NBS REPORT

8439

RADIO FREQUENCY PROPAGATION AND PREDICTION SYSTEM, SS-267 QUARTERLY PROGRESS REPORT

April - June, 1964

D. W. Patterson
Program
Coordinator

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
BOULDER LABORATORIES
Boulder, Colorado

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
8500-12-85409 8520-12-85529 8530-12-85439 8230-40-82431 8260-40-82466	June 30, 1964	8439

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CONTENTS

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Foreword

This report covers effort carried out during the period of April 1 through June 30, 1964, by the Ionospheric Research and Propagation Division and the Radio Systems Division of the Central Radio Propagation Laboratory, National Bureau of Standards. The effort was conducted under the following NBS projects which cover the SS-267 tasks as shown:

NBS Project No.	SS-267 Task
82431	7648
82466	7664
85409	7645
"	7659
"	7660
85529	7646
"	7642
85439	7040
"	7647

RADIO FREQUENCY PROPAGATION AND
PREDICTION SYSTEM, SS-267

Objective: To develop the concept for a system which will provide the Naval communication a capability for the selection of best operating frequencies for Navy HF circuits; and for predicting the time of onset, the intensity and duration of ionospheric disturbances and their effect upon Navy communications.

Progress: To achieve the objectives of this program the Central Radio Propagation Laboratory is carrying out studies and experimental tasks to develop information and techniques for improving predictions of HF radio wave propagation; to select best circuit operating frequencies; and, to improve predictions of the expected time of onset, duration and intensity of ionospheric disturbances which affect HF radio communication services. In addition to the above studies, consideration is being given to the formulation of system concepts for incorporating increased capabilities in the above areas into the Naval communications. Four discrete system areas are under study: (1) a frequency prediction system, (2) a frequency selection system, (3) a disturbance warning system, and (4) a master frequency control center. The composite system will be termed the Radio Frequency Propagation System (RFPS).

During the past quarter, effort in all tasks has been directed toward providing information to be used in establishing an initial concept for the RFP System. Approximately a year has been spent in preliminary investigations to establish the overall requirements for the system, the bounds or limits within which the system must operate, and the state of our knowledge of the techniques and components which are to be considered as building blocks for the system.

Because of the complexity of the RFP System and its interface requirements with other systems both in and outside of the Navy and the short time schedule to operational employment, it is considered desirable, in fact essential, to develop a system concept as early in the program as practical. Documentation of the initial system concept started in May and was scheduled for completion by the end of June. Some unanticipated events will cause a delay of about three weeks in the schedule.

The initial concept will be directed principally to ship/shore communication circuits, but with due consideration of other Naval communication requirements. It is expected that some reorientation of the tasks under this program will be required after an acceptable system concept has been developed.

Visits were made during the quarter to discuss various aspects of the system with the U. S. Army Radio Propagation Agency; Radio Frequency Spectrum Division, CNO; Stanford Research Institute and the Navy Electronics Laboratory.

Plans for next quarter: The initial concept will be completed during the next quarter. The concept will be evaluated within NBS and by such other groups as are designated by the Bureau of Ships. Based upon the results of the evaluation, the various tasks will be carefully reviewed to assure optimum alignment with system requirements.

Program coordinator: D. W. Patterson

SS-267 SYSTEMS ANALYSIS AND DEVELOPMENT

Task 7645 Program Analysis and Integration

Objective: To perform analysis, integration and coordination functions of the SS-267 program to provide subsystem compatibility and compatibility with related programs of the NCS and DCS.

Progress: Preliminary system concepts for the RFPS were completed and presented for discussion early in this quarter. Following these discussions among various CRPL staff members and the BuShips project engineer, efforts were undertaken to make the necessary revisions and clarification of these concepts, and to prepare a comprehensive report covering the initial concepts and required new study areas to be published at the end of the quarter.

As a result of some serious questions from the Navy regarding the program effort, the entire program was subjected to internal review and a briefing of the organization, progress, objectives, etc. was prepared for presentation to the Navy on July 14, 1964. This effort has resulted in delaying publication of the initial systems concepts, which is now scheduled to occur the last week of July.

On May 4-6, project personnel (including contractor representatives) visited the Frequency Management Office, OP-944, to obtain first-hand information on frequency management procedures, requirements, reporting functions, and future plans. This visit was very informative and many of the results are incorporated in the initial system concepts.

On May 7, project personnel visited the U. S. Army Radio Propagation Agency at Fort Monmouth to discuss the work of that Agency related to the requirements of the SS-267 program. The main discussions covered the results of, and future plans for, experiments employing oblique sounders. Tests to establish spatial correlation of sounder data, planned to commence very shortly, should supply information needed in the SS-267 program for determining the utility of a sounder network to provide current ionospheric maps. Discussion of the details of the results of most of the RPA technical program was deferred for discussion at the visit to the Stanford Research Laboratory.

On May 11-12, a visit was made to SRI to discuss the results of sounding tests and the application of sounders to the SS-267 program. The results of oblique path measurements between Washington and Palo Alto, and Fort Monmouth and Palo Alto were discussed. These results indicate that for paths of moderate geographical separation oblique sounder data showed little correlation for considerable periods of time. Additional information will be obtained from the experimental program being conducted for RPA. A briefing on the techniques for providing hard copy outputs from oblique sounders was given by SRI personnel and discussions were held on the problems confronting the use of sounders for communication improvement.

On May 13, NEL was visited as part of the continuing liaison between SS-296 and SS-267. Discussions were held with the Operations Analysis Section on ship traffic studies, and with the technical sections concerned with transmitters, receivers, modulation, antennas, filters and multicouplers, SOAS, and communication processing. In addition, a briefing was given to a group of SS-296 project leaders on the status of the effort and plans for the SS-267 program. The discussion following this briefing was very beneficial toward establishing the interface requirements between the two systems. Most disconcerting was the concern of the filter and multicoupler personnel of having a large number of possible operating frequencies available to the ship. With the number of transmitters on major fleet vessels planned for simultaneous operation, the availability of a large number of possible operating frequencies will increase the potential number of spurious signals which could cause interference to reception to a point where it is not feasible to provide a capability for predetermining the interference potential prior to coming up on a frequency. If this indeed proves to be a serious problem, the planned capability of the SS-267 system to provide a suitable operating frequency from a pool of frequencies may be negated. Means to overcome this problem are being studied.

Plans for next quarter: Complete and distribute report on initial system concepts, begin evaluation of these and formulation of final concepts, evaluate role of existing tasks in supporting these concepts, prepare detailed proposals for modification of existing tasks and or implementation of new tasks.

Personnel: D. W. Patterson, W. R. Hinchman, K. P. Dixon, D. N. Hatfield

Task 7659 Study and Determine the Type of Radio Frequency Prediction System Installation for Ship and Shore Locations

Objective: To provide system engineering for the implementation of RFP System equipment for ship and shore locations.

Progress: The initial report on present techniques and procedures in Navy frequency assignment and control was prepared and submitted by the contractor. This information is being included in the initial systems report. A summary report covering the frequency assignment and employment information in JANAP-195(H) has also been submitted. Information on present and future ship-shore naval communication facilities is also being assembled. Data processing requirements were estimated for the initial systems concepts and will be included in that report.

Review of a report entitled "Communications, Data Processing, and Display Requirements of the Numbered Fleet Flags" prepared by NEL was undertaken as an indication of possible operational environment of the RFP System.

Plans for next quarter: Operations analysis and evaluation of the initial system concepts will be initiated during this quarter. Particular emphasis will be placed on determining the number and cost of proposed facilities and equipment. The study of data transmission and processing requirements will continue as will the assembly of background type information on present and future naval communications facilities.

Personnel: W. R. Hinchman, K. P. Dixon, D. N. Hatfield, Collins Radio Company

Task 7660 <u>Determine Master Frequency Control Center Operational and Installation Requirements</u>

Objective: To provide for the integration of the MFCC functions which do not relate directly to frequency prediction or selection, or to disturbance warning, but which are essential in the overall operation of the RFP System.

Progress: A detailed breakdown of the functions and procedures of the present Frequency Management Office was prepared, based largely on information obtained during the visit of May 4-6 to this organization. These are now being analyzed to determine peripheral equipment requirements for the MFCC. Logic programs for the MFCC functions have been prepared and will be included in summary form within the initial systems report.

Plans for next quarter: The initial requirements and logic for the MFCC will be reviewed and evaluated as part of the operations described under Task 7659.

Personnel: W. R. Hinchman, K. P. Dixon, D. N. Hatfield, Collins Radio Company

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SS-267 PREDICTION TECHNIQUE EVALUATION

Task 7646 Analysis and Correlation of Communication Circuit Characteristics

Objective: This task will monitor and analyze the characteristics of signals received over an operational Navy HF circuit and will correlate circuit performance with operating frequency and propagation conditions as determined by oblique and vertical ionospheric soundings and with standard predictions.

During this quarter, the taking of initial test data was completed and analysis of these data was started.

The initial plans called for simultaneous measurement of error rate and signal-to-noise ratio of signals received at the Navy's primary and secondary frequencies over the operational path between Hawaii and Cheltenham, Maryland. However, NBS was advised just before the experimental work was started that the station did not have the extra terminal equipment necessary for the experiment to be performed on pairs of frequencies. The experiment was thus performed using the Navy's primary frequencies only with serious loss in the usefulness of the data. The necessary terminal equipment was ordered by NBS with the hope that some simultaneous data on pairs of frequencies could be obtained before the experimental period was completed, but it was not possible to get the equipment delivered, installed, and adjusted in time to do this.

