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# VLF WAVE-PROPAGATION AND ATMOSPHERIC-NOISE MEASUREMENTS AT THULE, GREENLAND

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## INTRODUCTION

In the Arctic regions, the low and very low radio frequencies may be extremely effective for communication over medium ranges, especially during ionospheric blackouts. The usefullness of these frequency bands is primarily dependent upon reliable information on both radio-wave propagation and atmospheric noise. For all practical purposes, only the operational performance of communication circuits is available at the present time; information is lacking on the components of the system such as antenna efficiency and atmospheric-noise level.

During February and March, 1951, a preliminary study of some phases of this problem was made in the Alaskan area,[1] but additional preliminary data taken during another season of the year were considered desirable as a basis for the design of future experimental equipment and procedures.

A Navy research group, composed of one representative of the Naval Research Laboratory and two representatives of the Bureau of Ships, conducted preliminary wave-propagation experiments in the Arctic regions during the summer of 1951. The experimental equipment was located at Thule, Greenland (76° 32′N, 68° 52′ W). A more favorable location with less man-made interference would have been desirable; however, such a site could not be obtained at the time. Five weeks were spent at the Laboratory for the procurement and calibration of the equipment, and five weeks were devoted to actual experimentation in the Arctic.

The purposes of this inquiry were to determine the magnitude of the atmospheric noise and the absolute signal levels of low-frequency signals. Attention was focused on obtaining information that will help in the determination of the signal-noise relationship. Previous work in the Arctic was generally concerned with investigations of signal intensity or atmospheric noise rather than a study of both.

[1] *Dinger, H. E., Garner, W. E., and Leavitt, G. E., "Measurements of Some Low- and Very Low-Frequency Signal Intensities in the Alaskan Area," NRL Report 3921, January 18, 1952 (Confidential)*

INSTRUMENTATION

Instrumentation consisted of one AN/URM-6 Radio Interference-Field Intensity Meter and one AN/PRM-1 Radio Interference-Field Intensity Meter. In both instruments, the time constant of the circuitry was 600 milliseconds, the same for both charge and discharge. To facilitate recording the data, each instrument was equipped with an Esterline-Angus graphic recorder; continuous 24-hour recordings were thus obtained. A simple scale was provided to convert the reading on the chart directly to microvolts, and the field intensity in microvolts per meter was obtained by dividing this value of signal level by the effective height of the antenna.

A large loop antenna supplied with the AN/URM-6 meter, a 100-inch whip, a 50-foot top-loaded vertical, and a 50-foot vertical antenna held aloft by a balloon were used in this investigation. The effective height of the large loop antenna was known; hence, an accurate determination of the field intensity at the test site could be made using the AN/URM-6 meter. The effective height of the other types of antennas was then calculated from the measured antenna voltage (signal level) and the field intensity. Hence, the signal level can be converted to absolute values in microvolts per meter for all antennas used during these tests.

DATA

Field-intensity and atmospheric-noise measurements were made at 18, 19, and 250 kc. The atmospheric-noise measurements were made at a frequency slightly removed from the radio-signal frequency at 18 kc, and only atmospheric-noise measurements were made at 250 kc. For the 18-kc field-intensity measurements, the source of transmission was the U.S. Navy radio station NSS at Annapolis, Maryland (approximately 38°N, 76°W); this transmitter is about 2,210 nautical miles from the receiving site at Thule, Greenland. At 19 kc, the signal was transmitted from the U.S. Navy radio station NPM in the Hawaiian Islands (approximately 21°N, 165°W), and about 4,050 nautical miles from the receiving site. During the first two days of experimentation, the NPM signal was the only one received at Thule.

Each frequency was monitored at intervals throughout the day to verify that the proper signal was being received. Since the presence of a transmitted signal would invalidate atmospheric-noise data and the absence of a transmitted signal would invalidate field-intensity measurements, this verification was essential.

At the end of each 24-hour period, the recorder chart was removed and the data transcribed. The signal level for a given hour was obtained by averaging the peaks of the signal level over the period extending from 30 minutes before the hour to 30 minutes after the hour. This signal level was then converted to field-intensity data. Curves were plotted to show the relationship between field intensity and the time of day. To obtain sufficient information for plotting an average-day curve, data for the same hour of each day were taken from these graphs and averaged (Figure 1). These data were averaged from a 28-day measuring period from 11 August to 11 September 1951. The 250-kc atmospheric-noise data, which constitute about 148 hours of chart records, were taken from 12 August to 5 September 1951; they were then averaged for each hour in the same way as the data taken at 18 kc. The average atmospheric-noise level at 250 kc is plotted as a function of the time of day in Figure 2.

