A High Frequency Radio Propagation Quality Figure

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High frequency radio communications are often disrupted by solar activity which causes sudden ionospheric disturbances followed by ionospheric storms which may be recurrent in nature. These disturbances of the earth's atmosphere result from changes in the state of ionization of the ionosphere and in the structure of the ionized layers. The ionization change is produced by the impact of X-ray radiation and of charged particle emission from the sun. Although much research has been done in atmospheric physics, the onset of these ionospheric disturbances cannot be predicted with complete accuracy.

Impact on High Frequency Communications

Regardless of the source, ionospheric ionization changes disrupt many long distance communication circuits which utilize reflections from the ionosphere. A communication circuit may be disrupted by several changes in the ionosphere structure but the most frequent causes are increased signal absorption (higher losses) and radical changes in ionospheric layers, resulting in changes of layer height and increased multipath propagation.

Changes in layer height influence the useful range of frequencies for a particular communication path. Consequently, accuracy of information on ionospheric layer heights is reflected in the accuracy of predictions of usable frequencies for any specific propagation path. The most widely used technique for collection data on ionospheric layer heights has been vertical incidence sounding. For many years, sweep frequency pulse sounders have been used in a vertical incidence mode to measure and record the vertical incidence critical frequency and the effective height of the various layers of the ionosphere, as a function of frequency. Through relatively complex mathematical calculations, these measurements can be translated to usable frequencies over an oblique communication path.

Because vertical sounders cannot be operated at the reflection points of all conceivable communication circuits, the results of a few vertical sounders must be extrapolated to cover large areas of the earth. However, this procedure seriously degrades the accuracy of the results. Converting vertical incidence ionospheric data to usable oblique communication frequencies is sufficiently complex and its use so widespread that specialized computer programs have been developed to perform the computations. To a limited extent, automated long-term frequency prediction capabilities have existed for some time. Several agencies publish such information for a number of communication paths. It is usually presented in terms of median values of maximum usable frequencies for a specific calendar month, plotted on a 24-hour scale.

The processes involved in deriving these predictions are presently combined into a composite computer program which was developed by National Bureau of Standards, Boulder, Colorado, under a Bureau of Ships project. The computer input consists of data representing the adjusted averages of many solar and geophysical phenomena which affect radio frequency propagation via the ionosphere as well as data on antenna and communication equipment characteristics intended for use on the particular path. Study efforts now under Bureau contract are aimed at advancing the state-of-the-art in this prediction method, and the results of these studies will be used to modify the present computer program to incorporate new data found to be of value.

