which would be switched in as required. Such a technique would permit the required instantaneous wide-band coverage, provided that high sensitivity and phase stability could be achieved and maintained. This approach was investigated and found feasible for practical use by the construction and demonstration of a complete direction-finding system.

BRIEF DESCRIPTION OF PRINCIPLES

The simple sketch in Fig. 1 illustrates the basic principles of the dual matched-channel direction finder (2, 3, and 4) which was utilized in the instantaneous broadband very-low-frequency intercept system. The loop labeled N-S and the loop labeled E-W are considered to be at right angles to each other and to cross at their centers. The vertically polarized

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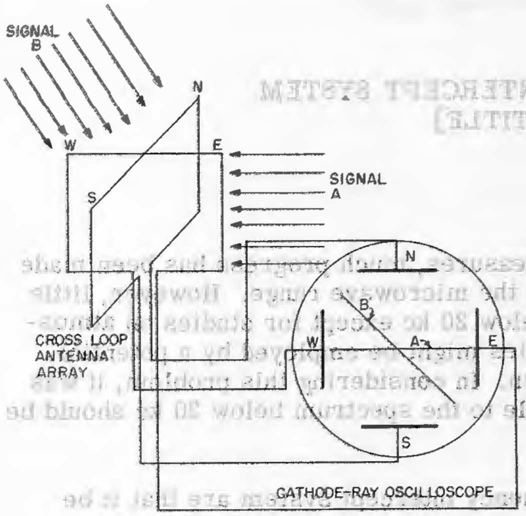

Fig. 1 - Simplified sketch to illustrate instantaneous direction-finder principles

component of an electromagnetic field crossing the antenna array will induce a voltage in each loop proportional to its direction of arrival. When these voltages are applied to the orthogonal plates of a cathode-ray tube, the angle of the resulting trace with respect to the deflection plates is the same as the direction of arrival of the wavefront to the loops of the antenna array. The wavefront of signal A is traveling from east to west. Signal A will induce a voltage in the E-W loop proportional to cos 0°, and a voltage in the N-S loop proportional to sin 0°. The resultant bearing trace on the screen of the cathode-ray tube is a straight horizontal line. Likewise, if the wavefront of signal B crosses the antenna from a northwest to southeast direction, the voltage induced in the N-S and E-W loops are proportional to cos 45° and sin 45°, respectively. The resultant trace on the screen of the cathode-ray tube is shown as line line B.

It should be noted that the cathode-ray-tube bearing presentation is independent of the type of modulation or length of transmission of the signal. Another important property of the system is its ability to display two or more signals simultaneously. If two stations operating independently of one another are utilizing type A1 emission, the display presented on the cathode-ray tube will be, intermittently, two straight lines and a parallelogram. The intergration effect of a cathode-ray tube with long persistence allows the bearings to be taken by aligning the cursor line of the alidade with the straight line bearings. If the two stations are utilizing type A0 or F1 emission, a parallelogram bearing display will appear on the cathode-ray tube. The bearings can be taken by aligning the cursor line of the alidade parallel to the sides of the parallelogram. The pattern of the bearing display is dependent upon the number of signals present, their relative strength, and the types of emission being received.

The basic arrangement shown in Fig. 1 is generally useless in intercept applications because of its lack of sensitivity and selectivity, therefore, filters and amplifiers must be added.

Mismatch in gain and phase between the two directional channels of a dual matched-channel direction finder will produce errors in the bearing readings. Figures 2, 3, and 4 are plots of bearing error versus channel phase mismatch and channel gain mismatch as the true bearings are varied. Figure 5 shows the effect of channel phase mismatch on the bearing trace when the true bearing is 45°.

EXPERIMENTAL EQUIPMENT

The block diagram of Fig. 6 shows the relative arrangement of the different units in the experimental system. These basic units are

(1) the antenna array,

(2) the bandpass filters,

(3) the receivers or amplifiers, and

(4) the indicator.

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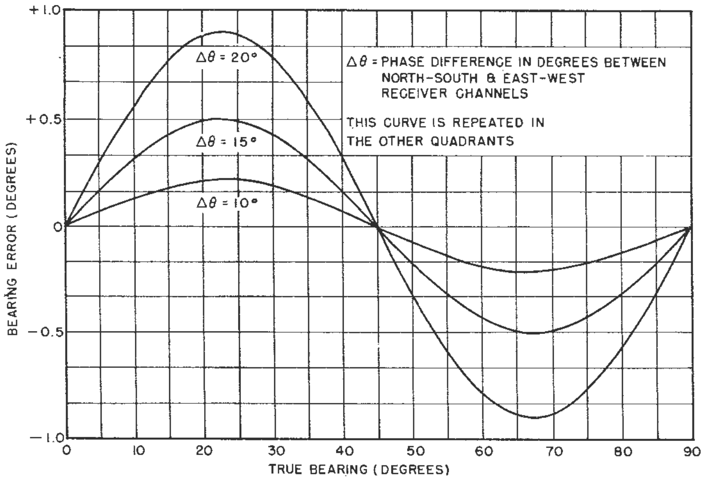

Fig. 2 - Bearing error versus channel phase mismatch (10 to 20 degrees)

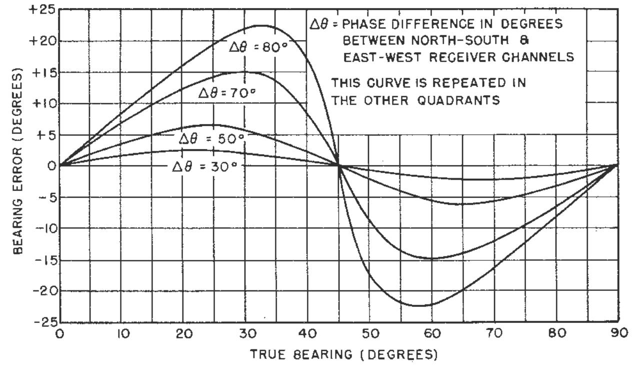

Fig. 3 - Bearing error versus channel phase mismatch (30 to 80 degrees)

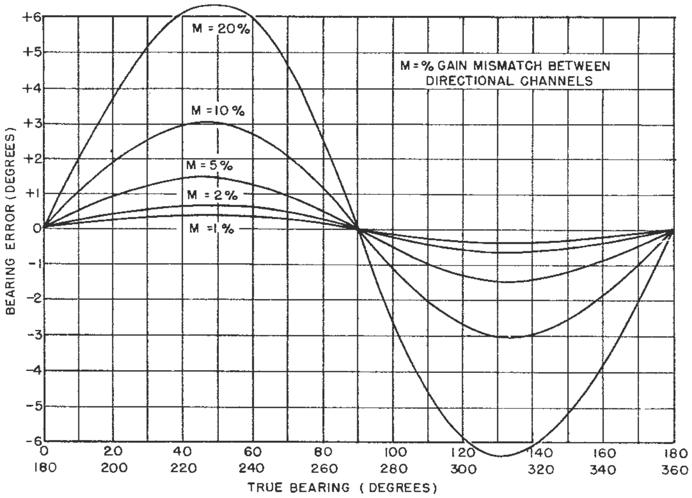

Fig. 4 - bearing error versus channel gain mismatch

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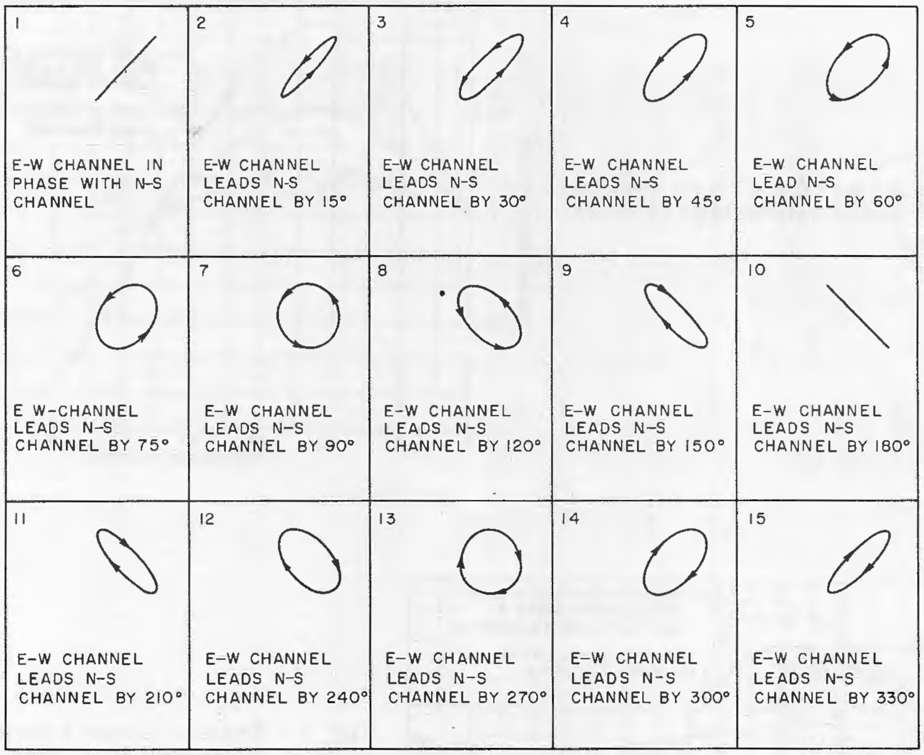

Fig. 5 - Effects of channel phase mismatch on the bearing trace for a signal arriving at a true bearing of 45 degrees

The signals are collected by the antenna array, selected by the filters, amplified in the receiver, and displayed as bearing lines on the indicator. The phase and gain match of the two directional channels are very important in the design of the equipment. It is also important to keep the time constants short enough so that no noticeable display wandering is present when the system is subjected to strong signals such as may occur in times of intense atmospheric disturbance, or when searching for very weak signals in the presence of very strong signals.

