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RADIO FIELD INTENSITY STUDIES ON THE ARCTIC VOYAGE OF THE ICEBREAKER USS EDISTO (AGB-2)

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RADIO FIELD INTENSITY STUDIES ON THE ARCTIC VOYAGE OF THE ICEBREAKER USS EDISTO (AGB-2)

Burt H. Weston, Jr.

May 2, 1950

Approved by:

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CAPTAIN F. R. FURTH, USN, DIRECTOR

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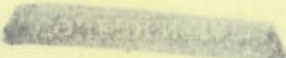
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ABSTRACT

A number of observations involving studies in low-frequency radio wave propagation over the Annapolis to Newfoundland and Labrador paths were made during January 1950 on the voyage of the U. S. Navy icebreaker USS EDISTO by an engineer from this Laboratory.

Field strength measurements were made on Navy radio NSS at Annapolis on 18, 88.5, and 122 kilocycles. Interference zones caused by skywave and groundwave interaction were observed on 18 kilocycles. The virtual height of the reflecting layer for the 18-kilocycle skywaves may be calculated from the observed position of these interference zones. Field intensity readings on 88.5 and 122 kilocycles show variations resulting from daytime skywave absorption by the D layer. Little work was done in the medium- and high-frequency range because of the shortened trip.

PROBLEM STATUS

This is a final report for this phase of the problem. Other studies will be continued under the problem.

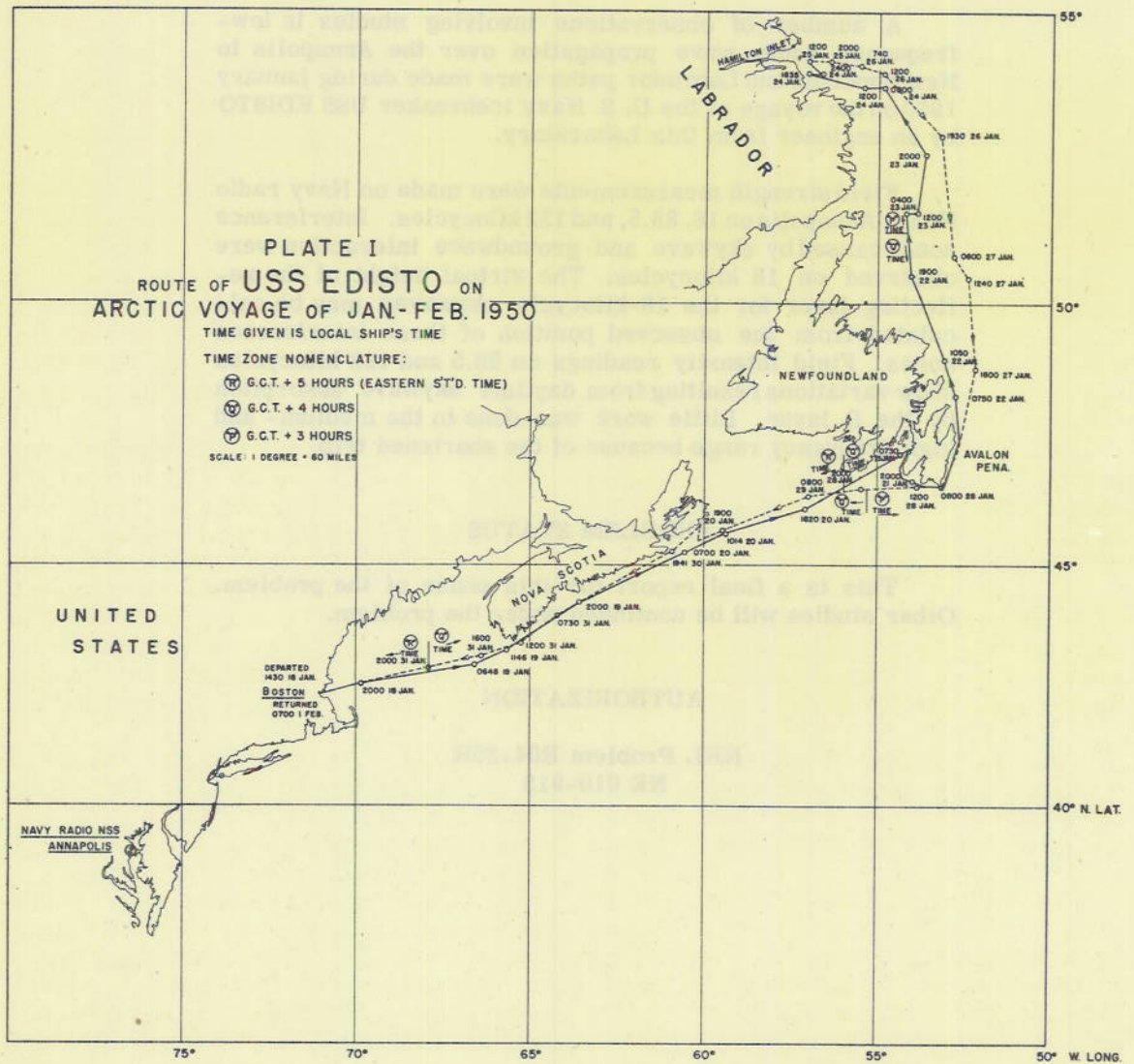
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NRL Problem R04-35R
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RADIO FIELD INTENSITY STUDIES ON THE
ARCTIC VOYAGE OF THE ICEBREAKER
USS EDISTO (AGB-2)