Oblique Incidence Pulse Sounders

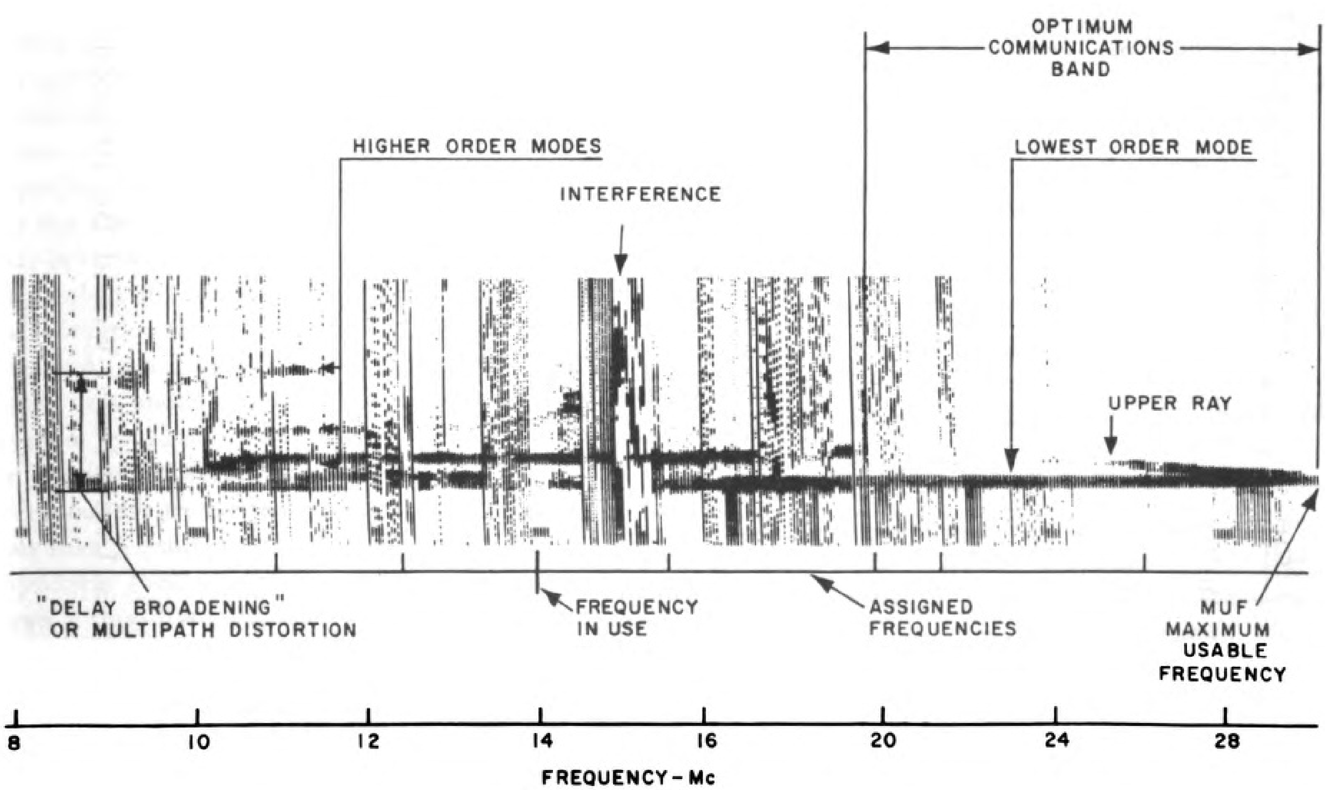
Developments in recent years have resulted in the successful operation of step frequency pulse sounder transmitters and synchronized sounder receivers operating over an oblique propagation path. Briefly, the sounder transmitter steps through the high frequency spectrum on a finite number of channel frequencies in a given time period, emitting high peak power pulses on each channel. The sounder receiver is tuned in time synchronization to each of the channel frequencies covered by the transmitter and, when propagation conditions permit, receives and displays on an oscilloscope the pulse arriving over the propagation path from the sounder transmitter. Since the useful frequency range for a given propagation path is limited, only those channel frequencies which can be supported by the ionosphere for the particular path measured will result in a suitable pulse in the output of the sounder receiver.

Figure 1 shows a typical display of oblique sounder pulses received as a function of frequency. The information provided in this type of display can readily be used in selecting a communication operating frequency for optimum propagation conditions over the path between the oblique sounder transmitter and the sounder receiver. Further, the oblique sounder ionogram clearly displays the various propagation modes that are predominant over the path and the resulting multipath propagation conditions. This latter parameter can be related to the percentage of distortion that can be expected in a radio communication circuit using a frequency under those conditions.

Another phase of BuShips R & D effort has resulted in development of a hard copy printer of oblique sounder receiver outputs. The digitalized sounder output is fed to signal processing circuits which produce control voltages for a modified electric typewriter. The typewriter steps across a page in synchronism with the channel stepping of the oblique sounder and prints a quantized figure from 1 to 9 to indicate relative signal to noise ratio of signals received on each sounder channel. Further, distortion (multipath) measurements are made and compared to an adjustable threshold level. If the distortion level of the oblique sounder signal exceeds the threshold level selected, the ribbon on the typewriter is shifted from black to red and thus indicates an excessive distortion in that sounder channel.

Figure 2 is typical of the type of output resulting from the printer which is provided to communication circuit controllers on a continuous 24-hour basis. The greatest advantage of the display is that it permits the operators to review immediately the past activity of the ionosphere and establish trends in the movement of maximum observed frequency (MOF) and lowest observed frequency (LOF). This provides the basis for advance short term prediction of time and direction for changing a communication circuit frequency. This information alone permits a significant increase in communication circuit operating efficiency. Obviously, the oblique sounder transmitter and synchronized receiver provide appropriate tools for direct measurement and indication of high frequency propagation conditions over a particular path, without further interpolation or extrapolation.