Sense determination circuits have been omitted from the experimental intercept system. It was felt that the additional circuitry that would be involved was not justified. Consideration should, however, be given to the inclusion of such circuits in operational equipment.

Antenna Unit

The effectiveness of a loop antenna at these very low frequencies is proportional to its area. Therefore, the experimental antenna array (Fig. 7) was constructed to be as large as was practical with the available materials. Each loop is nearly 80 ft high and is 140 ft across at its base. The effective height of each shielded loop of this antenna array was calculated to be 0.065 and 0.26 m at 5 and 20 kc, respectively. The calculated radiation resistance is 0.000925 microhm at 5 kc and 0.237 microhm at 20 kc. It was experimentally determined that a one-turn shielded loop antenna is optimum for this broadband matched system.

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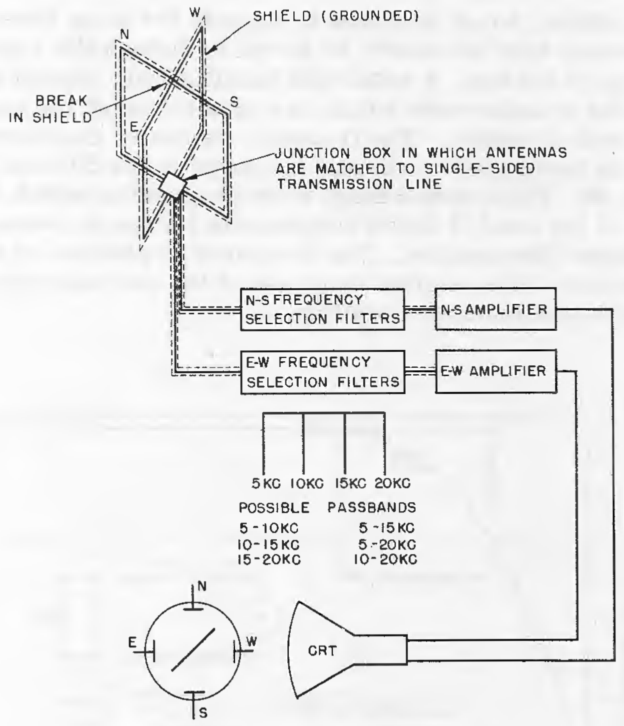

Fig. 6 - Block diagram of the broadband very-low-frequency intercept system

Fig. 7 - The cross loop antenna array

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The messenger cables, which are used to support the loops between the poles, and the guy wires are broken with insulators so as not to disturb the electric fields. The shield of each loop has a gap at the top. A watertight junction box, located near the base of the center pole, houses the transformers which are used to match the balanced loops to the 50-ohm unbalanced lead-in cables. The frequency response characteristics of all matching transformers, such as those used to connect the loops to the 50-ohm lead-in cables, are similar to within 0.1 db. The transformers were designed to match the impedance of the loops at the low end of the band (5 kc) to compensate for the increase in effective height of the loops at the higher frequencies. The measured impedance of each loop is +j4 ohms at 5 kc. Figure 8 indicates the relative response of the loop and associated circuits with frequency, compared to the matched condition.

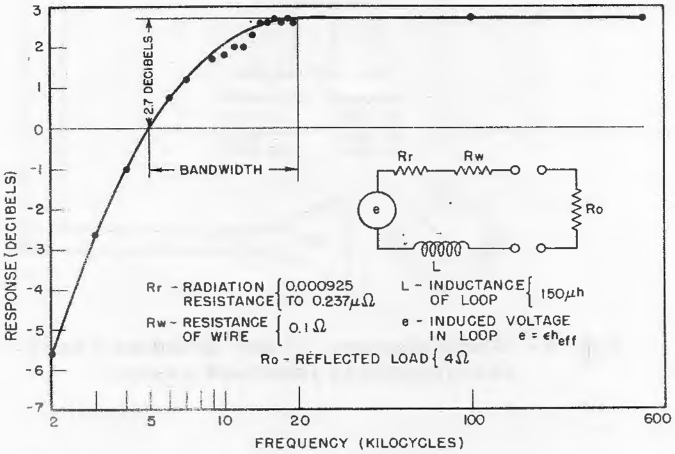

Fig. 8 - Relative signal power delivered to the receiver by the antenna array matched at 5 kc

It was understood at the time the antenna was constructed that these loops might be larger than necessary; however, since this was an experimental model, the first consideration was to build something which had a higher probability of working, delaying the "miniaturization" of the equipment until the feasibility of the system had been proved.

Filter Unit

The stringent requirement for match in both gain and phase between the two channels plus the desire for sharp cutoff characteristics make the filter unit the most complex unit in the system.

Preliminary investigations indicated the need for high quality components in the filter unit to maintain the required gain and phase relationship. High-Q toroids and mica condensers were used to fulfill these requirements. Reasonable values of both inductance and capacitance are obtained when the filters are designed for 1000 ohms characteristic impedance. Impedance matching transformers are used for the transformation of the characteristic impedance of the antenna lead-in cable (50 ohms) to the filter impedance (1000 ohms).

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The desired tuning characteristics of the filter unit (Fig. 9) are achieved by the use of three matched pairs of high-pass m-derived filters and three matched pairs of low-pass m-derived filters, which can be arranged in the circuit so that any one of six passbands can be selected by means of a switch. It was necessary to incorporate six filter sections in each filter in order to obtain the desired frequency response. The two end sections were designed with an m of 0.6 for impedance matching purposes. Two of the intermediate sections used to achieve sharp cutoff characteristics have an m of 0.2 and the remaining two sections, which are used to maintain high attenuation outside of the passband, have an m of 1.0.

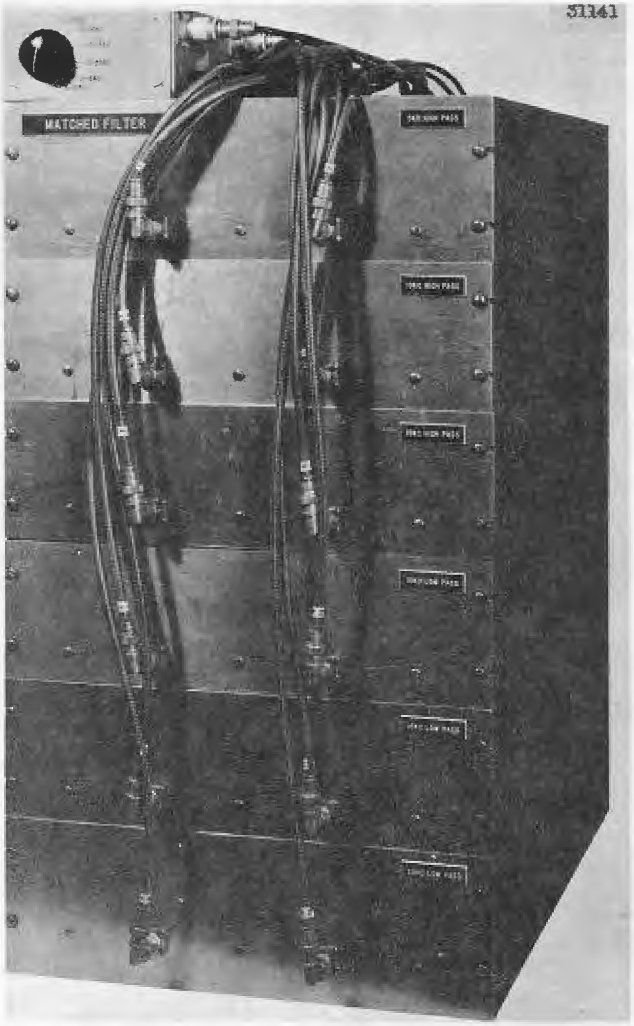

Fig. 9 - Matched-channel filter unit

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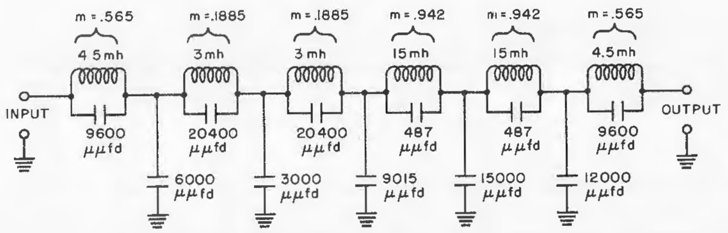