INTRODUCTION

Late in December of 1949 this Laboratory was invited to participate in one of the periodic Navy icebreaker voyages into the Arctic by sending along personnel for scientific investigations. The mission of the ship was ice reconnaissance in northern waters and it was to leave in mid-January for a six weeks' cruise. It was felt that the voyage would afford an excellent opportunity to gather scientific data for a number of active NRL projects.

The specific purposes for NRL participation were: (1) to conduct field intensity studies in the low and very low radio frequency ranges, (2) to conduct propagation studies in the high radio frequency band, (3) to conduct a survey of the brightness of the night sky in the Arctic and Sub-Arctic regions, and (4) to permit NRL personnel to acquire experience and knowledge in planning and executing such a project for future operations of this sort. The first of the above projects was in connection with studies of long-range navigation being made at the Laboratory, the second was to aid in determining the most reliable frequency for year-around, day-and-night, air-to-ground communication over a 2000-mile range in the Arctic. The night-sky brightness survey data were taken for the Optics Division and no results are contained in this report. The other studies were under Radio Division II.

The Laboratory was represented on the voyage by one electronic scientist. An engineer from the Interference and Standardization Unit of Radio Division II assisted in calibrating one of the ship's antennas to be used for field-strength measurements on the low and very low frequencies. The writer reported aboard the EDISTO for the voyage on January 16, 1950.

The itinerary of the USS EDISTO (AGB-2) called for about six weeks of ice reconnaissance in the Davis Straight and Lower Baffin Bay area. Stops were to be made at Argentia, Newfoundland, Hamilton Inlet, Labrador, and several places on the southwest and west coasts of Greenland, including Grondal and Disko Island. The ship sailed from the Boston Naval Shipyard, Boston, Mass., on January 18, 1950 (see Plate 1) and proceeded in a northeast direction arriving at Argentia, Newfoundland, at 1000 January 21. The ship departed at 1500 the same day and sailed around Avalon Peninsula, Newfoundland, for Hamilton Inlet, Labrador. The return trip from the mouth of Hamilton Inlet to Boston was begun at 1415 January 25 and the ship docked in Boston at 0700 February 1. The NRL representative returned to the Laboratory the next day.

Because the trip was shortened, only a small amount of data was accumulated on the NRL projects. The data that were obtained, however, are presented for such conclusions

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as are justified. Positive quantitative conclusions would require a great deal more data taken from observations over a longer period of time.

MEASUREMENTS AND OBSERVATIONS

Field Intensity Studies in the LF and VLF Range

One of the requirements which exists in connection with the navigation studies mentioned above is the investigation of low-frequency daytime skywaves. Skywaves are greatly influenced by the stability of the ionosphere reflecting layers. The virtual height at which reflection of skywaves occurs is one of the terms usually used to describe the behavior of the ionosphere because it is a quantity that can be readily measured. A convenient method for the investigation of layer height is the Hollingworth method which consists of computing the height from the position on the earth's surface of the zones of signal maxima and signal minima caused by interaction between the ground and skywaves (Reference (1)). This may be done by measuring the field intensity at moderate distances from the transmitter as the distance between transmitter and receiver is varied. Such an investigation was carried out on this voyage using the low-frequency transmission from Navy radio NSS at Annapolis, Maryland. These transmissions were on frequencies of 18, 88.5, and 122 kilocycles.