Attempts were made to take data on a full-time basis between April 7 and May 7;on a half-time basis between May 7 and May 27. When full-time data taking was attempted, however, it was only possible to obtain usable data a fairly small percentage of the time because of the nature of the Navy's normal operating procedure and the poor quality of the oblique incidence records that were produced during the experiment. The following is a list of causes of loss of data:

(1) During conditions of poor signal, the experimental channels were combined with regular communication channels in a twinning operation.

(2) During conditions of poorer signal, transmissions were taken from the Army antennas at LaPlata.

(3) During most of the experiment the oblique incidence sounder was not adjusted for proper contrast and in many cases the time could not be read from the records. The operation of the sounder was not under NBS control.

(4) The Cheltenham Station kept no log on times of frequency changes and had no positive method of advising NBS on the exact time that frequency or operating changes were made.

In spite of these difficulties, enough quantity and quality of data were obtained to give a useful evaluation of the sounder as a distortion measuring device relative to 75-baud FSK signals. Moreover, the data obtained should be of value in determining the optimum operating frequency relative to the value of MOF.

Experimental procedure: Measurements were made on two channels of the multiplex package of the Navy communication circuit. Transmissions were single sideband FSK with a data rate of 75 bauds (100 wpm). One of the experimental channels (channel 10) was held at a constant tone (mark signal), but the tone was cut off for 2-minute periods every ten minutes in order that signal-to-noise ratio could be monitored by a receiver with a 30 cps bandwidth. Most of the "noise" measured was actually interference from adjacent channels in the multiplexed arrangement of signals. Because of this, the signal-to-noise ratios remained nearly constant at about 20 db except during periods of weaker signals.

On the other experimental channel (channel 8), a 75 baud pseudorandom test signal was transmitted continuously from a pattern generator. An identical pattern generator was compared with the signal at the receiving end, and any disagreement between the two was recorded as an error. The error rates were printed out in errors per minute.

The signal-to-noise measurements were made at two-minute noise breaks in time coincidence with the oblique sounder records. By taking one-minute samples of error recorded during the center of the period of the noise breaks, near simultaneous measurements of error, signal-to-noise and oblique sounding were obtained. The error rate data were made from signals taken from the operational Navy communication receivers. These receivers operate with two rhombic antennas feeding them in a space-diversity arrangement. The signal-to-noise and oblique sounder records were made without diversity using the most efficient of the two rhombic antennas. Signals from one of the antennas were about 10 db stronger than from the other.

In addition to error rates and signal-to-noise measurements, a magnetic tape recording was made containing samples of error pulses and timing pulses. Short-term error distribution curves will be derived from these data.

Results: Figure 1 shows cumulative distributions of error rates for signals with different values of multipath distortion. Multipath distortion is defined here as the percentage of the bit length (13.3 ms) of multipath elongation measured in the received pulse. For example, zero multipath distortion would yield a received pulse of 1 ms on the oblique sounder record. If a received pulse of 2 ms duration is received, it has been elongated by 1 ms. The percentage distortion in this case is $\frac{1}{13.3} \times 100 = 7.5\%$.

A sharp increase in error rate at distortion percentages above about 20% is evident from figure 1. This corresponds to multipath delays of 2.7 ms and greater. For delays less than this, the error rate does not vary greatly for signals using this bit length; for example, error rates in the 16 to 20% distortion bracket are only 1.4 times greater 90% of the time than those in the 6 - 10% bracket. Error rates for signals with measured distortion of 5 percent and less are greater than those with somewhat higher distortion. The error rate averaged over 90% of the time for signals in this low distortion bracket is greater than in all other distortion brackets up to and including the 16 - 20% bracket. This effect is caused by fades of relatively long duration of signals that are measured near the nose of the oblique incidence ionogram. There is a region near the nose of the ionogram where the signal is unstable part of the time. This is part of the well-known "nose-extension" that causes the MOF to be generally greater than the classical MUF. It may be caused by scattering. The curves in figure 1 tend to cross at values of higher error rate showing that there are times when higher multipath readings do not indicate lower error rates. These are probably times when long duration fades are present on the signals that measure less multipath distortion.

The curves in figure 2 show the variation of error rate for signals received at different frequencies compared to the MOF. Frequencies with values of 76 to 80% of the MOF yielded the lowest error rates. Again the curves tend to cross.

Figure 1 - CUMULATIVE DISTRIBUTIONS OF ERROR RATES FOR SIGNALS WITH DIFFERENT VALUES OF MULTIPATH DISTORTION

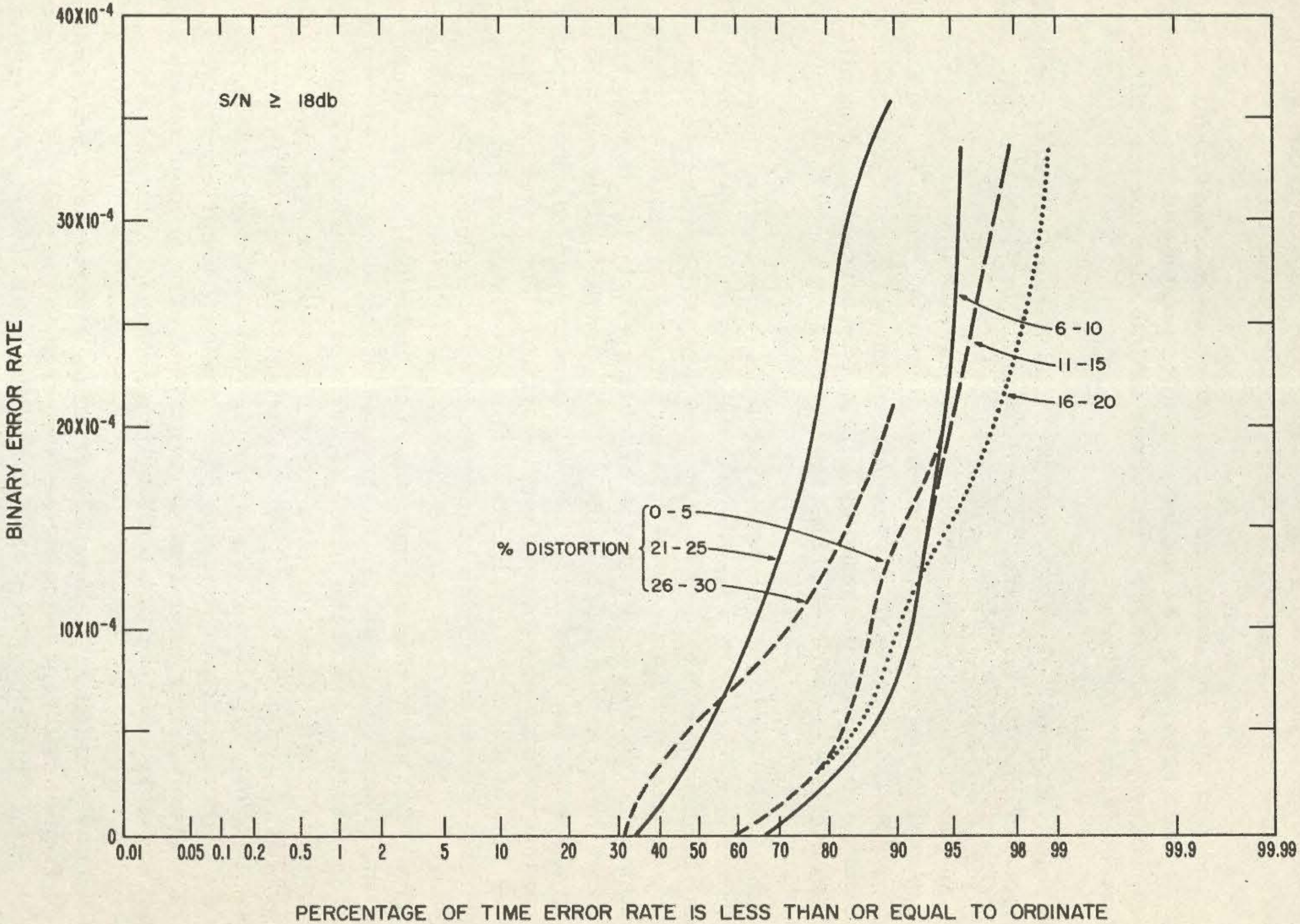
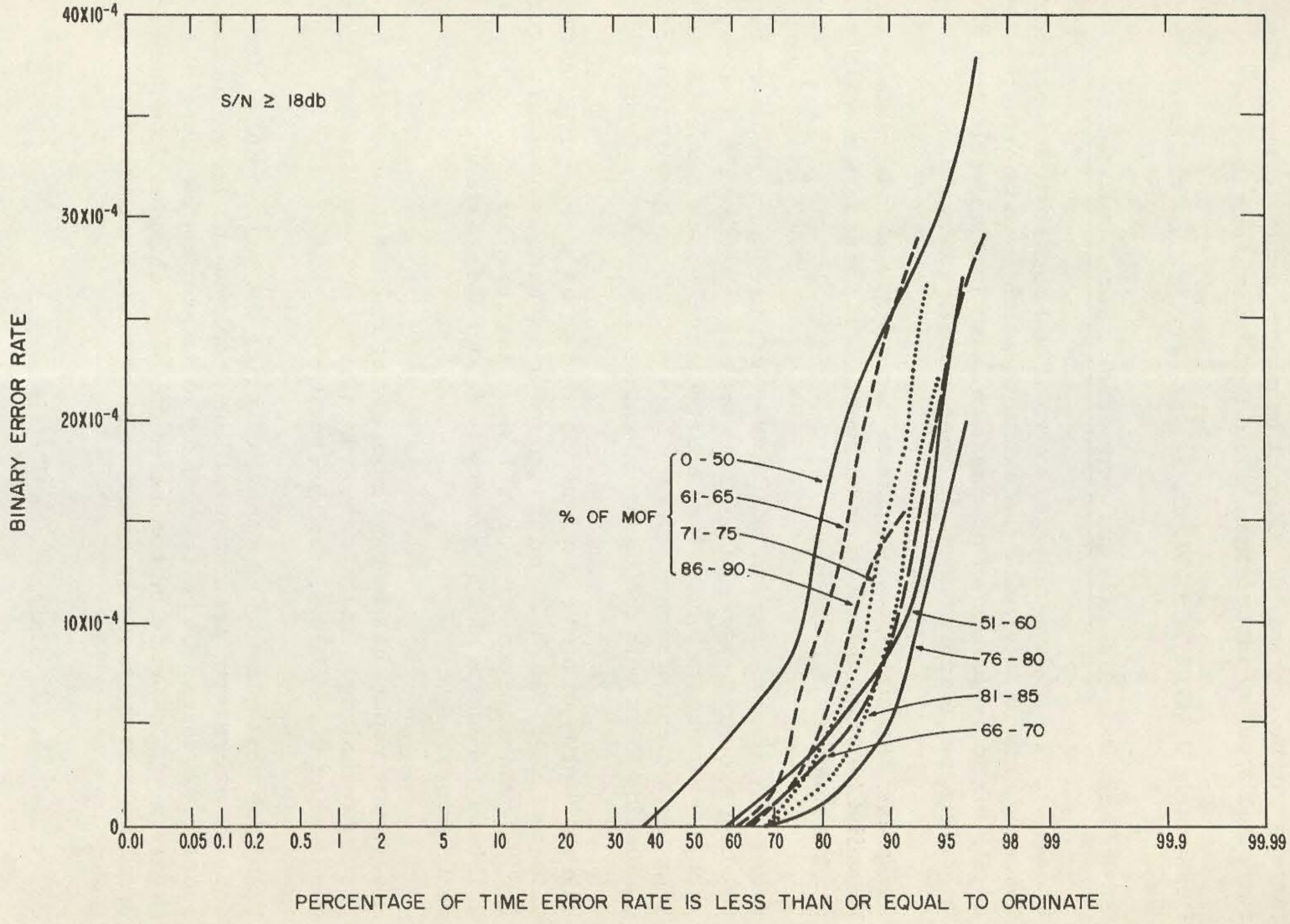