Figure 1. Typical oblique sounder ionogram.



Sta.	Time	S/N vs. Frequency (Channels)																	LOF Dev.	MOF Dev.
NPM	0000				<u>4</u>	<u>5</u>	<u>5</u>	<u>4</u>	<u>3</u>	6	7	8	8	9	8	8	7	7	4	8
NPM	0010			<u>3</u>	<u>4</u>	<u>4</u>	<u>5</u>	<u>3</u>	4	4	5	5	6	8	8	7	7		5	8
NPM	0020		<u>2</u>	<u>2</u>	<u>3</u>	<u>3</u>	<u>4</u>	<u>4</u>	6	5	4	7	8	8	7	6			4	7
NPM	0030	<u>1</u>	<u>2</u>	<u>3</u>	<u>3</u>	4	4	6	7	8	8	9	8	7					3	6
NPM	0040	<u>1</u>	<u>1</u>	<u>2</u>	<u>2</u>	<u>3</u>	4	3	5	7	6	5							2	6
NPM	0050	<u>1</u>	<u>2</u>	<u>2</u>	3	3	4	4	5	5	6	6							3	5
NPM	0100		<u>2</u>	<u>3</u>	<u>3</u>	<u>4</u>	5	7	7	6	5								3	4
NPM	0110	<u>2</u>	<u>3</u>	<u>3</u>	<u>4</u>	<u>4</u>	5	6	7	7	6								4	5
NPM	0120	<u>1</u>	<u>2</u>	<u>3</u>	3	4	4	6	7	6									4	5
NPM	0130		<u>1</u>	<u>2</u>	<u>2</u>	<u>3</u>	5	6	6	5									3	5
NPM	0140			<u>1</u>	<u>2</u>	3	3	5	6	5									4	5
NPM	0150			<u>2</u>	<u>3</u>	<u>4</u>	4	6	5										4	5

-- Figures Underlined Would Be Printed in Red Indicating That These Signals Exceed Distortion Limits.

Figure 2. Propagation data printer format.

Oblique Sounder System Tests

The Bureau has recently completed procurement, installation, engineering testing and evaluation of two commercial oblique sounder systems. One system was installed and operated between Washington and Honolulu and the other between Washington and several ships operating in the Atlantic. The test and evaluation of these systems in parallel with Navy communication circuits established that the oblique sounder system could provide reliable propagation data on an up-to-the-minute continuous basis for use by communication circuit controllers in selecting operating frequencies.

The experience gained in these tests was used to the fullest extent in developing interim oblique sounder system standards for the Defense Communication Agency, covering system parameters and characteristics of a worldwide common user radio transmission sounder system (CURTS). The test also served as a basis for system specifications to be used in developing militarized equipment for Navy operational evaluation. The appropriate plans and procurement action have been initiated to pursue this development without delay.

Propagation Quality Figure

Obviously, there are many potential operational applications of the propagation data provided by an oblique sounder system. Figure 3 shows the possible location of Navy operated sounder transmitter sites in a worldwide sounder network. One potential use for sounder data would be to derive, display and disseminate a propagation quality figure to indicate the status of ionospheric propagation conditions. This quality figure would provide a direct indication of the status of available frequency range as normal, less than normal or greater than normal, and it would indicate the degree of deviation from normal conditions.

Figure 4 is a simplified functional block diagram of the system under consideration. Fundamentally, the system would use a shore-based oblique incidence sounder receiver properly synchronized to receive sounder transmissions in a time sequential manner from a quantity, for example up to ten, of appropriately located sounder transmitters. Figure 5 shows a true-distance, true-azimuth representation of particular paths that would terminate in Hawaii. The MOF-LOF output data from the sounder receiver would be digitalized and automatically and continuously compared with standard 15 or 30 day maximum useful frequency (MUF)– lowest useful frequency (LUF) predictions for the respective propagation path. The result would be a real-time output, representative of the deviations from the standard predictions. These deviations could be represented by positive or negative numerical values or by deviations above or below a fixed level, such as level five. Figure 6 is a comparison of predicted MUF and the measured MOF for two days on the Washington-Honolulu sounder path during July 1963.