Fig. 10 - Schematic of 20-kc low-pass filter

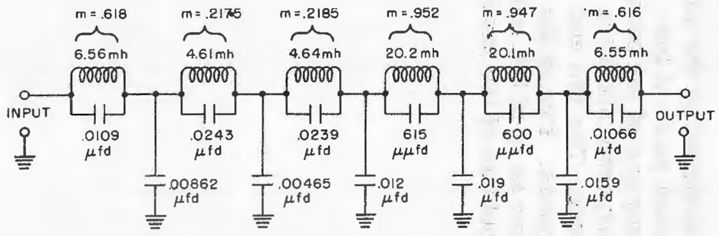

Fig. 11 - Schematic of 15-kc low-pass filter

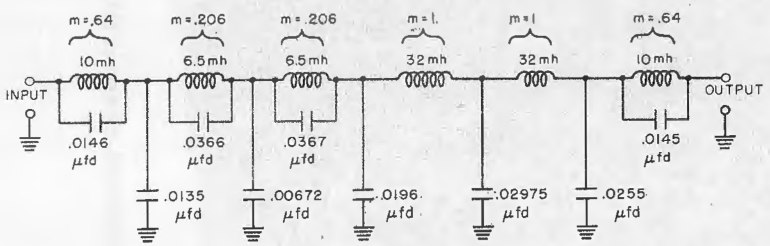

Fig. 12 - Schematic of 10-kc low-pass filter

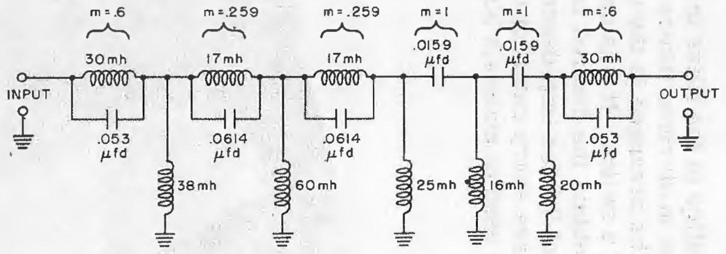

Fig 13 - Schematic of 5-kc high-pass filter

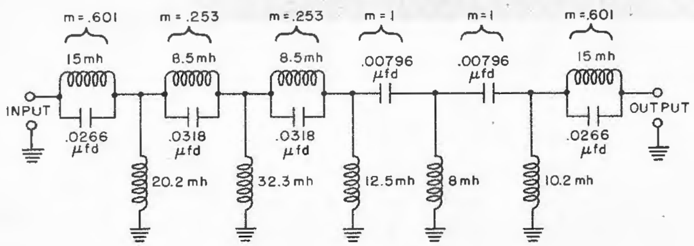

Fig. 14 - Schematic of 10-kc high-pass filter

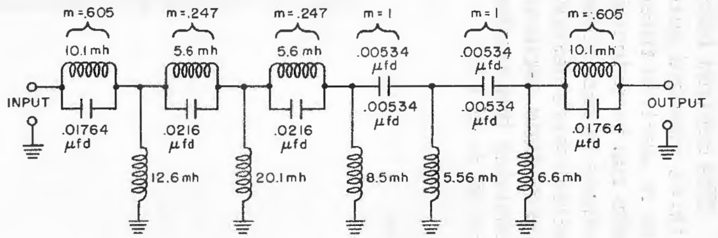

Fig. 15 - Schematic of 15-kc high-pass filter

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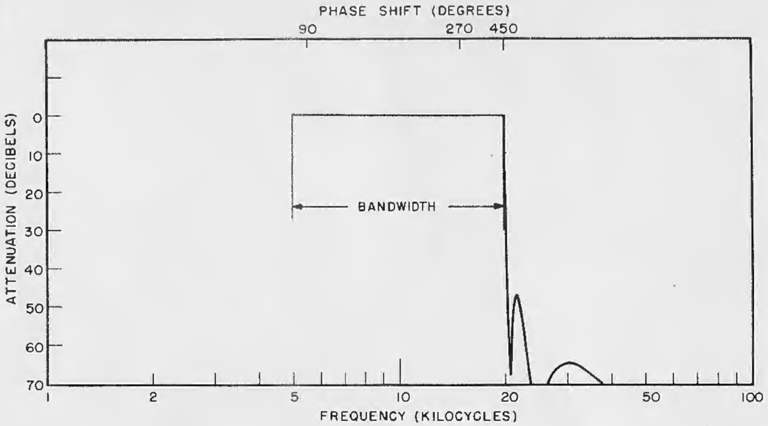


Fig. 16 - Response curve for 20-kc low-pass filter

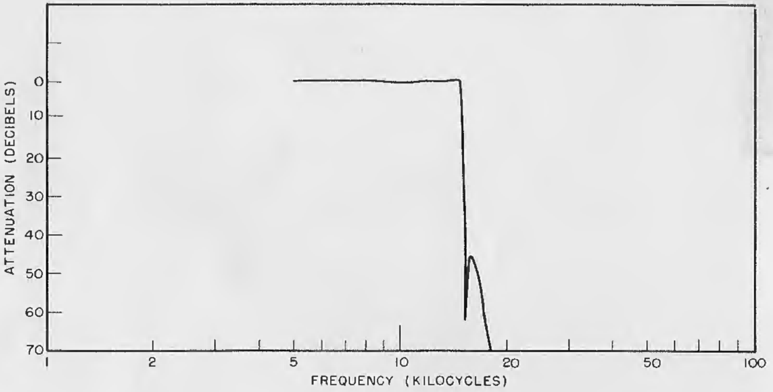
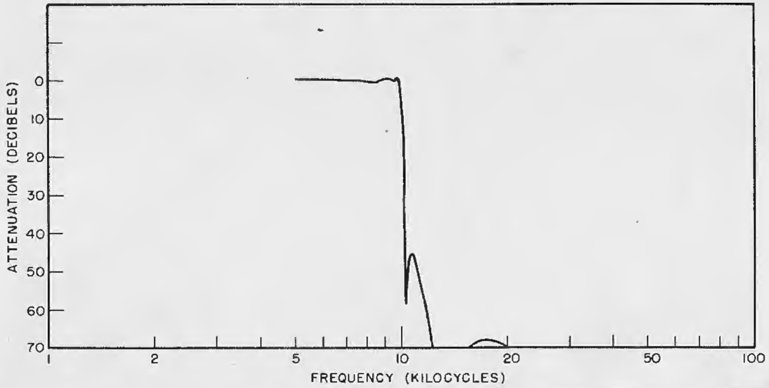
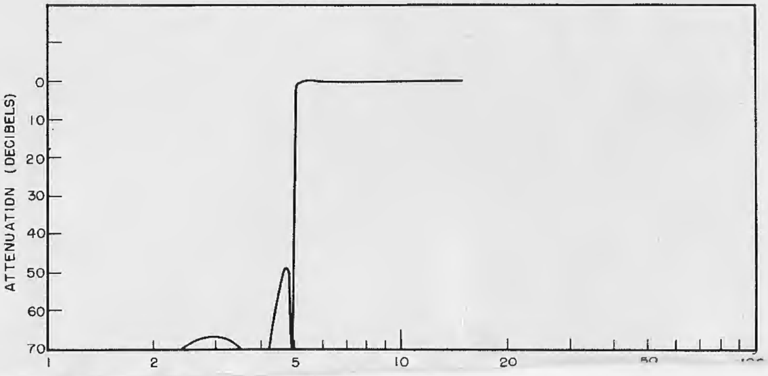