Figure 2 - CUMULATIVE DISTRIBUTIONS OF ERROR RATES FOR SIGNALS RECEIVED AT FREQUENCIES THAT WERE DIFFERENT PERCENTAGES OF THE MOF



Plans for next quarter: To complete the data analysis and issue a report on the results. It is not believed that taking more data on the same experimental setup could serve much useful purpose. Experimental work should be continued on a circuit on which all the parameters can be controlled. Circuit behavior, using different transmission rates and types of modulation, could then be investigated.

Personnel: J. C. Blair, W. B. Schlak, Jr., L. L. deGraffenried, G. E. Wasson

Task 7652 Data Analysis and Commercial Sounder Evaluation

Objective: To analyze oblique, vertical and backscatter ionospheric sounding data to determine the extent to which such information is applicable to evaluation of propagation conditions and selection of operating frequencies for naval communication circuits.

Progress: An attempt was made to use oblique sounder data from the Hawaii-Cheltenham path to make short-term forecasts of MOF values for the month of August 1963.

A five-day running median MOF curve was used as a guide for extrapolating expected values of MOF on the day following the five-day period. Forecasts for various short intervals were made during each hour for the entire month, and the forecast errors were measured by comparing them with the observed values.

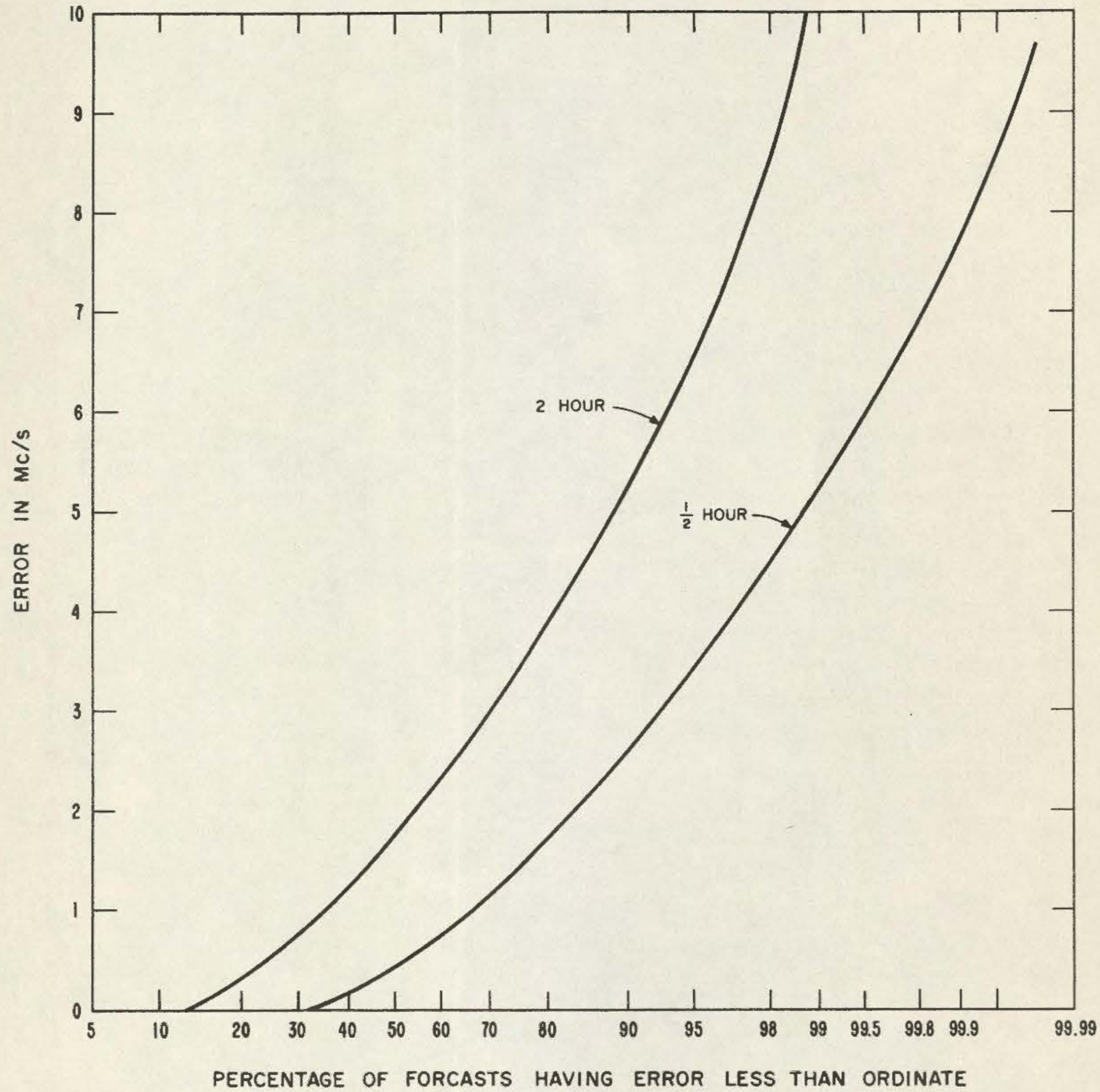
The reliability of a five-day running median as a tool for predicting values of MOF one-half and two hours in advance is shown in figure 3. If a maximum forecast error of 1 Mc/s is allowable, 66% of the one-half hour forecasts and 36% of the two-hour forecasts would be satisfactory.

A separate report has been written giving more details of this forecasting technique. Additional work is being done on forecasting the times when the MOF falls below specified values.

Plans for next quarter: A report covering the analysis of oblique sounder data for short term prediction will be prepared and issued during this quarter. Studies will be carried out to determine the experimental program which should be conducted on the Washington-Londonderry circuit assuming that this circuit will be made available for propagation tests.

Personnel: J. C. Blair, H. E. Petrie

FIG. 3 - FORECAST RELIABILITY USING 5 DAY RUNNING MEDIAN MOF TO FORECAST MOF 1/2 HOUR AND 2 HOURS AHEAD



SS-267 PREDICTIONS OF CIRCUIT PERFORMANCE AND USEFUL FREQUENCY RANGE

Task 7647 Analysis and Correlation of IGY and Other Data

Objective: This task is to enlarge and improve knowledge of the relationships among the solar/geophysical variables and their effect on HF communications.