When the deviations are averaged over a finite period of time, the resulting output should be an excellent indication of the actual propagation conditions at that particular time, on that particular path. As the comparisons and measurements are made on additional propagation paths, on other azimuthal bearings, a more complete presentation of propagation conditions is obtained. Assuming that measurements are made on at least four appropriately spaced paths corresponding to the points of the compass, propagation conditions in all directions could be deduced.

Such additional factors as field strength, signal noise ratio, multipath (distortion) and phase perturbations on individual sounder channels could eventually be measured, weighted and combined with the above MOF-LOF deviations, resulting in a complex but refined singular propagation quality figure. Monitoring the quality figures on several propagation paths could result in a limited advance warning of impending radio disturbances on other communication paths, particularly when correlated with other measurements of solar activity.

Once the propagation quality figure is established, it must be disseminated to the Fleet and other users on a continuous real-time basis to realize maximum utility of the information. It can be readily transmitted by modulation of a nearby oblique sounder transmitter with a simple phase code with resultant transmission to the shipboard sounder receiver. The quality figure would be displayed on the output of synchronized oblique sounder receivers in the form of 0-9 numerical display on a nixie tube. A sequence of four digits could also be transmitted to represent propagation quality over paths to the north, east, south and west. This data could be exchanged periodically on a worldwide sounder network, resulting in almost instantaneous transfer and presentation of quality figures over vast areas of the world.