Fig. 17 - Response curve for 15-kc low-pass filter





FREQUENCY (KILOCYCLES) 100

Fig. 18 - Response curve for 10-kc low-pass filter

Fig. 19 - Response curve for 5-kc high-pass filter

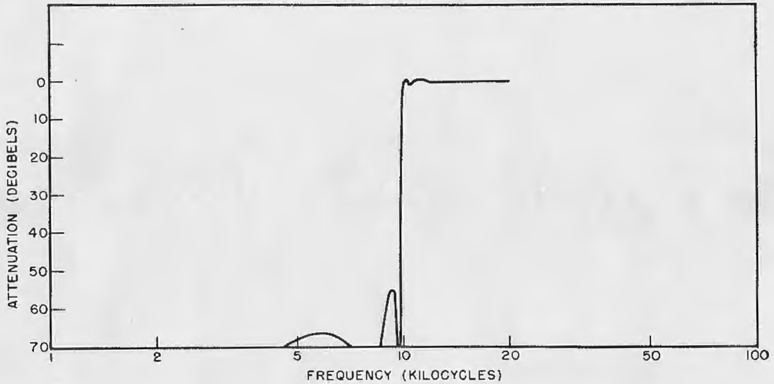


Fig. 20 - Response curve for 10-kc high-pass filter

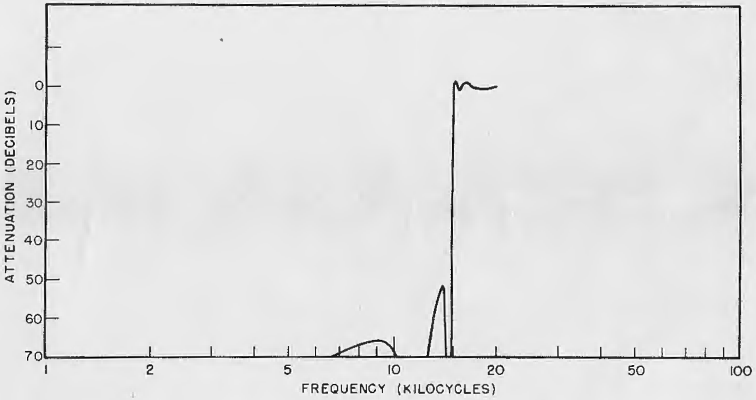


Fig. 21 - Response curve for15-kc high-pass filter

Circuit diagrams are shown in Figs. 10 through 15 for the different filters. The values of the inductors are as indicated. The values of the capacitors, however, were varied slightly where necessary in order to obtain a nearly perfect match in both phase and gain between the two channels. The response curves of these filters are shown in Figs. 16 through 21.

The degree of match between the two channels was checked by applying a common signal to each and observing the pattern traced by the output signal when applied to the X and Y axes of a matched-channel cathode-ray oscilloscope as the frequency of the signal was varied across the band. These tests indicated substantially perfect match in both gain and phase throughout the passbands. The passbands were taken as the bandwidths between the 3-db attenuation points of the filter frequency response curves.

To maintain the high degree of attenuation in the band rejection regions, it was necessary to design a band selector switch with extremely low input and output coupling capacitance. The top view of the selector switch (Fig. 22) shows the wide spacing and shielding used in the experimental model.

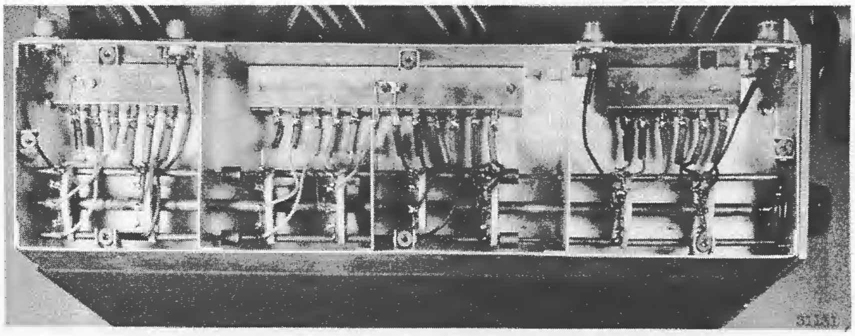


Fig. 22 - Band selector switch for filter unit

Receiver Unit

The receiver unit (Figs. 23, 24, and 25) for the system is basically a pair of matched amplifiers which were designed to have:

(1) ganged gain controls,

(2) 1000 ohms input impedance,

(3) low noise,

(4) wide bandwidth, and

(5) fast recovery time.

Two gain controls are located in the receiver. One is a step attenuator, which is in the front of the unit, and the other, which is continuously variable, is located after the first amplification stages.

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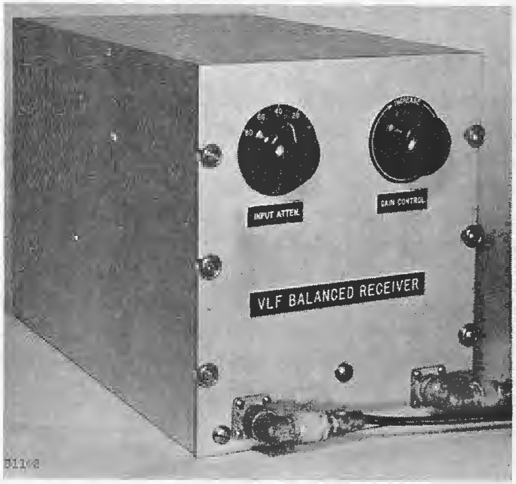

Fig. 23 - Matched-channel receiver unit

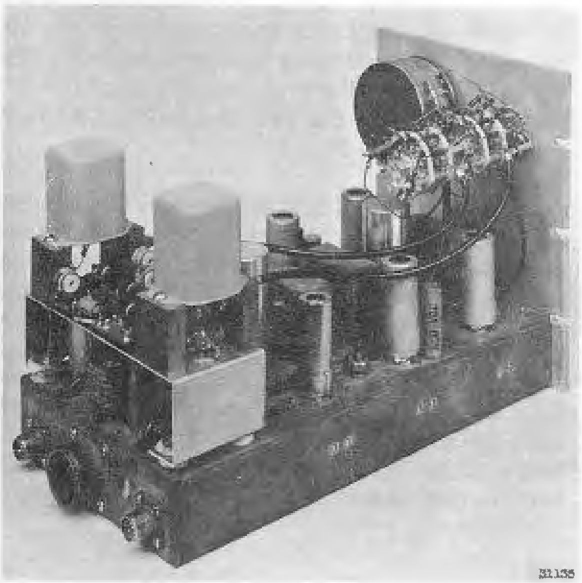

Fig. 24 - Top view of chassis, matched-channel receiver unit

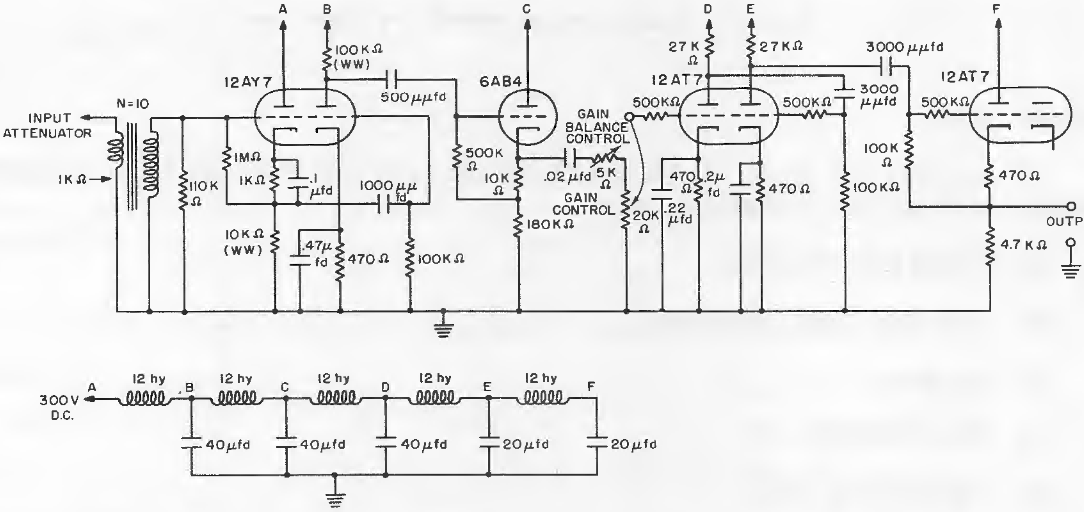

Fig. 25 - Schematic of receiver

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The input step attenuator (Fig. 26), which is used when strong signals are encountered, was designed to have a constant characteristic impedance of 1000 ohms for proper termination of the filter unit. It can be used to vary the gain in 20-db steps up to a maximum of 80 db. Considerable difficulty was encountered in obtaining matched potentiometers for the continuously variable gain control. Helically wound dual-ganged potentiometers linear to within 0.1 percent were finally used. With these, continuously variable attenuation was possible over a 26-db range with no apparent bearing error being introduced.