Progress: Principal effort during the quarter was devoted to completion of the report on distribution of MUFs, to further correlation computations for the Auroral Absorption Effects study and the Magnetic Activity vs. MUF study, and to preliminary work on correlation of foF2 in Space and Time. In addition the studies of Es Probabilities and System Loss and the study of Polar Sporadic-E were continued.

In the MUF-Distribution study, the final form of presentation of results was selected, final computations were made, and the draft of the report was completed. It was decided to smooth the results from 13 stations and present them as a function of geographic latitude, 6 local time hours, 3 seasons, and 3 sunspot numbers. Figure 4 is an example of the presentation. A method was found for fitting the observed distributions of MUF to a standard distribution by introducing the coefficient of skewness. Statistical tests were used to confirm the validity of basing the analysis on each fourth hour of local time. Confidence intervals at the 95% level were computed for all the lower and upper decile ratios at Washington, Fairbanks, and Maui. The variations of the ratios with geographic latitude, local time, season, and sunspot number were explicitly determined. The report is expected to be available about September 1, 1964.

Auroral Absorption Effects were investigated by computing the correlation of magnetic index Kp with excess system loss on the 4700-km Barrow to Boulder path. The analysis was made for each month from August 1959 to August 1960 at 4 frequencies, 5, 10, 15 and 19 Mc/s.

The study of the influence of magnetic activity on the Maximum Usable Frequency was continued by determining the relationship between the two variables at several additional locations and time periods. The Washington vs. Fredericksburg correlation was found for 1954-55; the Fairbanks correlation was found for 1954-55 and 1957-58; the Maui-Honolulu computation for 1957-58 was completed. Additional correlation computations for high sunspot number conditions are now in process for the following MUF vs. K-figure locations:

MUF EXCEEDED 10% AND 90% OF HOURS
(Ratio of MUF to Monthly Median)

Sunspot Number:	Medium		No. Hemis.: May, June, July, August		
Season:	Summer		So. Hemis.: Nov., Dec., Jan., Feb.		
Geog. Lat. (N or S)	00	04	08	12	16	20
			Upper Decile			
80°	1.27	1.23	1.20	1.18	1.25	1.23
70°	1.23	1.19	1.19	1.17	1.17	1.19
60°	1.20	1.18	1.19	1.17	1.14	1.17
50°	1.17	1.19	1.21	1.17	1.15	1.16
40°	1.17	1.22	1.23	1.18	1.17	1.17
30°	1.20	1.30	1.22	1.19	1.19	1.18
20°	1.26	1.38	1.17	1.23	1.23	1.28
10°	1.26	1.44	1.11	1.28	1.28	1.22
			Lower Decile			
80°	.82	.80	.82	.85	.80	.79
70°	.83	.82	.79	.82	.82	.82
60°	.83	.82	.77	.79	.82	.83
50°	.81	.81	.76	.77	.81	.82
40°	.78	.78	.75	.78	.78	.78
30°	.77	.73	.75	.79	.77	.74
20°	.77	.69	.78	.82	.78	.73
10°	.79	.63	.84	.85	.81	.77

Figure 4

White Sands vs. Tucson
Reykjavik vs. Reykjavik
Okinawa vs. Aso
Huancayo vs. Huancayo

The study of foF2 with itself under conditions of simultaneous time and space separation is designed to secure information required to make use of ionosonde observations at a reference station to predict usable frequencies at another location at a different time. Earlier studies of separate space and time autocorrelations of foF2 were helpful in choosing the most promising approach to this problem. (Some of the earlier work was undertaken under Task 7664.) Initial computations involving foF2 observations at Washington, White Sands, and San Francisco in June 1958 have been carried out.

Various methods of attack on two sporadic-E tasks have been considered during the quarter. Arrangements were made to secure original recordings of Es signal intensity on three high-latitude paths for use in the polar Es investigation.

R. M. Davis, Jr. attended the Spring Meeting of URSI in Washington, D. C. Several papers in the fields of auroral absorption and sporadic-E reflection coefficients were pertinent to this task.

Plans for next quarter: Reports on two tasks - Auroral System Loss and Magnetic Activity vs. MUF - are scheduled for completion next quarter. Extensive computations for the Es System Loss and Polar Es tasks will be carried out. Space-time correlations of foF2 will receive a substantial effort. Finally, the study of Quality Characteristics of circuits will be initiated.

Personnel: R. M. Davis, Nancy L. Groome

Task 7650 <u>Develop Frequency Prediction and Assignment Report Format</u>

Objective: This task will develop data formats suitable for transmitting frequency prediction and assignment information over the NCS.

Progress: Activity during this quarter was in three areas:

(1) investigation of monthly geophysical and solar data formats;
(2) investigation of monthly propagation prediction formats; and
(3) preliminary consideration of short term (day-to-day or hour-to-hour predictions.)

In the investigation of monthly geophysical and solar data formats, the evolution of the prediction formats used within CRPL and the formats currently being used by other organizations were considered. The following formats are recommended in the initial RFPS system.

(1) F2 region - (a) Monthly median foF2 and M(3000)F2 in predicted coefficients on punched cards provided monthly by CRPL or in case of emergency generated by an interpolation between coefficients corresponding to solar activity extremes. (b) Predicted dispersion of the F2 MUFs in the same format as (a) above.

(2) F1 region - Mathematical expression for the F1(3000)MUF as a function of sun's zenith angle and the solar activity index. No monthly predictions or formats are required.

(3) E region - (a) Predictions of regular E-layer 2000 MUF as a mathematical expression as a function of sun's zenith angle and solar activity index. (b) Predictions of sporadic-E layer in terms of the monthly median Es 2000 MUF and the predicted dispersion as expressed by coefficients as for the F2 layer.

(4) D region ionization - A prediction of the ionospheric absorption index as a function of sun's zenith angle and solar activity index. No monthly predictions needed.

(5) Atmospheric noise - Numerical representation of the worldwide distribution, time and frequency dependence. No monthly predictions needed.

(6) Geomagnetic latitude - Mathematically expressed. No monthly predictions needed.

(7) Ground conductivity and dielectric constant - World maps of land masses numerically represented for computer showing only a distribution between land and sea water. No monthly predictions needed.

(8) Solar activity - A prediction of an equivalent 12-month moving average Zurich sunspot number. A single prediction not to exceed 3 digits is needed monthly.

(9) Zenith angle of the sun - Expressed mathematically as a function of geographic location and the subsolar point. No monthly predictions needed.

A draft report "Frequency Prediction and Assignment Formats for the U. S. Navy Radio Frequency Propagation and Prediction System," Report Number 1, "Monthly Geophysical and Solar Data Formats," leading to the above recommendations was prepared.

In the investigation of monthly propagation formats, the formats used by other organizations such as U. S. Army, the Brazilian Navy, etc., were considered in addition to the prediction formats which we have developed in connection with computer programs. It was concluded that many propagation related characteristics of high frequency sky wave communication circuits are currently predictable. These include Maximum Useful Frequency (MUF), system loss, available signal-to-noise ratio, reliability, Lowest Useful Frequency (LUF), etc.

For the initial RFPS, a prediction of the frequency range which is likely to provide the required service was considered essential and, therefore, a basic format for the initial system is this useful frequency range. The useful frequency range will vary with time, length of circuit, and geographic location, and will depend upon the circuit equipment and traffic requirement. Time variations will be represented by computations at one-hour intervals for each month. The length of the circuit and the geographic location variations will be represented by dividing the required service area of each Naval Communication Station into appropriate sectors. Initial planning should assume sectors generated by a series of circles spaced at 500 kilometer intervals of 10 degrees. Variations of circuit equipment and traffic requirements will be represented by a classification of these equipments and requirements. A study is required to determine the number of classifications involved, but initial planning need not consider more than eight reference circuits from any Naval Communication Station.

The diurnal variations of the useful frequency ranges for the eight reference circuits will be predicted at least one month in advance and will be provided to the Naval Communication Station in the form of a hard copy, i.e., tabulations from the computer plus a magnetic tape for use in computer facilities at the Naval Communication Station. The useful frequency limits will be expressed in two significant figures.

A draft report "Frequency Prediction and Assignment Formats for the U. S. Navy Radio Frequency Propagation and Prediction System" Report Number 2 "Monthly Propagation Prediction Formats" in support of the above conclusions was prepared.

In the preliminary consideration of short term (day-to-day or hour-to-hour) predictions, it is concluded that information will be issued to the Naval Communication Station if adjustments in the useful frequency range based on monthly predictions are required. The updating information will be developed from the Disturbance Warning System, and other information such as oblique and vertical ionosonde information, revision of the ionospheric maps (these revisions are now available on the basis of two week periods and extension to shorter time periods is planned). The updating information will be transmitted via radio in terms of percentage adjustments in both useful frequency limits. These adjustments will be in two significant figures supplemented by a plus or minus indication. The Naval Communication Station will make a supplemental and overriding evaluation of the updating information supplied based on observations such as oblique ionosondes and broadcast monitoring. The Naval Communication Station should be able to evaluate its current situation and depend upon the monthly propagation information for an extrapolation of this situation.