The 18-kilocycle FOX transmissions were available every hour throughout the day, and the 122-kilocycle broadcasts were available as five minutes of time signals preceding even hours of Greenwich civil time. Arrangements were made with Naval Communications for transmissions from Annapolis on 88.5 kilocycles during the first fifteen minutes of even hours of Greenwich civil time from 1200 to 2015. By means of this schedule it was possible to make field-intensity readings on the three frequencies on even hours of Greenwich time from 1200 to 2015 each day. Some monitoring beyond this time was done on 18 and 122 kilocycles. A record was kept by the operating personnel of the current in the antenna of each of the three transmitters. These records showed that the variations in the power output of the transmitters could be neglected for these tests.

Equipment Used

The equipment used in making the field-intensity measurements on LF and VLF consisted of a Model LP-5 signal generator, a Model RBA receiver, one of the ship's antennas, a dummy antenna having the same capacity as the ship's antenna plus lead-in for coupling the signal generator to the receiver, and an oscilloscope for output indications. The equipment was set up in the standard manner for making field-intensity measurements by the substitution method. Space for the installation was provided in the electronics repair room which adjoined the main radio room on the boat deck. This location made possible a short coaxial lead-in from the antenna used. The capacity of the antenna and lead-in was measured with a radio frequency bridge at the connection to the receiver. It was found to be 1430 micromicrofarads on both 50 and 200 kilocycles.

The effective height of the antenna was determined by dividing the amount of 18-kilocycle signal from NSS (picked up by the ship's antenna) by the amount of field intensity of the same signal. The amount of signal from the ship's antenna was measured with the LP-5 signal generator. The field intensity was measured with Portable Field Intensity Measuring Equipment AN/URM-6. The same procedure was followed using a radio teletype signal on a frequency of 112.5 kilocycles. Table 1 is a tabulation of five values of effective height obtained by the above method.

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TABLE 1
LP-5 RBA Setup to Obtain Effective Height

Time	Frequency (kilocycles/second)	LP-5 Output (μv)	AN/URM-6 ($\mu\text{v}/\text{Meter}$)	Effective Height Calculated (Meters)	Remarks
1015	18	1500	1979	0.76	NSS CW telegraphy
1020	18	1500	1908	.79	NSS CW telegraphy
1045	112.5	560	954	.59	Radio teletype
1415	18	1500	2121	.71	NSS CW telegraphy
1610	112.5	570	1100	.52	Radio teletype

The average of the three values obtained on 18 kilocycles was 0.75 meters. This value was used to convert all observations on 18 kilocycles to absolute values of field intensity. The average of the two values obtained on 112.5 kilocycles was 0.55 meters and was used for computation of field intensity from observations made on 88.5 and 122 kilocycles. The accuracy of 0.75 meters as the effective height of the antenna at 18 kilocycles was checked while in port at Argentia, Newfoundland, by again setting up the AN/URM-6 and measuring the 18-kilocycle NSS field intensity and comparing the value obtained with that computed from the RBA, LP-5 setup. The value obtained with the AN/URM-6 was 2800 microvolts per meter and with the RBA, LP-5 equipment was 2880 microvolts per meter. These two values differ from each other by less than 3 percent. The low value of effective height obtained was probably partially due to the fact that the forward end of the antenna was just a few feet above the deck of the ship.

The directional characteristics on 18 kilocycles were determined for the ship's antenna (Figure 1) by "swinging the ship" in the vicinity of Boston Lighthouse. The ship was moved slowly around in a circle while the field intensity of NSS on 18 kilocycles was read every ten degrees of azimuth. The field intensity was found to vary about 4 decibels throughout the test. Corrections have been applied, depending on the ship's orientation, to all observed values of field intensity of 18-kilocycle NSS transmissions.