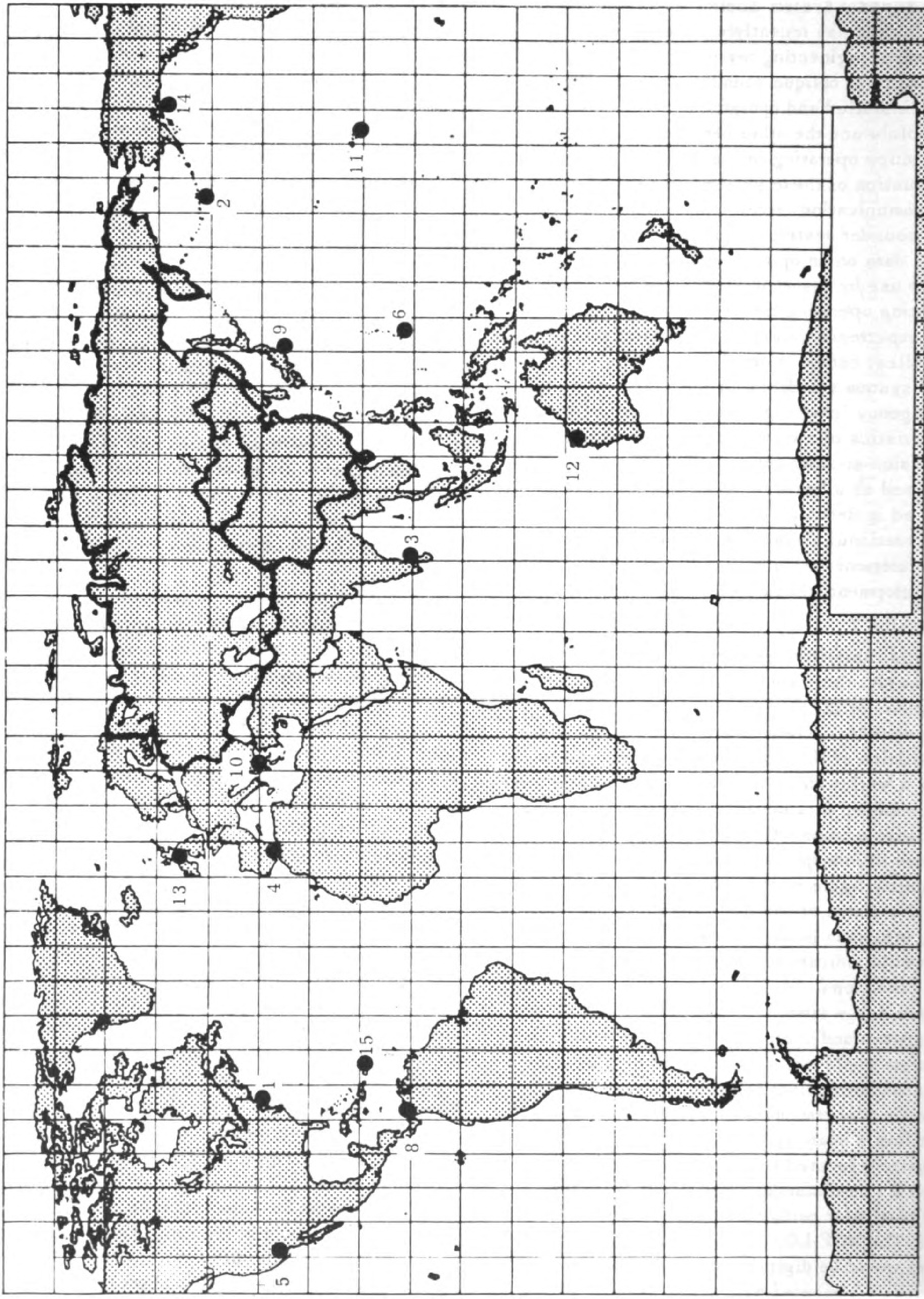


Figure 3. Deployment of worldwide sounder network.