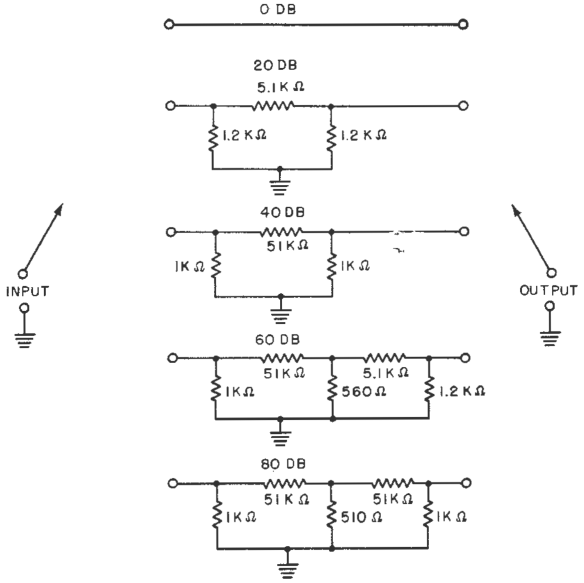

Fig. 26 - Schematic of input step attenuator

When the received signal is weak, it is not feasible to use the constant-impedance step attenuator as the termination of the filter unit. The input attenuator is then bypassed and the signal is applied directly to an impedance-matching transformer. The matching transformer steps up the impedance from 1000 to 100,000 ohms. A 100,000-ohm resistor terminates the secondary of the transformer and acts as a grid resistor for the first amplifier tube. A cathode follower was used here because its high input impedance does not load the preceding circuits. It should be noted that a high impedance for the secondary of the input transformer is desirable in order to allow antenna noise to override electron tube noise, thereby providing the best possible noise figure.

Several other precautions were taken to insure a low-noise receiver. They were:

(1) the use of wire-wound resistors for all current-carrying resistors in the first two stages,

(2) the use of miniature tubes to reduce microphonic noise,

(3) the elimination of the low-frequency response below 5 kc to reduce hum, microphonics, and flicker noise.

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The bandwidth of the receiver is 45 kc, and the measured noise figure is less than 4 db above that of an ideal matched receiver. A potentiometer was incorporated in each amplifier to permit the balancing of gain between the two channels. A cathode follower was used as an output stage so that the effect of the cable capacitance between the receiver unit and the indicator unit would be negligible.

Indicator Unit

The indicator unit (Fig. 27) is composed of a cathode-ray display tube and its associated deflection amplifiers (Fig. 28). A long-persistence type 5CP7 cathode-ray tube was used because of its desirable integration characteristic which aids in the separation of a repetitive signal from sporadic noise bursts. It also aids in obtaining bearings on signals of short duration. In order to excite the compound phosphor of the cathode-ray tube sufficiently for a bright image, 4000 volts accelerating potential was used.

Power output pentodes (6AG7) were used in the paraphase amplifiers, which converted the receiver's single-ended output to push-pull output and drove the deflection plates of the cathode-ray tube. A 500-volt plate power supply was needed to furnish the paraphase amplifiers with the voltage required for full-scale linear deflection. Direct coupling in the final stages, with the centering controls of the cathode-ray tube located in the grid circuits of the paraphase amplifiers, was abandoned because of the long time required for the cathode-ray tube spot to recenter itself after the system had been subjected to a very strong signal. Capacitive coupling throughout the system and the placement of the centering controls directly across the deflection plates of the cathode-ray tube (Fig. 28) corrected this condition in the experimental model.

Fig. 27 - Matched-channel indicator unit

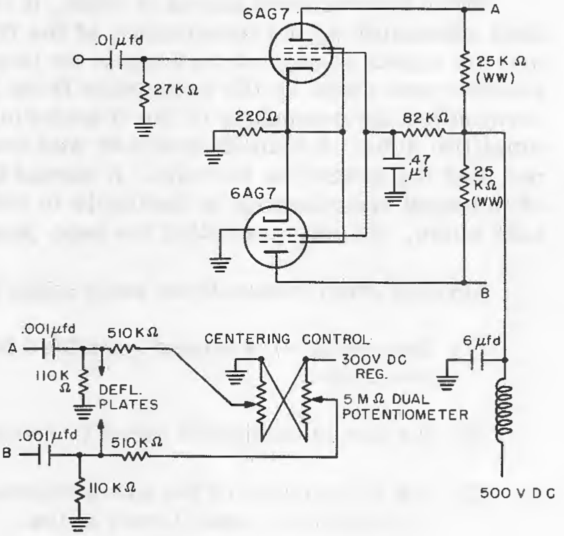

Fig. 28 - Schematic of deflection amplifiers and centering controls for the indicator unit

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ANTENNA SIZE CONSIDERATIONS

In order to achieve the best possible sensitivity, it is necessary to insure that the equivalent receiver noise is much lower than the atmospheric noise level produced in the antenna system. This can be achieved by using an antenna of sufficient size. The sufficient size of an antenna is dependent upon the noise level at the geographic location of the antenna site and the receiver noise referred to the antenna. After an antenna is made large enough so that the atmospheric noise greatly exceeds the equivalent receiver noise in the antenna, there is no advantage in making the antenna structure larger. The experimental antenna delivers at least twice as much signal voltage (6 db) as is necessary for the existing receiver even on the quietest days at this particular location. In this case, if it were desirable to reduce the antenna size to a minimum and still maintain the same operational sensitivity, it would be necessary to reduce the receiver noise. There are at least two ways in which this may be accomplished:

(1) the noise bandwidth of the receiver can be narrowed, or

(2) the noise figure of the receiver may be improved.

The bandwidth of the system is 15 kc, which is established by the filter unit located in front of the receiver. The noise bandwidth of the receiver itself, which follows the filter, is 45 kc. The wide bandwidth of the receiver is necessary in order to maintain a high quality video display for strong signals. This bandwidth need not be maintained throughout the receiver, but only in the final stages, where overload is likely to occur. If additional filters are inserted immediately following the noise-contributing stages, the receiver noise can be reduced by 4.5 db. It may also be possible, by the use of suitable circuit techniques in the first stages, to reduce the noise figure by an additional 3 db. In this way, the gain of the existing experimental antenna could be 13.5 db less without degrading the system. From the graph in Fig. 29, it can be seen that a reduction in voltage output of the antenna system by a factor of four corresponds to a size reduction from the present 622 sq m to 90 sq m if the same loop cable is used as the experimental loop winding, or to 110 sq m if a more practical cable such as RG-18/U is used.

OPERATIONAL DATA

The following operational data were complied during several days of actual operation of the system. Figure 30 is a photograph of the experimental installation. On the table to the left is the filter unit, the band selector switch, the receiver, and the indicator unit of the intercept system. On the table to the right is a zero-beat heterodyne unit and a model RAK radio receiver. Since the model RAK is one of the more sensitive very-low-frequency receivers in wide use by the Navy, it was used in conjunction with the intercept system for aural identification and frequency determination of signals above 14 kc. This gave a direct comparison of the operational sensitivity of the broadband very-low-frequency intercept system with that of typical receiving equipment at these frequencies. Because similar equipment was not available to cover the lower portion of the band, it was necessary to develop a zero-beat heterodyning receiver with an audio output to work in the region below 14 kc. With this operational arrangement, it is possible to acquire such information as

(1) call letters,

(2) direction, and

(3) the approximate frequency

of all signals detected.

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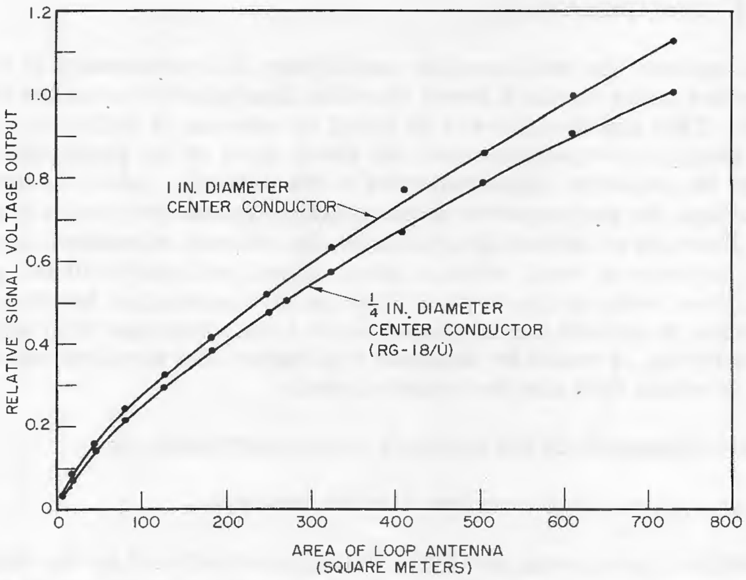

Fig. 29 - Relative signal voltage output from a loop antenna under matched condition as the size of the loop and loop materials are varied