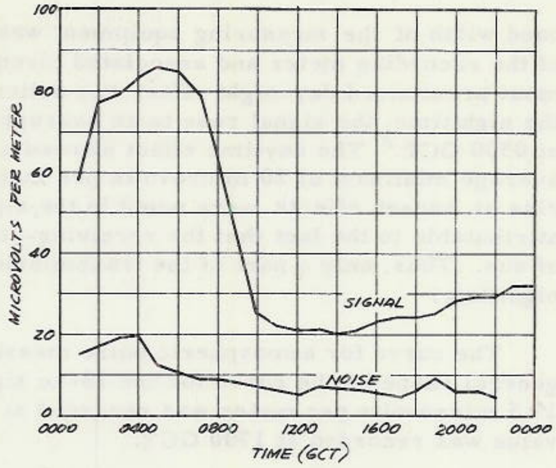


*Figure 1 - Average values of signal and noise at 18 kc*

To obtain maximum useful information from the small amount of available data, the methods of mathematical statistics were employed. By the proper use of these methods accurate predictions of future events can be made. The accuracy of a prediction increases as the quantity of available data is increased; however, accurate results can be obtained with small amounts of reliable information.

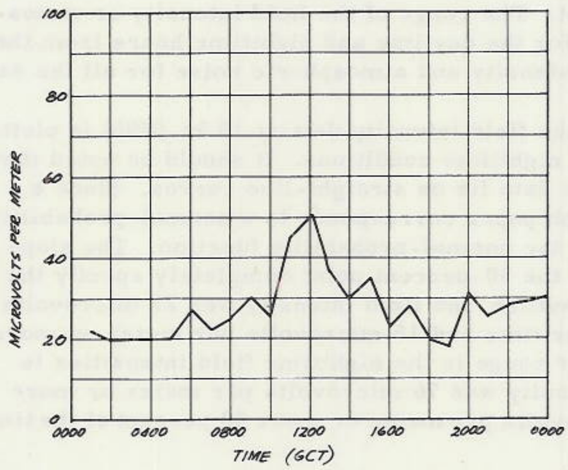


*Figure 2 - Average values of atmospheric noise at 250 kc*

The data used in this report were divided into two main sections: 18-kc atmospheric-noise and 18-kc transmitted-signal (NSS) data. Each section was further divided into two periods corresponding approximately to the daytime and the nighttime hours.

RESULTS

The diurnal variation of the average values for field intensity and atmospheric noise at 18 kc is shown in Figure 1. The model AN/URM-6 equipment was used in the field-intensity position for the noise measurements. The

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band width of the measuring equipment was about 100 cps, and the time constant of the recording meter and associated circuits was about 600 milliseconds. A most pronounced day-night effect was noticed in the field-intensity curve. During the nighttime, the signal rose to an average maximum of 86 microvolts per meter at 0500 GCT.[2] The daytime effect showed a much lower field intensity, and the average minimum of 20 microvolts per meter was reached at 1400 GCT. No sunrise or sunset effects were noted in the signal data; this condition was probably attributable to the fact that the receiving-station site was in a region of 24 hours of sun. Thus, only a part of the transmission path was in darkness during the nighttime.

The curve for atmospheric noise measured at 18 kc followed the same general shape as the curve for the 18-kc signal. An average maximum value of 19.5 microvolts per meter was recorded at 0400 GCT, and the average minimum value was recorded at 1700 GCT.

A curve showing the diurnal variation of the atmospheric noise at 250 kc is given in Figure 2. The band width of the AN/PRM-1 measuring equipment was about 3000 cps, and the time constant of the recording meter and associated circuitry was about 600 milliseconds. No transmitted signal was available for recording at or near 250 kc; hence there is no comparison of signal and noise data. The average maximum of the 250-kc atmospheric noise, which is about 50 microvolts per meter, was reached at approximately 1200 GCT or nearly 7 hours after the average maximum of the 18-kc atmospheric-noise level was attained. In general, this noise level at 250 kc was somewhat higher than at 18 kc.

Mathematical statistical procedures were applied to obtain the Gaussian distribution curves for the periods of the day and night when the average signal in Figure 1 was essentially constant. The range of the field intensity or atmospheric noise was obtained at 18 kc for the daytime and nighttime hours from the hourly average values of the field intensity and atmospheric noise for all the days.

The statistical distribution of the field intensity data at 18 kc (NSS) is plotted in Figure 3 under both daytime and nighttime conditions. It should be noted that all points within the accuracy of the data lie on straight-line curves. Since a straight line on this particular graph paper corresponds to a normal-probability curve, the field-intensity data obey the normal-probability function. The slope of the line and the field intensity at the 50-percent point completely specify the distribution function. During the daytime, the field intensity was 22 microvolts per meter or more 50 percent of the time and 15 microvolts per meter or more 90 percent of the time. The greater range in the nighttime field intensities is shown by the fact that the field intensity was 76 microvolts per meter or more 50 percent of the time and 46 microvolts per meter or more 90 percent of the time.