Presentation of 18-Kilocycle Data

Figure 2 is a presentation of the hourly field-intensity readings on 18 kilocycles. These curves show the combined effects of (1) diurnal variation due to skywave absorption by an ionized layer, (2) variation due to the passage of the ship through a zone of skywave-ground-wave reinforcement or cancellation, and (3) decrease in field intensity due to increased distance from the transmitter. These curves (one curve has been interpolated between two days) show that at six locations during the voyage conditions in the form of zones of high or low field intensity were observed. The approximate location of a zone of high field intensity has been estimated to occur at 398 miles from Annapolis at 0100 January 19 (Figure 2b). During the day of January 19 (Figure 2c) the field-intensity values show a continuous downward trend to a minimum at 2125, local time, 680 miles from Annapolis. Shortly after sunset on each of the next two days there are again recorded low values of field intensity. On January 20 the dip occurred at 1900 (Figure 2d) when the ship was 965 miles from Annapolis, and on

January 21 at approximately 1700 (Figure 2e) the dip occurred when the ship was 1090 miles from Annapolis. A fourth zone of what appears to be some abnormally low signal-strength values occurred during the morning of January 22 (Figure 2f). This is apparent when these values are compared with the morning values of January 21. The fact that there is no well-defined dip in this case may have been due to the fact that during the morning of January 22 the ship was traveling in such a direction that constant distance from Annapolis was maintained. The radius of this arc was about 1190 nautical miles. On the return trip to Boston, a fifth dip in field intensity was observed shortly after sunset on January 31 (Figure 2m). The ship was estimated to be 480 miles from Annapolis at this time.

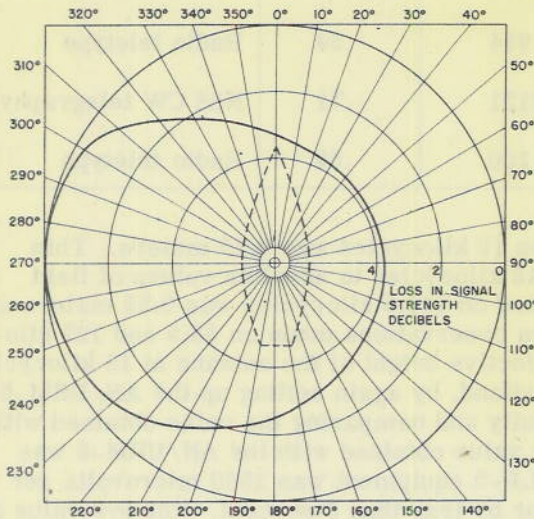


Figure 1 - Directional receiving pattern on 18 kc for antenna on USS EDISTO January 1950

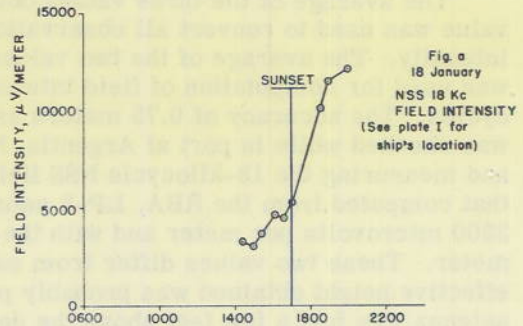


Fig. a
18 January
NSS 18 Kc
FIELD INTENSITY
(See plate I for
ship's location)

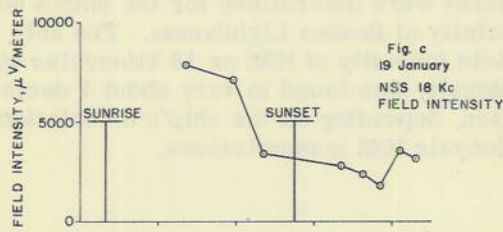


Fig. c
19 January
NSS 18 Kc
FIELD INTENSITY

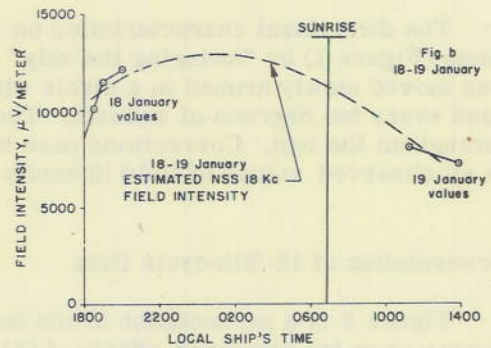


Fig. b
18-19 January
18 January values
18-19 January
ESTIMATED NSS 18 Kc
FIELD INTENSITY
19 January values