Routine liaison with other organizations continued. This liaison is normally not a specific part of the development of Frequency Prediction and Assignment Formats, but is often quite applicable to the general problem of improved HF circuit predictions. During the past quarter, direct conversations were held with representatives of Stanford Research Institute concerning the hard copy prints for the oblique sounders, with representatives of Jansky and Bailey, Institute for Defense Analyses, U. S. Army, AVCO Corporation, and the Office of Emergency Planning. Indirect contacts included the Department of Scientific and Industrial Research, Slough, England, the International Frequency Registration Board, Geneva, Switzerland, and HRB Singer, State College, Pennsylvania.

Plans for next quarter: Publication of draft reports listed above and continued consideration of the short term prediction formats.

Personnel: G. W. Haydon, G. G. Gilbert

Task 7040 <u>Computer Programs and Studies</u>

Objective: To expand existing computer program and to develop new computer programs for predicting the percentage of time circuit performance will exceed a given threshold as a function of time of day, circuit characteristics, ionospheric conditions and frequency and to provide information for the management of radio frequencies. A primary objective is to develop a capability of predicting performance on a short term, i.e., daily and hourly, basis.

This task is basically divided into two areas of effort: (1) refinement where desirable, of existing computer input data; and investigation of possible new sources of input data in an effort to improve the accuracy of HF propagation predictions; and (2) development of appropriate computer programs as required to utilize most effectively all input data resulting from investigation.

Progress: A prototype HF propagation prediction program (figure 5), which includes revised signal distribution and noise distributions, is being checked against actual operating circuits both oblique sounding and fixed frequency operations.

The prototype program translates the probability of an adequate signal-to-noise ratio of various modes of propagation to the overall probability that the signal-to-noise will be adequate for the circuit. Sporadic-E modes are recognized as important contributions, and further work on less important contributions of the high angle rays, off-great-circle propagation and nonconcentric ionosphere are being deferred until such time the sporadic-E contribution can be evaluated.

A report "A Numerical Representation of the High Frequency (3-30 Mc/s) Atmospheric Radio Noise" including a numerical representation of the revised atmospheric radio noise and the distributions contained in CCIR Report Number 322 is in the typing and editorial processes. A sample numerical map and it's distribution is shown in figures 6 and 7.

Liaison with other agencies was nil the past quarter with no agencies visited.

Plans for next quarter: Include sporadic-E into the computer routine to make a fair evaluation of progress thus far on the prototype model.

Visits to Stanford Research Institute, NAVCOSSACT, OPNAV 944G, and Collins Radio are tentatively planned.

Personnel: D. L. Lucas, R. A. Hanson, J. D. Harper, Jr.

5 JAN 1963 SSN= 29. MC 33.017

TRANSMITTER 61.33N - 149.90W RHOMBIC 20H 114L 70DEG PWR= 12.00KW

RECEIVER 38.50N - 121.68W NOISE= 3 RHOMBIC 20H 114L 70DEG

BEARINGS 129.6 331.8

N.MILES 1723.1

REQ.S/N= 50DB

OPERATING FREQUENCIES

GMT	MUF	FOT	3	5	7	9	11	13	15	20	25	30	FOT	
1	19.2	16.5												
			4F	3F	2F	2F	1F	1F	1F	1F	1F	00	1F	MODE
			24	18	11	11	0	1	1	2	2	0	1	ANGLE
2	15.6	13.4	38	96	98	85	54	63	57	3	0	0	66	RELIABILITY
3	11.7	9.5												
			4F	2F	1F	1F	1F	1F	00	00	00	00	1F	MODE
			26	12	1	1	3	3	0	0	0	0	1	ANGLE
4	9.0	7.3	73	82	39	33	2	0	0	0	0	0	35	RELIABILITY
5	7.6	6.2												
			3F	1F	1F	1F	00	00	00	00	00	00	1F	MODE
			21	1	2	3	0	0	0	0	0	0	1	ANGLE
6	6.9	5.6	58	50	16	0	0	0	0	0	0	0	33	RELIABILITY
7	7.0	5.7												
			3F	2F	1F	1F	00	00	00	00	00	00	1F	MODE
			22	14	2	4	0	0	0	0	0	0	1	ANGLE
8	7.1	5.7	62	57	25	1	0	0	0	0	0	0	36	RELIABILITY
9	6.7	5.5												
			3F	1F	1F	1F	00	00	00	00	00	00	1F	MODE
			23	2	3	4	0	0	0	0	0	0	2	ANGLE
10	6.7	5.5	62	49	21	0	0	0	0	0	0	0	36	RELIABILITY
11	6.8	5.5												
			3F	1F	1F	1F	00	00	00	00	00	00	1F	MODE
			22	2	3	4	0	0	0	0	0	0	2	ANGLE
12	6.8	5.5	62	50	22	0	0	0	0	0	0	0	36	RELIABILITY
13	7.2	5.8												
			3F	2F	1F	1F	00	00	00	00	00	00	1F	MODE
			22	15	2	4	0	0	0	0	0	0	2	ANGLE
14	7.2	5.8	29	47	16	1	0	0	0	0	0	0	17	RELIABILITY
15	6.7	5.4												
			3F	2F	2F	1F	1F	1F	00	00	00	00	1F	MODE
			20	13	16	2	3	3	0	0	0	0	1	ANGLE
16	8.5	7.4	0	45	15	24	3	0	0	0	0	0	10	RELIABILITY
17	13.6	11.7												
			00	4F	3F	2F	2F	2F	1F	1F	1F	00	1F	MODE
			0	25	19	11	11	13	1	2	2	0	1	ANGLE
18	18.3	15.7	0	0	69	98	67	29	57	26	0	0	68	RELIABILITY
19	20.9	18.0												
			00	4F	3F	2F	2E	2F	2F	1F	1F	1F	1F	MODE
			0	24	18	10	7	11	12	1	2	2	1	ANGLE
20	22.3	19.2	0	0	55	99	99	71	51	71	21	1	76	RELIABILITY
21	22.7	19.5												
			00	4F	3F	2F	2E	2F	2F	1F	1F	1F	1F	MODE
			0	24	17	10	7	11	12	1	2	2	1	ANGLE
22	22.8	19.6	0	0	59	99	99	75	42	74	26	2	75	RELIABILITY
23	22.6	19.5												
			00	3F	3F	2F	2F	2F	2F	1F	1F	1F	1F	MODE
			0	17	18	10	10	11	12	1	2	2	1	ANGLE
24	21.5	18.5	0	13	95	98	91	64	48	65	15	0	74	RELIABILITY

Figure 5 Sample predictions produced by prototype HF prediction routine

(Contours in Tens of Decibels Above KTB at 1 Mc/s)

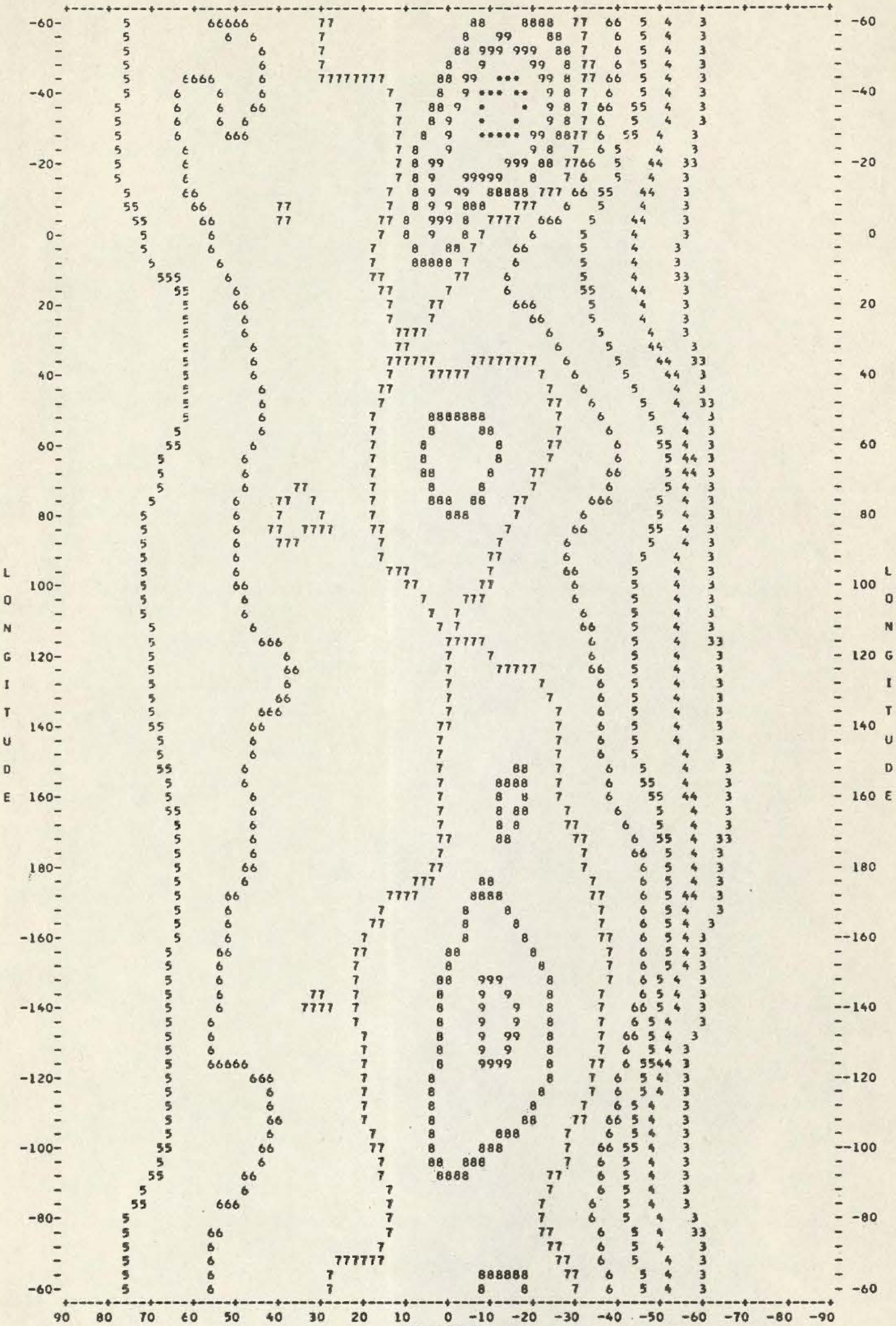


Figure 6 Expected value of 1 Mc/s radio noise (0000-0400 hours LMT) December-January-February