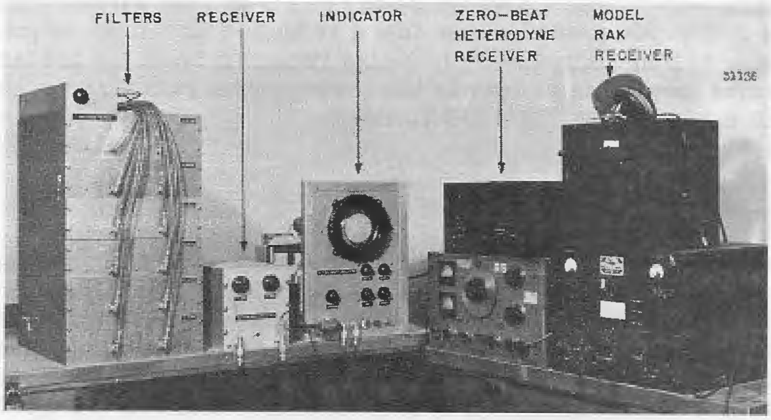

Fig. 30 - The experimental intercept installation

Sensitivity Comparison

The model RAK receiving equipment and the broadband very-low-frequency intercept system were operated simultaneously. The RAK receiver was operated with an inverted L-type antenna 60 ft high and 350 ft long. The antenna arrays of the RAK receiving equipment and the intercept system were sufficiently large so that the limit of operational sensitivity of each was dependent upon atmospheric noise only. It is assumed that the

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operators were equally adept in detecting signals in the noise aurally and visually. Three factors which are of major significance in the operational sensitivity comparison are:

(1) bandwidth of the receiver system,

(2) azimuthal separation of the noise and signal, and

(3) integration effects.

By direct comparison of the bandwidths only, it would appear that, on the basis of output signal-to-noise ratio, the RAK receiving equipment is on the order of 20 db more sensitive than the intercept system. However, the ability of the intercept system to separate the atmospheric noise from the signal azimuthally, and the ability of the cathode-ray-tube phosphor to intergrate the recurrent signal deflections make the intercept system essentially as sensitive as the RAK receiving equipment.

During the operational period, there was only one time when a signal was detected with the RAK receiving equipment but not with the intercept system. This occurred during a period of very low noise level and the signal was barely detectable on the RAK equipment. In contrast to this, on several occasions signals were detected with relative ease with the intercept system but could not be detected with the RAK until an experienced operator exerted considerable effort to discern the signal in the noise. Generally, however, any signal which can be heard on the RAK receiver can be seen on the intercept system and vice versa. It should be emphasized that the intercept system can monitor whole bands of frequencies continuously, whereas to monitor the same bands with the RAK receiver or similar equipment would entail the manual tuning of the receiver back and forth. This type of searching is extremely tiresome, especially when the actual presence of the signal is not known.

Intercepts·

Fourteen signals were detected by the broadband very-low-frequency intercept system; seven of these were identified by correlating the audio output from the RAK receiving equipment with the visual display of the intercept system. The call letters of these stations, as well as geographical locations, operating frequencies, bearings, and distances from the intercept site are listed in Table 1. One signal, which was received at a frequency of approximately 8.5 kc, was traced to radiation from a nearby power line. This signal was eliminated during subsequent tests by disconnecting the commercial power lines one mile from the intercept site and supplying the electrical needs with locally generated power. The remaining six signals have been established as emanating from real transmitting installations and are now being investigated.

The bulk of the bearing information was recorded during two 24-hour tests in which bearings of all intercepted stations were recorded at 15-minute intervals. These tests started at 0800 EDT on June 2, 1955 and June 7, 1955. The bearing error versus time data accumulated during these periods are presented in graphical form in Figs. 31 through 36. The spread of values in the local morning and evening twilight periods marked on Figs. 31 and 32 indicate that these may be periods of maximum bearing error.

The various indicator displays are presented in Figs. 37 through 43. The only display in which the bearing trace is not elliptical is that of Fig. 37. This should not be interpreted as meaning that ellipsing always occurs on the signal traces of distant stations and never of local stations. If these photographs had been taken at another time, the conditions may have been reversed; that is, the bearing trace of the local station could have had considerable ellipsing and the bearing traces of the distant stations none.

[redacted]

TABLE 1
Identified Intercepted Signals

Call Letter	Location	Frequency (kc)	Bearing (degrees)	Distance (miles)
GBR	Rugby, England	16.0	48.5	3700
GBZ	Criggion, England	19.4	48.5	3650
FUB	Radio Paris, France	17.0	51.5	4000
NBA	Balboa, Panama	14.9	185.5	2050
NLK	Seattle, Washington, U.S.A.	18.5	301.0	2300
NPM	Lualualei, Hawaii	16.6	281.0	4900
NSS	Annapolis, Maryland, U.S.A.	19.0	52.5	51