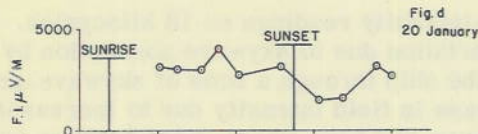


Fig. d
20 January

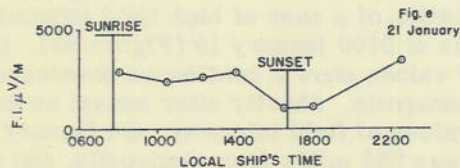


Fig. e
21 January

Figure 2a and b - Field intensity readings, 18 kc

Figure 2c, d, and e - Field intensity readings, 18 kc

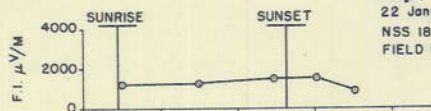


Fig. f
22 January
NSS 18 Kc
FIELD INTENSITY

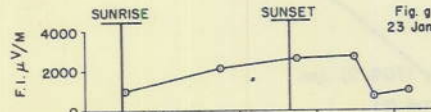


Fig. g
23 January

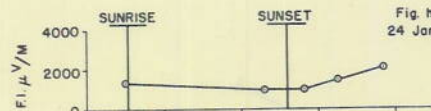


Fig. h
24 January

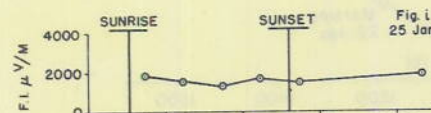


Fig. i
25 January

Figure 2f, g, h, and i - Field intensity readings, 18 kc



Fig. j
26 January
NSS 18 Kc
FIELD INTENSITY



Fig. k
27 January

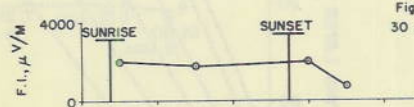


Fig. l
30 January

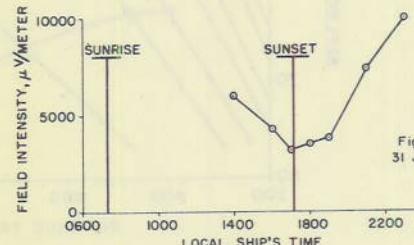
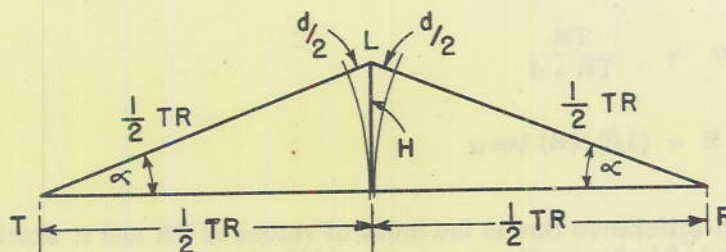


Fig. m
31 January

Figure 2j, k, l, and m - Field intensity readings, 18 kc

Ionosphere Height Computations

The position of the zones of high and low field intensity discussed in the previous section may now be used to determine the virtual height of the reflecting layer involved. Figure 3 shows a series of curves relating distance, height of the reflecting layer, and path difference between the groundwave and skywave coming from the transmitter. For simplification, flat earth has been assumed. The sloping lines are lines of constant path-length difference, and their positions have been calculated by means of the following relations:



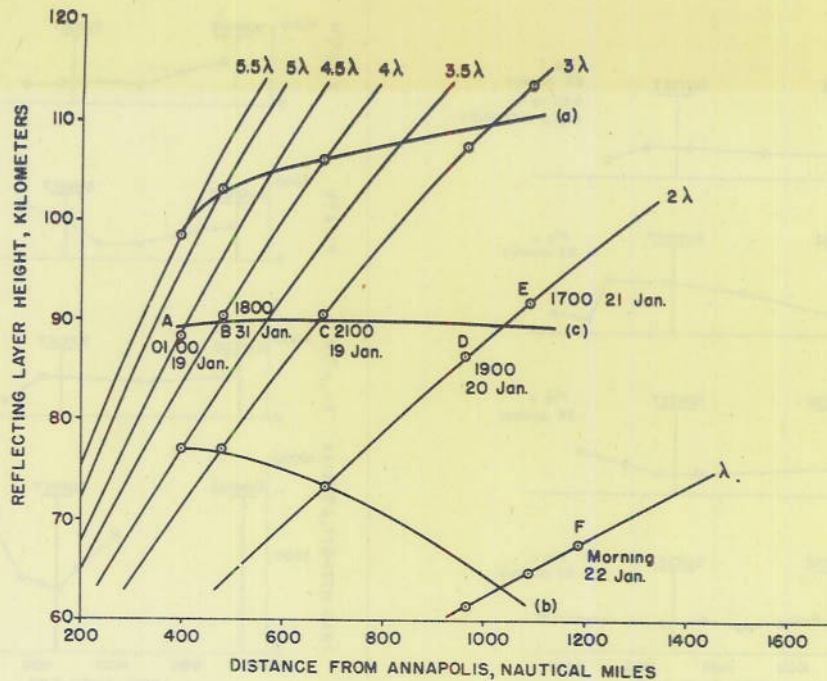


Figure 3 - Possible virtual heights of the ionosphere (assuming flat earth)

Where:

H = ionosphere reflecting layer height

TR = ground-ray path between transmitter and receiver

TLR = skywave path between transmitter and receiver

d = skywave-groundwave path-length difference

then:

$$\text{TLR} = \text{TR} + d$$

$$\cos \alpha = \frac{1/2 \text{ TR}}{1/2 (\text{TR} + d)}$$

$$\cos \alpha = \frac{\text{TR}}{\text{TR} + d} \quad [1]$$

$$H = (1/2 \text{ TR}) \tan \alpha \quad [2]$$

A given path-difference line is the locus of values of TR and H which will satisfy equations [1] and [2] above. If one assumes 180° phase change upon reflection of the skywave from the ionosphere, then half-integral wavelength-path differences will cause wave reinforcement at the receiving point, and integral wavelength-path differences will result in wave cancellation. Point A in Figure 3 shows a possible reflecting-layer height at 0100 January 18 and illustrated in Figure 2b. Similarly, points B, C, D, E, and F are

possible reflecting-layer heights to account for the signal dips shown in Figure 2c, 2d, 2e, 2f, and 2m respectively. Points A through E indicate that reflection probably occurred from a 90-kilometer layer height. Point F shows that reflection probably occurred from a layer height of 68 kilometers. A tabulation of the observed conditions outlined above follows:

TABLE 2

Figure 3 Reference Point	Distance from Annapolis (nautical miles)	Effect observed	Reflecting layer height, (kilometers)	Path-length difference, (wavelengths)	Type of wave interference
A	398	Rise in field intensity	88.5	4.5	reinforcement
B	480	Dip in field intensity	90.3	4.0	cancellation
C	680	Dip in field intensity	90.6	3.0	cancellation
D	965	Dip in field intensity	86.5	2.0	cancellation
E	1090	Dip in field intensity	92.0	2.0	cancellation
F	1190	Dip in field intensity	68.0	1.0	cancellation

Some discussion of these wave-interference phenomena in connection with NSS is given in References (2) and (3) and a more general discussion in Reference (4).

Ambiguity exists in this method for finding reflecting-layer height. Two additional positions have been plotted for each of the points A through E in Figure 3. Each of these locations will satisfy the observed results, and lines drawn through each set of points will represent a possible layer height. Since the virtual height is lower for larger angles of incidence (corresponding to greater distances) the heights represented by curve (a) may be discounted. Curve (b) may also be discounted as it would be the result of greater refractive properties than the ionosphere has been found to have. Curve (c) represents the most probable virtual height. If the layer height represented by curve (c) is the most probable one for the daytime propagation of these frequencies, then the nighttime virtual height of reflection would be as represented by point F, since ionization increases at the lower atmospheric levels during daytime.

An additional factor which may have influenced the low field-intensity values observed during the morning of January 22 as compared with those of the previous day would be a change in ground conductivity. On January 21 the ship was southeast of Avalon Peninsula, Newfoundland, and had an all-seawater path for the groundwave from Annapolis. During

the morning of January 22 the ship was off the east coast of Newfoundland. The great-circle path between receiver and transmitter in this case was about half land, half sea-water, which would result in a lower ground conductivity. Other things being equal, a lower ground conductivity would result in lower field intensity (see Reference (5)).