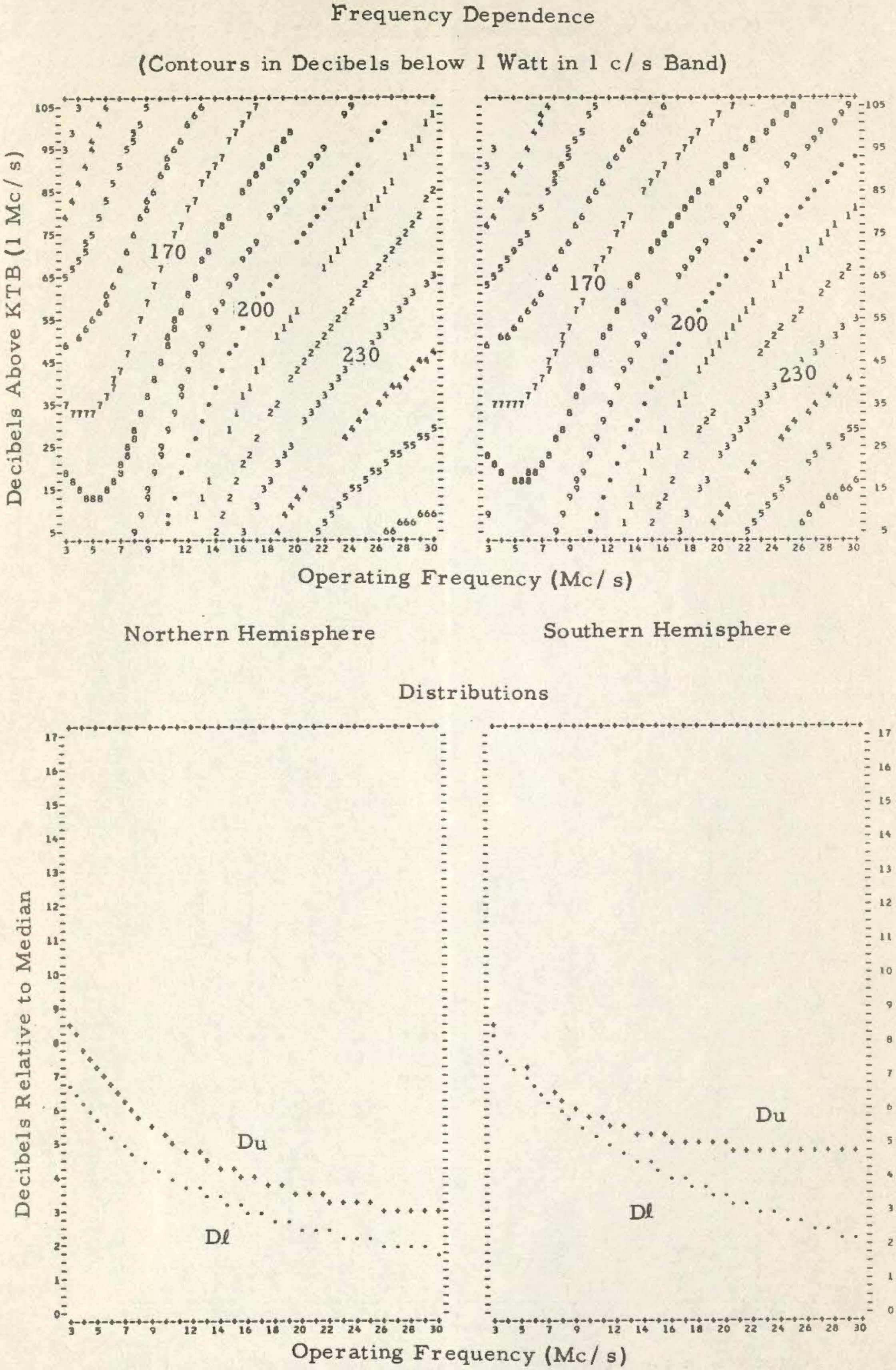


Figure 7 Frequency dependence and distribution of atmospheric radio noise (0000-0400 LMT) December-January-February

Quarterly Report

April 1, 1964 - June 30, 1964

Almanac Data Compilation (Navy)

82431 Task 7648 of Navy SS-267 Program S. M. Ostrow

OBJECTIVES OF PROGRAM: To collect, organize and analyze ionospheric and other data required for the development of more efficient and effective radio communication systesm. To assist other projects working on different phases of a larger program with required data collection and analyses. To set up procedures for efficient current data procurement and processing, as required.

OBJECTIVES FOR THIS QUARTER: (1) Complete the analysis, summarization and evaluation of the statistical analysis of Washington data, using the Edgeworth distribution. Apply the analysis to data from additional locations. (2) Continue work on numerical mapping of foEs. (3) Continue work on numerical mapping of h'F,F2. (4) Continue study of comparisons of the correlation of Washington foF2 with different solar indices. Extend the comparison to foF2 data from other locations. (5) Begin investigation of the parabolic approximation to the vertical ionization distribution for possible use with ionospheric predictions in communications problems. (6) Begin investigation of the feasibility of using oblique incidence and satellite sounder data in ionospheric mapping.

ACTIVITY SUMMARY: (1) The results of the analysis of Washington foF2 and M(3000)F2 data by use of the Edgeworth series as a statistical model indicated that the model was satisfactory for describing the variation of these data around the monthly median values. The study of the possible variations of the statistical parameters of the series for Washington data was continued, and evaluation was in progress the end of the quarter. Data for Christchurch and Maui were processed by the computer program, and summarization and evaluation of the results was begun. Preparation of data from other selected stations for analysis was carried on concurrently. Preliminary results indicate significant diurnal, seasonal and solar cycle variations at a given location in the statistical parameters. The standard deviation also seems to vary with average level of disturbance during a given month, and an attempt to derive a quantitative relationship is being made. The evaluation of the analysis of Christchurch and Maui data is not yet advanced enough to permit conclusions about possible differences with geographic location.

(2) Work continued on numerical mapping of foEs. foEs data for March, June September and December (the "seasonal" months) was prepared and organized, and medians and deciles computed for solar cycle minimum and maximum years. Numerical mapping of median foEs was redone for June solar maximum and minimum in terms of magnetic dip instead of geographic latitude, providing a more accurate representation. The new June median foEs maps were turned over to

D. Lucas for application in Task 7040, to replace the preliminary sample foEs maps prepared in the previous quarter. Preparation of median foEs maps for March, September and December was begun. Because of the large amount of work that is necessary to include the longitude variation in the numerical representation, the four "seasonal" months will be represented first in two dimensions only, magnetic dip and local mean time. These will be available by the middle of July for immediate use by Task 7040. The remaining eight months of foEs data have been contracted for keypunching and are to be delivered July 10.

(3) Work continued on preparation of additional h'F,F2 data for numerical mapping of h'F,F2. Some preliminary work on mapping h'F,F2 data was done, but progress was limited because most of the effort of the group was directed to other aspects of Task 7648 and SS-267 in accordance with scheduled priorities.

(4) Comparison of the correlation of foF2 with each of the three indices of solar activity, 10.7 cm Ottawa solar radio noise flux, Zurich sunspot number, and Minnis IF2 ionospheric index of solar activity, were completed for six representative ionosphere stations, Thule (inside the auroral zone), College (auroral Zone), Washington (mid-latitude), Maui (low-latitude), Huancayo (equatorial) and Christchurch (southern hemisphere, mid-latitude). The results from all stations confirmed the initial results using Washington data, and the analysis is considered completed. As expected from the earlier results indicating very high correlations between the three solar indices, no significant difference was found between correlations of foF2 with each of the three solar indices. In all cases the correlations were high, usually above 0.9, and the differences between the correlation coefficients with different solar indices were of the order of .02, which is not significant. While usually the correlation with IF2 was .01 or .02 higher than the others, it is interesting to note that this difference was not greater even though data of several of the ionospheric stations used for this study were also used to establish the IF2 index. Confirming previous CRPL work, the second degree relationship between foF2 and each solar index often had a significantly better correlation coefficient than the first degree relationship. A preliminary memorandum report on the results of the study was submitted to D. W. Patterson, the program coordinator. Work was begun on drafting a final report for this work.