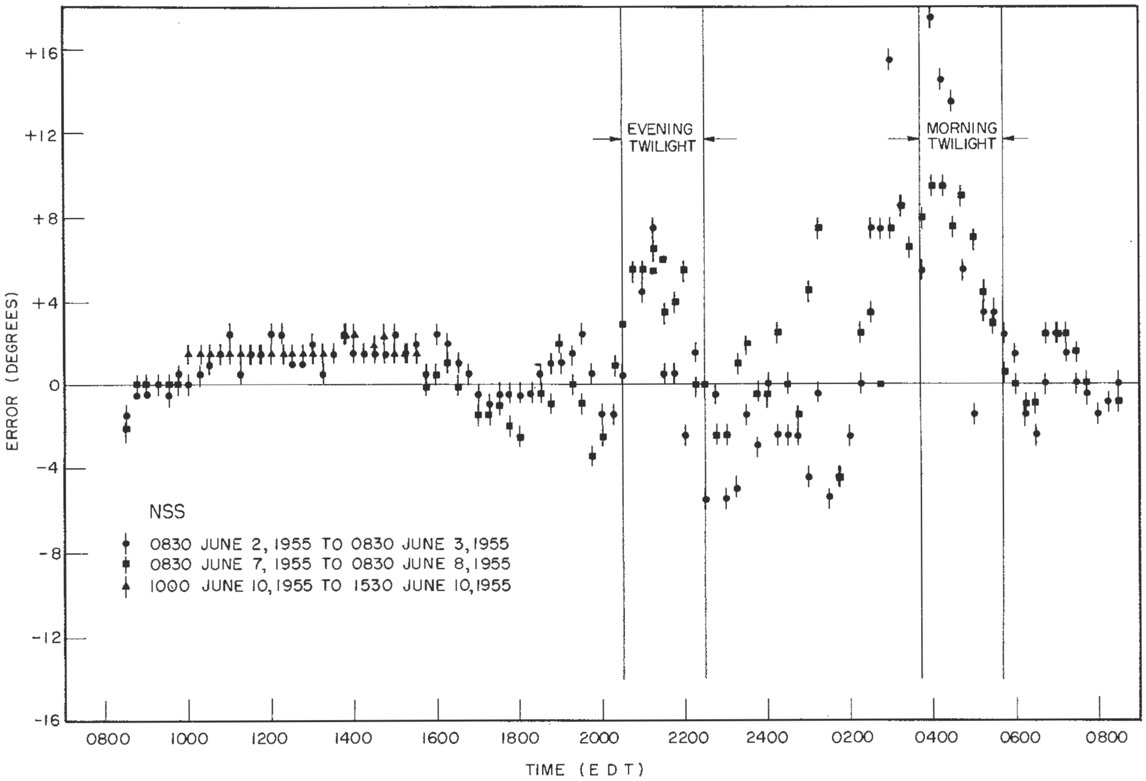

Fig. 31 - Bearing error curve, signal call letters NSS

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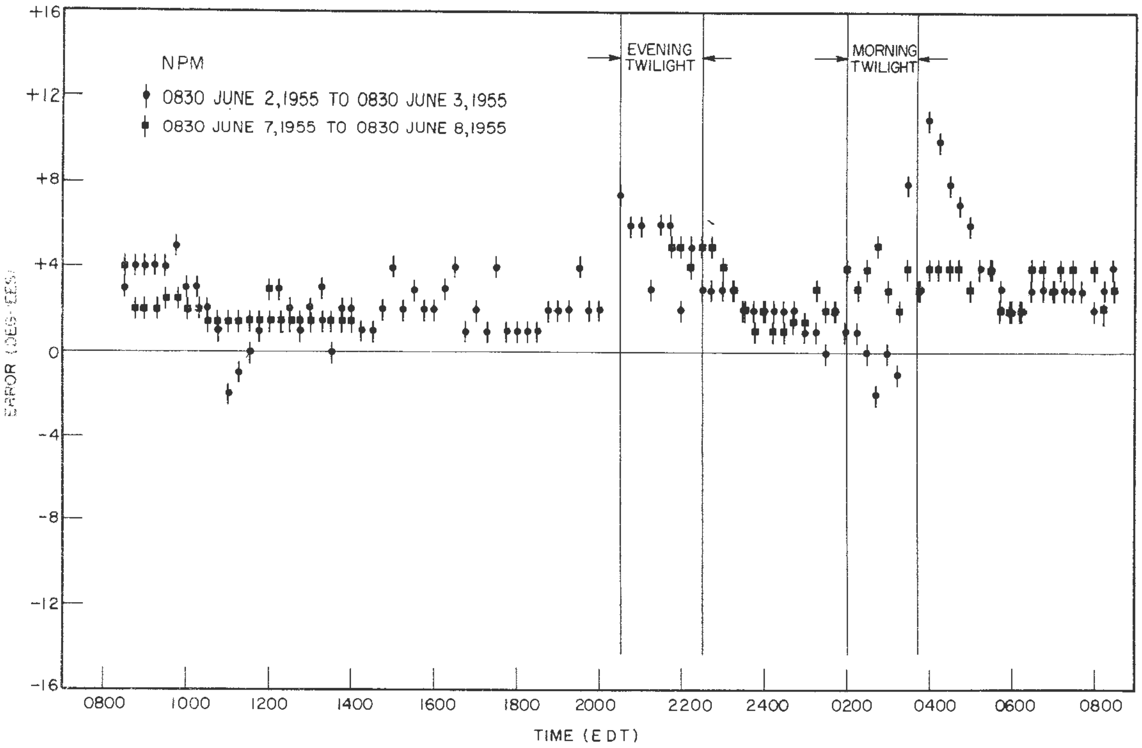

Fig. 32 - Bearing error curve, signal call letters NPM

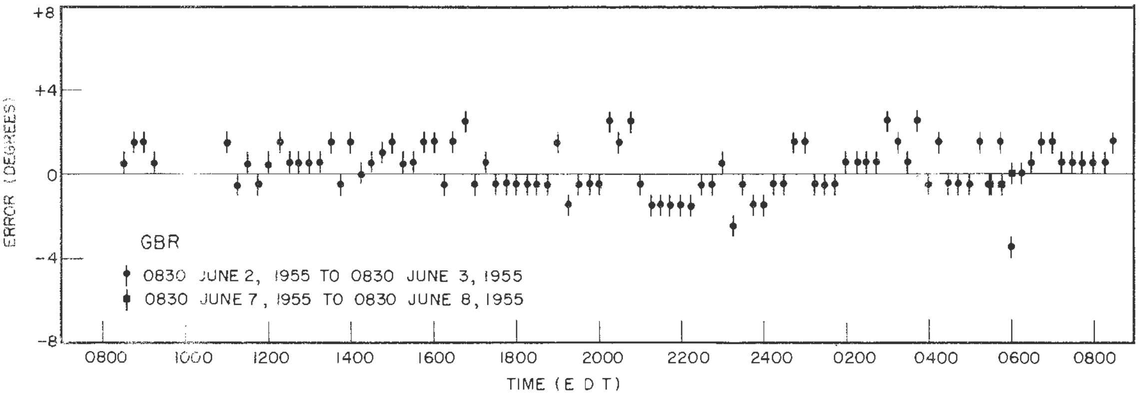

Fig. 33 - Bearing error curve, signal call letters GBR

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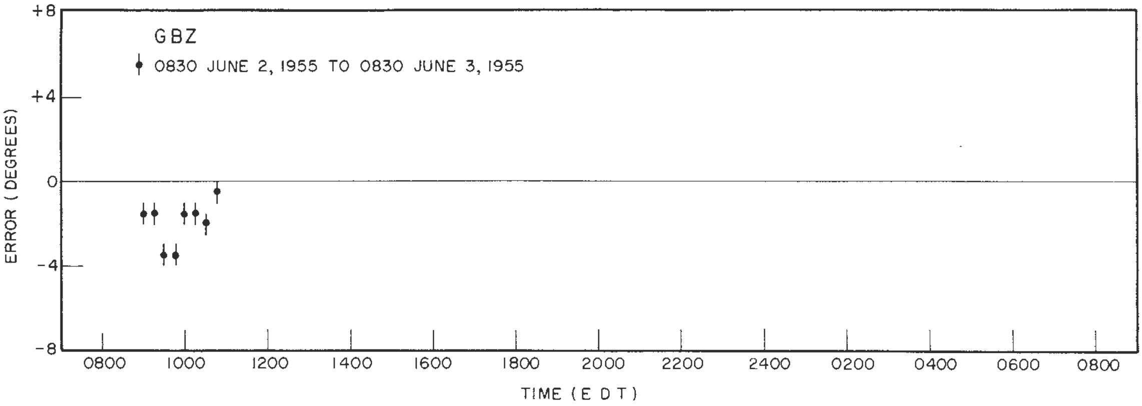

Fig. 34 - Bearing error curve, signal call letters GBZ

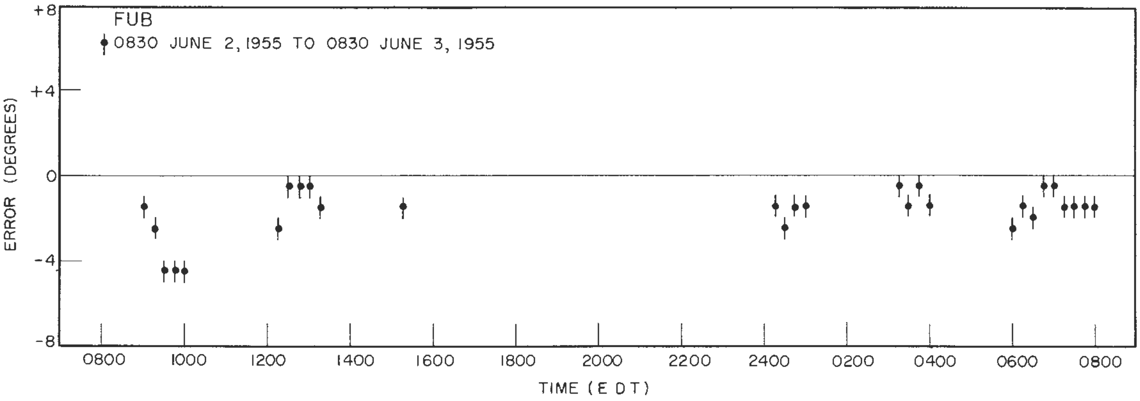

Fig. 35 - Bearing error curve, signal call letters FUB

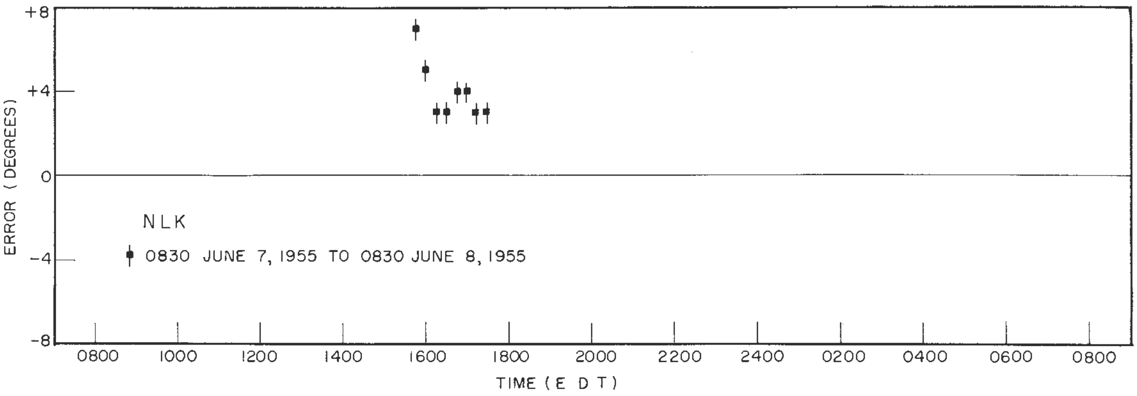

Fig. 36 - Bearing error curve, signal call letters NLK

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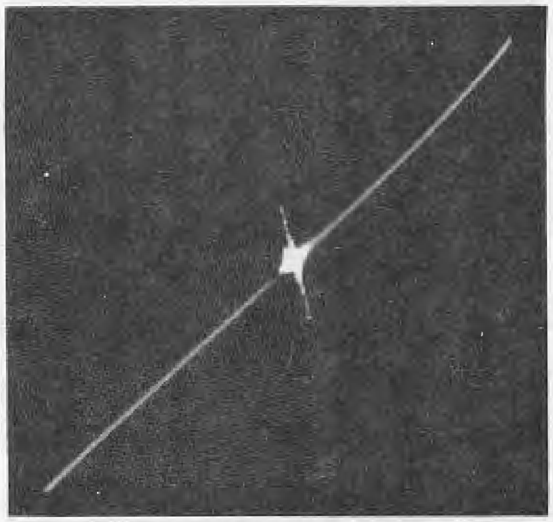

Fig. 37 - Indicator display, signal call letters NSS, taken November 26, 1954, at 1600 EST. The trace at 350 degrees is a storm signal.