Presentation of 88.5 Kilocycle and 122 Kilocycle Data

The intent of the observations on 88.5 and 122 kilocycles was to investigate the properties of the ionosphere as would affect daytime skywaves. As was the case in the 18-kc observations, no equipment was available with which to study the polarization of received signal. The observed values of field intensity are a resultant of the downcoming wave component and the groundwave. The variations of this resultant are plotted in Figure 4 and are an indication of the skywave stability. On several of the days, the diurnal variation can be noted i.e.,—a general morning decrease in signal strength and a rise after sunset. Since this variation occurred throughout the trip, it probably is due to D-layer absorption (Reference (6)).

The diurnal variation as shown by the extreme range of signal levels recorded during any one day was 12 decibels on 88.5 kilocycles and 19 decibels on 122 kilocycles.

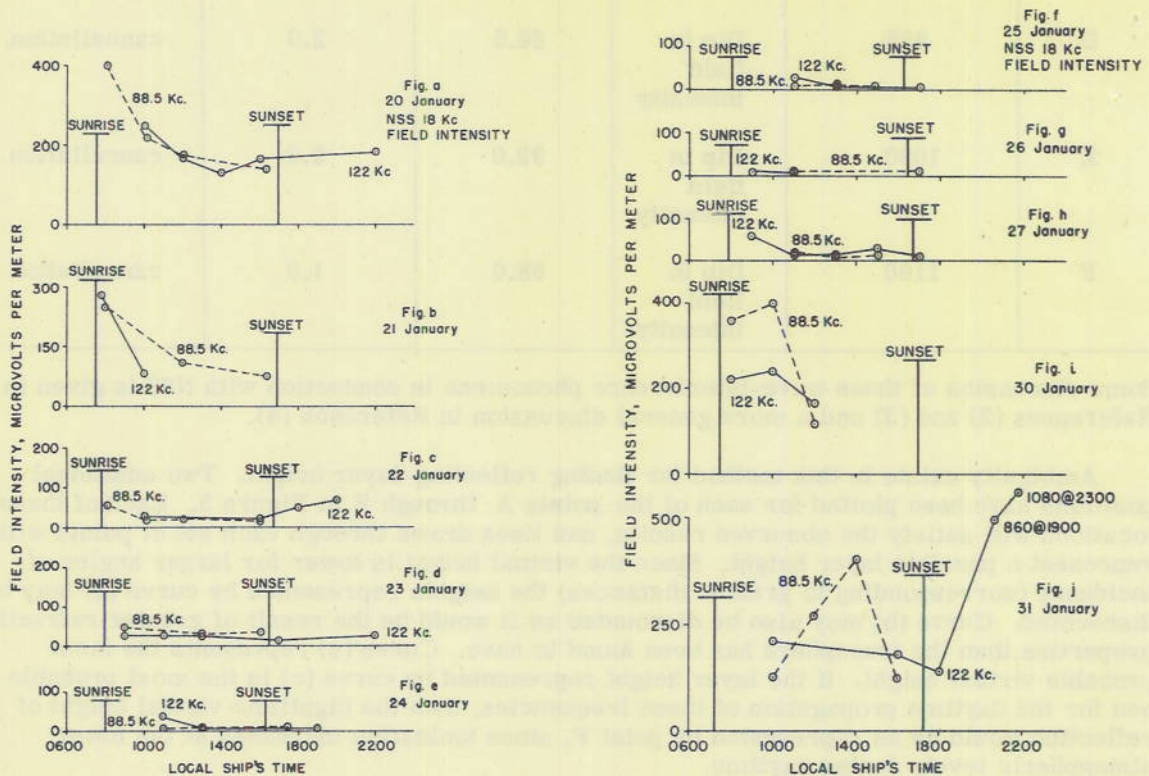


Figure 4a, b, c, d, and e - Field intensity readings, 88.5 and 122 kc

Figure 4f, g, h, i, and j - Field intensity readings, 88.5 and 122 kc

Sonne Monitoring Program

At the time of this voyage the Air Force was operating an experimental station using the Sonne system of navigation with signals being emitted for one 24-hour period a week on 193 kilocycles. The station was located near Watson Laboratories, Red Bank, New Jersey. It was felt that by monitoring these transmissions on this trip into the Arctic some useful data might be added to a Bureau of Ships monitoring program for this station and at the same time information might be gained which would bear upon the long-range navigation problem. Because of the shortened trip, very little data was accumulated. Some observations were made on the afternoon of January 30, at which time the ship was off Halifax, Nova Scotia. Detailed Sonne charts were not available to compare an observed Sonne line of position to the navigator's reported position.