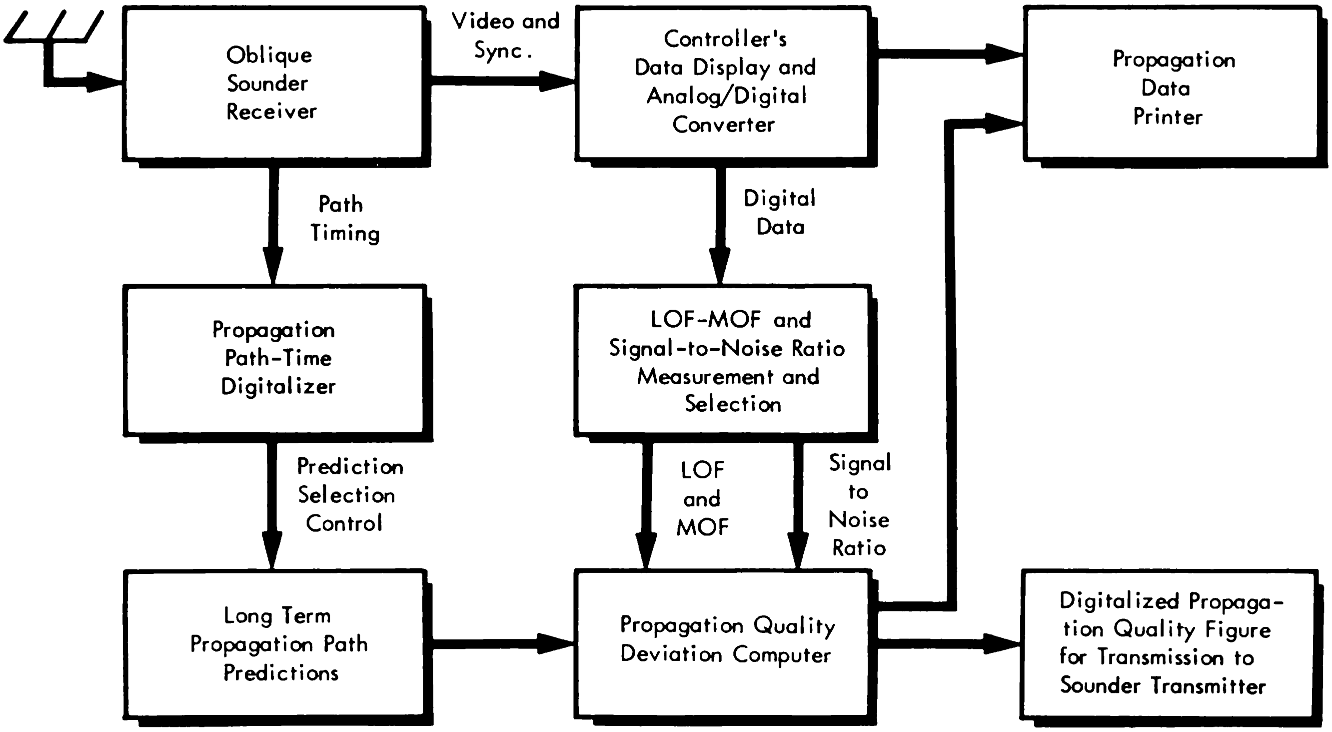
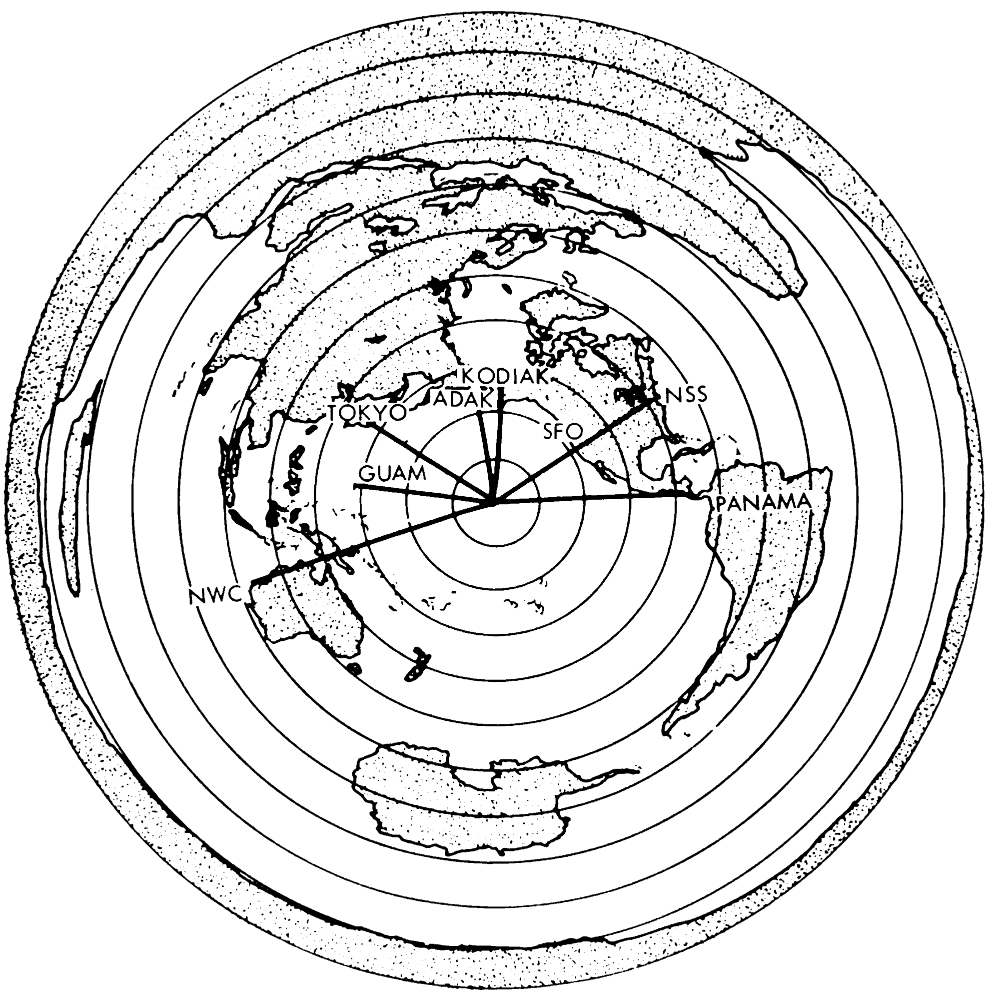


Figure 4. Functional block diagram.

Figure 5. Soundor paths terminating in Hawaii.



When radio disturbance forecasting is refined to provide at least a reasonable advance warning, these predictions can immediately be relayed to Fleet users by blinking the quality figure indicator on the oblique sounder receiver.

Preliminary analysis of data on seven oblique sounder paths terminating in Mountain View, California, is in process. These results will be correlated with other sources of ionospheric disturbance data and the results interpreted. If the technique proves worthwhile, it may be introduced as a part of the overall Navy communication system as well as a part of the Defense Communication System.

Adapted from a paper presented at the technical symposium of the Association of Senior Engineers of the Bureau of Ships, 10 April 1964, Washington, D.C.

Figure 6. MOF-MUF comparisons Washington to Honolulu.