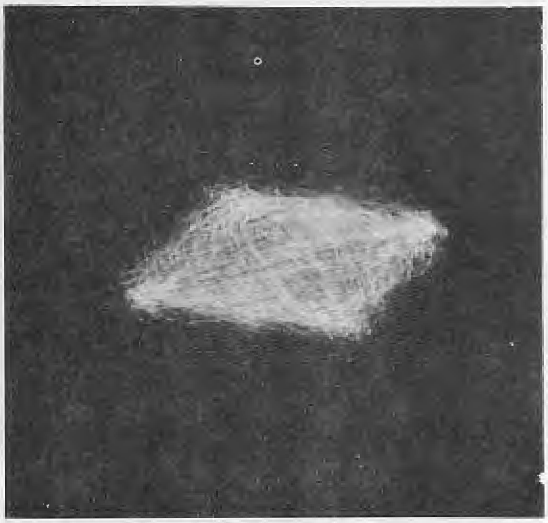

Fig. 38 - Indicator display, signal call letters GBR and NPM, taken December 9, 1954, at 2300 EST

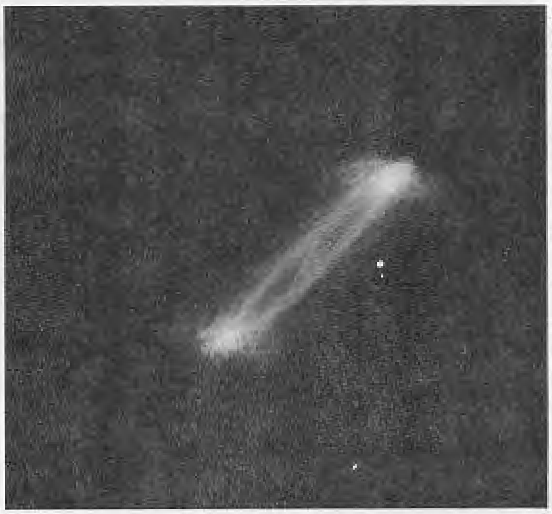

Fig. 39 - Indicator display, signal call letters FUB and NPM, taken December 9, 1954, at 2030 EST

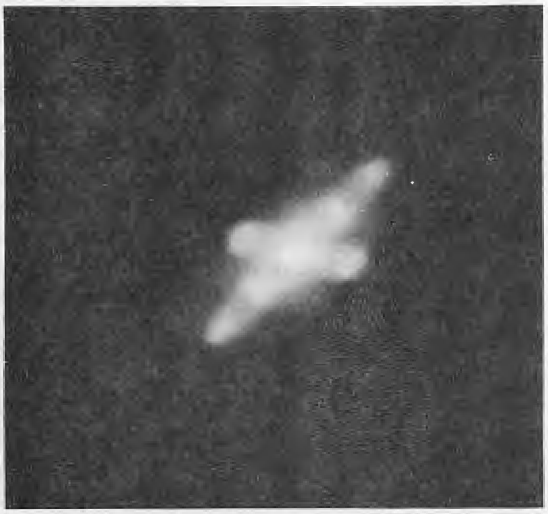

Fig. 40 - Indicator display, signal call letters FUB, GBR, and NPM, taken December 9, 1954, at 2100 EST. The field strength of FUB was approximately twice that of GBR at the time this photograph was taken.

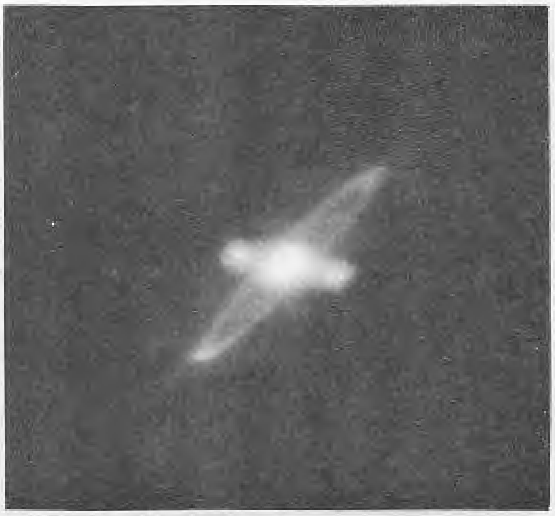

Fig. 41 - Indicator display, signal call letters FUB and NPM, taken December 9, 1954, at 2100 EST

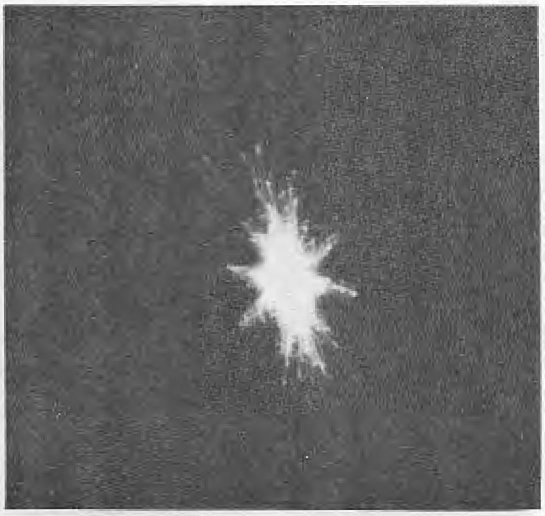

Fig. 42 - Indicator display of atmospheric noise signals, taken November 26, 1954, at 1530 EST

The maximum amount of ellipsing which has been observed on a bearing trace was of the order of 20 degrees (a ratio of 5 to 1 for the major to minor axis of the ellipse). The displays in Figs. 38 through 41 are good examples of the different types of bearing displays which occur when more than one signal is present in a band. It should be pointed out that the bearing displays shown in Figs. 38 through 41 may be realized in the presence of much stronger signals. This is due to the fast recovery time of the system, which allows the weak signals to be accurately displayed during the intervals between code elements of type A1 transmission. Of course this "look-through" property of the system does not function and a weak signal is completely hidden, if a very strong signal with type F modulation is received. Because type F modulation has never been received in the past, this difficulty has not been encountered. It is conceivable, however, that it may be encountered in the future, in which case additional filters should be incorporated in the system to eliminate this difficulty.

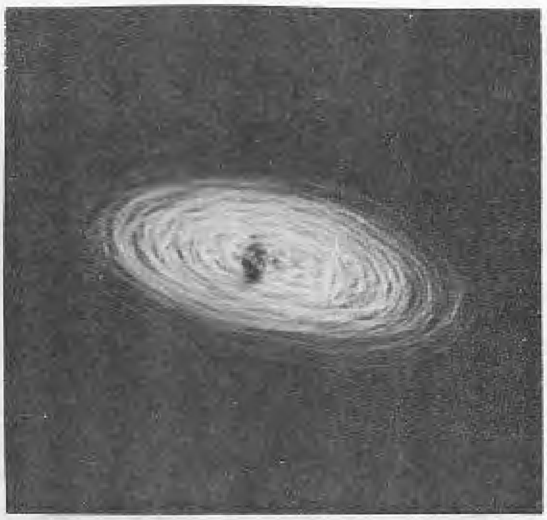

Fig. 43 - Indicator display of signal radiated by local power lines, taken November 26, 1954. Frequency, 8.5 kc, true bearing, 106 degrees.

CONCLUSIONS

The data compiled during the brief operational period of the broadband very-low-frequency intercept system indicate that it has a very high probability of intercept which would make it a valuable system for monitoring the 5 to 20 kc band. The high probability of intercept for this system is attributed to its

(1) good operational sensitivity compared with other equipment used at these frequencies,

(2) broadband coverage (not a scanning system),

(3) omnidirectional characteristics,

(4) ability to receive any type of transmission, and

(5) ease of operation.

The information available from the broadband very-low-frequency intercept system is

(1) presence of signal transmissions,

(2) apparent line of bearing to transmitter's location,

(3) simultaneous determination of the operating schedules of many transmitters.

When the broadband very-low-frequency intercept system is operated in conjunction with a suitable receiver which is designed or modified to cover the 5 to 20 kc range, additional information may be obtained, such as

(4) aural identification of the transmitter, and

(5) the approximate frequency of the transmitter.

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