CONCLUSIONS

There is some evidence of the ship having passed through several zones of interaction between the groundwave and one-hop skywave signals coming from the TBJ transmitter on 18 kilocycles at Annapolis, Maryland.

The position of one zone of abnormally high signal intensity and five zones of low signal intensity have been used to determine the virtual height of the ionosphere layers reflecting low-frequency skywaves to earth. The assumption has been made that the sky-wave suffers a phase reversal of 180° upon reflection from the ionosphere. A decrease in ground conductivity between two different paths present in the measurements of one of the dips may account for some of the decrease in field intensity for that case.

The directional characteristic (4 decibel variation) observed on 18 kilocycles with the ship's antenna may have been due to its physical similarity to a loop antenna.

The curves showing diurnal variation of field strength on 88.5 kilocycles and 122 kilocycles indicate that skywave reflection occurred from an unstable ionospheric reflecting layer. The greatest diurnal variation was 12 decibels on 88.5 kilocycles and 19 decibels on 122 kilocycles.

This method for taking ionospheric data has proved valuable, as can be seen from the results of this short trip. A great deal of propagation information may be accumulated by using the regularly scheduled transmissions of certain low-frequency and very low-frequency stations. In this case, if continuous readings had been taken on all of the transmissions of NSS on 18 kilocycles better definition of the high and low signal-level zones could have been obtained, and the virtual height and other characteristics of the reflecting layer involved could have been more accurately determined. Continuous readings should also have been taken on the low-frequency transmissions in order to make maximum use of the time spent on the voyage. To do this would have required more personnel.

RECOMMENDATIONS

It is recommended that maximum advantage be taken of trips such as this voyage of the USS EDISTO in order to conduct studies, including propagation, which require transportation to remote areas. It is further recommended that sufficient personnel be sent to insure that maximum use be made of the time available.

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ACKNOWLEDGMENT

Acknowledgment is made to the Commanding Officer of the USS EDISTO, Commander W. F. Morrison, and his staff, especially to LTJG Fields and the Communications Section, for their cooperation and assistance in supporting the work of the Naval Research Laboratory on this voyage.

CONCLUSIONS

There is some evidence of the ship having passed through several zones of interaction between the groundwave and one-way skywave signals coming from the TPI transmitter at Annapolis, Maryland.

The position of one zone of abnormally high signal intensity and five zones of low signal intensity have been used to determine the virtual height of the ionospheric layers reflecting low-frequency skywaves in each. The ionosphere has been made that the sky-wave reflects a plane several of 100' above reflection from the ionosphere. A decrease in ground conductivity between two different points present in the measurement of one of the low frequency waves of the decrease in their intensity in that case.

The directional characteristics of a desired variation observed on 12 kilocycles with the ship's antenna may have been due to its physical structure in a loop antenna.

The carrier showed diurnal variation in their strength on 12.5 kilocycles and 12 kilocycles. The greatest diurnal variation was 12 decibels on 12.5 kilocycles and 12 kilocycles on 12 kilocycles.

This method for taking ionospheric data has proved valuable, as can be seen from the results of this study. A great deal of propagation information may be accumulated by using the regularly scheduled transmission of certain low-frequency and very low-frequency stations. In this case, it continues regular had been taken on all of the transmission of 12.5 kilocycles better definition of the night and low signal-level zones could have been obtained, and the virtual height and other characteristics of the reflecting layer involved could have been more accurately determined. Continuous readings should also have been taken on the low-frequency transmission in order to make maximum use of the time spent on the voyage. To do this would have required more personnel.

RECOMMENDATIONS

It is recommended that continuing observations be taken of this type on this voyage of the USS EDISTO in order to obtain studies, including propagation, which require transmission to remote areas. It is further recommended that sufficient personnel be available to insure that maximum use be made of the time available.

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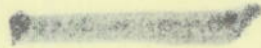
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