(5) An investigation of the possibility of deriving the parameters of the parabolic approximation to the vertical ionization distribution from currently available predicted ionospheric parameters was begun. By use of the Appleton-Beynon equation, a relationship was developed to derive the semi-thickness, y_m, of an assumed parabolic layer by an iterative computation, using the MUF factor and h'F2 as input. The relationship has not yet been tested for accuracy and economy of computation.

(6) To begin the investigation of the feasibility of using oblique incidence soundings data in ionospheric mapping, Mrs. Margo Leftin visited the Stanford Research Institute. This provided information on current SRI methods for deriving MOF data from oblique ionograms and on their program for converting oblique incidence data to vertical incidence. Several months of MOF data from the network of oblique sounders controlled by SRI were obtained for use in the CRPL studies.

In cooperation with Task 7664 (Forecast Parameters), vertical incidence sounder data was collected for selected time periods for which top-side satellite ionospheric soundings were available, and the data prepared for use in computer programs. Synoptic maps of the vertical incidence foF2 data for September 1963 are being prepared for this study.

OBJECTIVES FOR NEXT QUARTER: (1) Complete the evaluation of the statistical analysis of Washington data, and complete the summarization and evaluation of the analysis of Maui and Christchurch data. Prepare a report on these results. Apply the analysis program to data from additional ionosphere stations, well distributed geographically, in order to establish possible world patterns in the statistical parameters. (2) Complete numerical mapping of median foEs for solar maximum and minimum for March, September and December, in latitude and local mean time, to complete the set of "seasonal" months. Prepare foEs data for the remaining eight months of the year, for numerical maps, computing medians and deciles. Prepare final median foEs maps for all twelve months of the year in three dimensions, latitude, longitude and time. Begin work on the preparation of upper and lower decile maps for the same months. (3) Continue work on numerical mapping of h'F,F2, and prepare a sample map. (4) Complete final report on correlations between different solar indices, and on the comparison of the correlation between foF2 and each of the solar indices. Begin study of F1-layer MUF. (5) Complete study of the application of the parabolic approximation to the vertical ionization distribution, evaluating the accuracy of the methods developed. Prepare report on the study. (6) Continue work on the application of oblique and top-side ionospheric sounding data to ionospheric mapping, with emphasis on the preparation of synoptic maps for selected quiet and disturbed periods.

Prepared by:

S. M. Ostrow, 7/8/64

Quarterly Report

April - June, 1964

8260-40-82466	Forecast Parameters Task 7664	J. V. Lincoln Prepared by: Dale B. Bucknam

Objectives of Program: This project is to perform studies to improve our present knowledge of which solar and geophysical parameters affect short-time variations in the ionosphere. The time-correspondence, degree and certainty implicit in the relationships, will be studied to incorporate this information into a format compatible with computer programs to increase the efficiency of existing and future Navy HF communication systems.

This project is divided into sub-tasks which have been described in the quarterly report submitted for January-March 1964.

Objectives for this Quarter: These objectives were as follows, divided according to the sub-task into which they fall:

Synoptic disturbance mapping: To keypunch the foF2 data for September 1963, and to continue the development of the computer program to handle the data and produce synoptic maps of foF2. To continue the keypunching of the September 1957 data, which is to be inserted into the program as soon as it is available.

Utility of a single station to predict ionospheric conditions: To complete the analysis of the results of both the space and the time correlation studies, and to prepare a draft report describing the work and the results.

Riometer vs. f-min: Issue a report covering this subtask.

Propagation disturbance parameters: To keep abreast of scientific literature dealing with solar-terrestrial relationships. To utilize results of other NBS-sponsored research in these fields to improve our current forecasting techniques.

Auroral absorption particle effect study: To complete the literature survey, to punch data cards, and to develop a computer program to process the data.

Polar cap absorption particle effect study: To make computations and analyze results in an effort to determine the energy spectrum and the integral flux intensity of protons during PCA events.

Preparation of initial format for disturbance warning: To prepare memorandum report to Task 7645 on a disturbance warning subsystem available as of July 1, 1964.

Activity Summary: Progress in the various sub-tasks is summarized below for this quarter.

Synoptic disturbance mapping: Using September 1963 data, work has continued in the development of the computer program for preparing synoptic maps. One trial map of foF2 has been made using this data. The map looks promising. However, it now appears that maps of deviations of foF2 from the expected median would be more useful to the computer program. Therefore guided by this and other considerations further modifications and improvements are being made to the computer program in order to prepare such maps. Preliminary program testing, using data from the 20 July 1963 eclipse, was instructive in the development of the program. The punched cards of the data for September 1957, which will be used in the evaluation of this work, have been returned. The punching was completed by a subcontractor. These cards must now be tested for accuracy and run through a program for determining median values before they will be used in the synoptic mapping program. Studies in related fields by Obayashi, Lavrova, Jones and Gallet, Hill, and others, have again been reviewed. It should be pointed out that although the current studies utilize data from vertical incidence ionosondes almost entirely, F2 layer critical frequency values measured by other means such as by satellites or oblique-incidence ionosondes could be utilized. Data from such sources, if properly interpreted and if in sufficient quantity, could provide information for broad regions of the earth from which vertical incidence measurements are not available. Program techniques devised and tested, however, by using vertical incidence data should be equally applicable to any appropriate data acquired by whatever means.

Utility of a single station to predict ionospheric conditions: This work has progressed very nicely, yielding results which were not entirely expected. A report is now being drafted. The time-auto correlation study has compared foF2 values at initial times with values at hourly time increments up to 48-hours later. The study utilizes data from five stations, Huancayo, Maui, Washington, Anchorage, and Thule for the months June, September, and December of the years 1958 and 1962. In general, the correlation coefficient exceeds 0.50 over a time increment of four to five hours, however, in a great many cases (perhaps 30%) it falls below 0.50 in two hours or less. For any given station, and for any time increment over which the correlation is to be taken, the autocorrelation coefficient can vary widely depending upon the initial time used. The significance of this work is that ionospheric conditions (or HF conditions), at any instant, can not be reliably extrapolated forward in time at a given location over more than two hours. Thus new frequency predictions, or synoptic maps, may be required as frequently as every two hours. At this point the study is much too limited in scope to provide any clear picture of the dependence of the variation in correlation upon initial time, season, position in sunspot cycle, or geomagnetic latitude. Papers read included those by Lavrova and Liakhova.

Auroral absorption particle effect study: The literature survey on this subtask has continued. The survey indicates that at this time, there is considerable uncertainty in the identification of the particles or radiation contributing to auroral absorption events as observed by ground based instrumentation. For this reason, it is felt that a fruitful continuation of this subtask is beyond the scope of Task 7664. Consequently, the sub-task is being dropped from Task 7664 as of this quarter. Related works reviewed included those by Maehlum and O'Brien; Kundu; Brown and Barcus; Frank, Van Allen and Hills; Webber and Freier; Odintsova; and McIlwain.

Polar cap absorption particle effect study: Computations and analysis continue in this sub-task. The literature reviewed include the studies of Bailey; McIlwain; Bell; Frank, Van Allen, Whelpley, and Craven; Freier and Webber; McDonald; Malitson and Webber; Fichtel, Guss, and Ogilvie; McCracken; Lingenfetter and Flamm; Sauer; and others.

Propagation disturbance parameters: Papers reviewed, for specific or general application to Task 7664, include those by Ellison; McKenna; Lawrence, Little, and Chivers; Shapley; Snyder; Kerblay; Goncharova; Hakura, Takenoshita and Otsuki; Obayashi; Reid; Bruzek; Dalgarno, McElroy and Moffett; Brace, Spencer and Carignan; Anderson; Appleton and Piggott; Matsushita; Oksman; Akasofu; Sugiura; Campbell; and others. Such publications as "Soviet Bloc Research in Geophysics -- Astronomy and Space" are regularly surveyed for pertinent articles.

Preparation of initial format for disturbance warning: A memo report was prepared and submitted to Task 7645 describing the present capability of the National Bureau of Standards Central Radio Propagation Laboratory to provide a disturbance warning subsystem to the Navy Communication System. It also outlined several steps the Navy could take now to provide their own monitoring of disturbance parameters. Various disturbance parameters and their significance and use, were discussed in the report, as well as means of monitoring communication conditions.

Riometer vs f-min: The report of the Riometer vs f-min Correlation Study, though available in draft form some time ago, has been delayed in final editorial approval and therefore printing and distribution. The report should be shortly forthcoming.

A report will be written discussing an attempt at making mathematical (or mechanical) predictions of geomagnetic activity on the basis of daily flare and radio noise indices. This pilot study is felt to be of significance to the project since the results indicate that the methods of analysis hold promise. Better time resolution and the inclusion of additional disturbance parameters are expected to improve the precision of the forecasts. It would be necessary to obtain the data used for these indices on a rapid worldwide reporting schedule. This is an NBS funded program.

Another study, for another NBS project, surveyed the published solar flare prediction papers with an evaluation of their significance. The most promising appeared to be Avery, L. and D. E. Billings in Astro-Geophysics Memo. No. 163 (1964), and Murray, A. E., and C. M. Vossler in Cornell Aeronautical Laboratory Report No. VS-1799-X-1. As yet no method apparently is better than a trained observer, watching east limb activity and knowing a region's activity the rotation before thereby predicting flare productivity in the present rotation.