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[2] *Local time at Thule, Greenland was GCT plus 5*

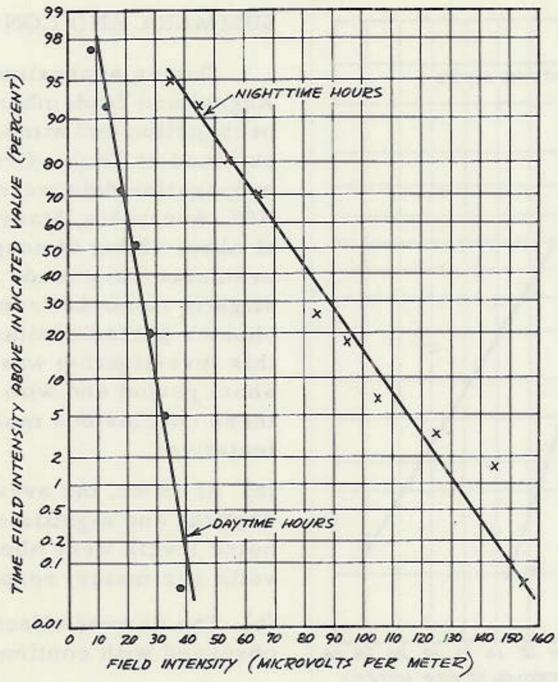


*Figure 3 - Field-intensity distribution curves at 18 kc*

The atmospheric-noise data obey the normal-distribution function for both the daytime and nighttime conditions. The distribution of the atmospheric-noise data at 18 kc is shown in Figure 4, and from this curve, the percent of the time that the atmospheric noise level was less than any given value can be read directly. For example, the average value of atmospheric noise was less than 15 microvolts per meter 90 percent of the nighttime hours.

The results of this analysis indicate that statistical methods may be an effective tool for the analysis of wave-propagation and atmospheric-noise data. The method used in the preceding analysis may not be adequate for atmospheric noise since it may be necessary to apply statistical methods to the fundamental characteristics of atmospheric noise (such as amplitude, duration, and time interval between pulses) instead of the normally measured atmospheric-noise data. Statistical methods also aid in determining the minimum time that is required for an adequate sample of atmospheric noise. Hence, with the proper measuring techniques and statistical methods, it may be possible to reduce appreciably the time required for collecting atmospheric-noise data.

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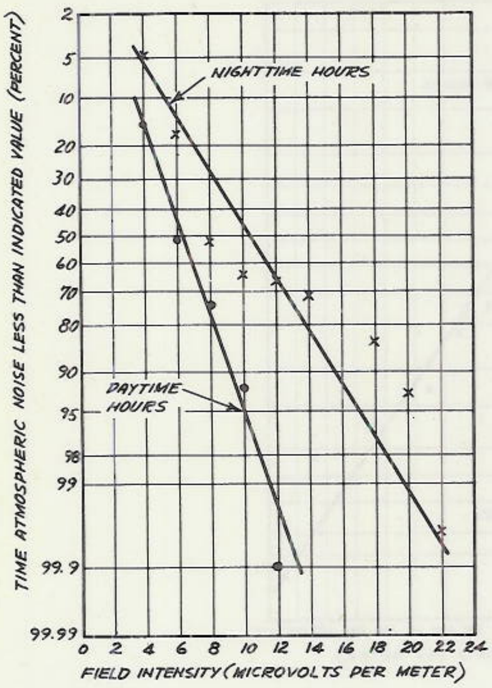


*Figure 4 - Noise-distribution curves at 18 kc*

## SUMMARY AND CONCLUSIONS

During approximately 5 weeks in August and September, 1951, data on wave propagation and atmospheric noise were obtained at Thule, Greenland. The wave-propagation data were taken for station NSS, Annapolis, Maryland, on a frequency of about 18 kc; atmospheric-noise measurements were made at a frequency slightly removed from 18 kc and for a shorter period of time on 250 kc. Since this investigation was made during a short period and with limited scope, these conclusions must necessarily be tentative:

(a) At 18 kc, the average values of the daytime and nighttime atmospheric-noise levels were about 6 and 10 microvolts per meter, respectively.

(b) The diurnal effect in noise level was observed with continuous daylight.

(c) On approximately 18 kc, the very low-frequency station NSS at Annapolis, Maryland, gave a usable communication signal essentially all the time.

(d) The atmospheric-noise level was higher at 250 kc than it was at 18 kc.

(e) The atmospheric-noise and wave-propagation data at 18 kc fit the Gaussian distribution curve, but the data at 250 kc were not sufficient for statistical analysis.

(f) The application of proper statistical methods to the Arctic program on very low-frequency research may greatly reduce the effort and time required to collect and analyze the data.

## ACKNOWLEDGMENTS

The success of the experiments was due to the splendid cooperation of the personnel of the Bureau of Ships, the Communications Office, CTF 118, the U.S. Weather Bureau, and Project BlueJay.

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