During the quarter J. V. Lincoln attended the Airlie House Space Environment Forecasting Symposium April 2-4 where mission requirements and present capabilities were discussed by many government and university or other groups. In particular, discussions were held with J. H. Meek of DRTE, Canada. She also attended the "In-house solar meeting" at Santa Fe where the research results of the past year and programs for next year of Sacramento Peak, High Altitude Observatory, Joint Institute for Laboratory Astrophysics, California Institute of Technology, Mt. Wilson Observatory, Kitt Peak Observatory and the Geophysical Institute of Hawaii were discussed.

Accompanying this report is a collection of CRPL-RWS information leaflets. These leaflets describe in considerable detail radio propagation forecasting, the parameters involved, and the service currently available from the National Bureau of Standards, CRPL Radio Warning Services. The format for providing circuit quality in terms of 1-9 will not be used in the RFPS. A new format providing for direct interpretation of disturbance severity into change in path frequency assignment will be developed.

Objectives for next quarter: The current PERT schedule calls for the completion of the following steps during the next quarter.

Synoptic disturbance mapping: The development of the computer program is to be completed and work is to progress on the production of trial maps. The maps will be in terms of the percent deviation from the median foF2 values.

Utility of a single station to predict ionospheric condition: The report of the work, discussed under Activity Summary, will be printed and distributed.

Preparation of an initial format for disturbance warning: New formats will be considered and analyzed and work will begin on a draft report.

Propagation disturbance parameters: A report will be prepared and printed. This work relies heavily on the broad range of literature surveyed (see Activity Summary) and the results of the other subtasks as well as non-Navy funded tasks.

Polar cap absorption particle effect study: Efforts will be made to relate proton energy spectrum and integral flux intensity to HF propagation. Work will begin on a draft report.

APPENDIX A

CRPL-RWS-90
(Supersedes
CRPL-RWS-61)

CRPL RADIO WARNING SERVICES
Central Radio Propagation Laboratory
National Bureau of Standards
Boulder, Colorado 80301

March 17, 1964

SUN-EARTH RELATIONSHIPS AND RADIO PROPAGATION FORECASTING

Advance forecasts of radio propagation conditions issued by the CRPL Radio Warning Services of the National Bureau of Standards include the CRPL-J reports for the North Atlantic area, the CRPL-Jp reports for the North Pacific area and the CRPL-Jb reports for general geomagnetic disturbances.

Advance forecasts of radio propagation conditions are based primarily on two factors: (1) the statistical associations between active regions on the sun and geomagnetic or radio propagation disturbances and (2) the 27-day recurrence tendency of geomagnetic and radio conditions.

The 27-day recurrence tendency is strongest, and hence the most reliable aid, from about three years before sunspot minimum until a few months after minimum. The last period of reliable recurrence patterns was from 1951 into 1954 but during the coming year, as we approach and pass through the minimum phase of the current cycle (now expected in late 1964), the 27-day recurrence tendency will again be the major factor in advance forecasting. This 27-day interval corresponds, of course, to the period of one solar rotation as seen from the earth. A recurrent series of disturbance may last from a few months to several years. As yet sources on the sun to be associated with recurrent storms have not been definitely identified. Although the storms may last the order of five days, they are very rarely of great storm severity, in terms of geomagnetic activity. Because of the great reduction in the normal useful range of the radio frequency spectrum during sunspot minimum, however, the radio propagation disturbances may appear to be as severe as, if not more severe than, the disturbances during the great geomagnetic storms of sunspot maximum.

At sunspot minimum the relation between disturbance and active solar region is much less clear than during sunspot maximum. Central meridian passage of an active region (evidenced by green coronal line emission) is followed, after 2 or 3 days, by a decrease in disturbance. Peaks of activity occur 3 or 4 days before CMP of the region, and 8-10 days after. Disturbance tends to maximize about 2 days after CMP for regions of expecially low activity (or ten days after a day when coronal intensity was exceptionally low at east limb).

During the maximum phase of the sunspot cycle, reliance for forecasting was placed primarily on statistical relationships between solar activity and geomagnetic or radio propagation disturbance. In this cycle sunspot maximum occurred March 1958. At the present phase of the cycle, sudden commencement storms normally of 1 to 2 days duration can be expected only rarely. In order to evaluate activity in solar regions, daily detailed reports are received at the forecasting centers of the following phenomena: plage regions, sunspots, flares, prominences, emission corona and solar radio noise emission (described in CRPL-RWS-89, March 16, 1964 "Glossary of Terms used in Radio Disturbance Forecasting"). The most commonly applied sun-earth relationships are:

(1) A geomagnetic storm with associated radio propagation disturbance is expected to begin within 1 - 2 days of the occurrence of an importance 3 or 3+ (very great) flare, regardless of its position on the sun. The probability of disturbance is greater if the flare occurs in the sun's central zone. The probability of disturbance is lowered unless there are concurrent solar radio noise outbursts, and is greatly increased if a polar cap absorption event is associated with the flare.

(2) When a solar radio noise outburst at frequencies $\leq$ 200 Mc occurs with its first part in the pre-maximum phase of a solar flare followed by a second part that is often more intense and of longer duration, geomagnetic disturbance may be expected to begin within 1 - 4 days. The more important the flare and the nearer to the sun's central meridian, the greater the severity of the disturbance. The preferred time delay for the onset of the geomagnetic disturbance is of the order of 2 days. If the outburst is also classified as Type IV, the probability of disturbance following is increased.

(3) When a giant sunspot group with complex magnetic polarities is at CMP, there is likelihood that a radio disturbance may result. The probability of a disturbance is heightened if the region is also the source of other forms of solar activity.

(4) Relatively inactive areas on the sun occasionally may exhibit an exceptionally rapid increase in size, brightness or activity. This increase in activity may sometimes be associated with a geomagnetic disturbance 1 - 2 days later. Such events are used as the only likely solar cause to explain disturbances that develop unexpectedly, more than to predict disturbance in advance.

(5) Early determination of the activity potential of a region can be made by observations as it appears at the east limb of the sun. Bright yellow corona emission, surges, loop or spray prominences, or increase in background flux of solar radio noise outbursts during the first days of transit of a region across the solar disk suggest the region to be of high activity potential.

It must be noted that all the above relationships are derived from statistical analyses. Thus, in individual cases the disturbance may materialize a day or so earlier or later than expected and, in some cases, not at all. In the long run, however, the probability of disturbance is heightened on days selected using the above criteria.

USCOMM-NBS-BL

APPENDIX B

CRPL-RWS-89
(Supersedes
(CRPL-RWS-62)

CRPL RADIO WARNING SERVICES
Central Radio Propagation Laboratory
National Bureau of Standards
Boulder, Colorado, 80301

March 16, 1964

GLOSSARY OF TERMS USED IN RADIO DISTURBANCE FORECASTING

The CRPL-J, Jp and Jb series of reports each include a brief discussion of the solar, geomagnetic and ionospheric data on which the forecasts are based. Some technical terms and abbreviations are necessary to make these discussions brief and cogent. Following is an explanation of such terms for this context.

* * *

Active region (on the sun) is a restricted area of the sun's disk which has unusual characteristics. An active region may be likened to a disturbance in the solar atmosphere and may include sunspots, prominences, flares, plages, bright corona, etc.

Sunspots (or spots) are dark markings on the sun's disk. The spots are cooler than their surroundings and thus appear black by contrast.

Flocculi are bright or dark cloud-like formations above the sun's visible surface.

Plages are extensive patches of bright flocculi.

Prominences are projections of luminous gas against the sky beyond the edge of the sun's disk. The same gas-clouds when seen on the disk usually appear as dark flocculi.

Flares are eruptions of very hot material in the sun's atmosphere. They rarely last more than an hour and appear bright against background of the sun's disk. Flares are observed in a narrow band of light, usually $H\alpha$.

The Corona is the outer layer of the sun's atmosphere. It can be observed only at the limb, while projected against the sky. The corona can be "seen" spectroscopically in many wavelengths of light, but most prominent are a red line, a yellow line, and especially, a green line. A coronal region is a portion of the sun's atmosphere in which the green-line corona is unusually bright. A coronal front is the sharp division between an area of faint and an area of bright corona. A region of unstable corona is one in which the intensity of the red line is greater than the green line. Yellow corona is observed rarely. It is an index of unusual activity.

Central Meridian is the imaginary line at any given time through the center of the sun's disk connecting its north and south points.

CMP (Central Meridian Passage) refers to the time an active solar region crosses the sun's central meridian.

The limb is the edge of the sun's disk. The east limb is the oncoming edge of the rotating sun.

A cycle (in this context a solar rotation or a recurrence cycle) is a 27-day interval or approximately the time required for one complete rotation of the sun. (This should not be confused with sunspot cycle which is the slow variation in solar activity. The average interval between minima of solar activity is 11.2 years, but the variation is not a strictly periodic phenomenon.)

A common unit of area of a solar region is a millionth of the sun's visible hemisphere. Unless otherwise stated, areas are corrected for foreshortening. Area is often also given in square degrees.

* * *

Magnetic Disturbance is characterized by relative large variations in the intensity and direction of the earth's magnetic field. A common measure of magnetic disturbance is the K-index, which is a character figure based on the range of variation in a standard 3-hour interval. The scale is 0 to 9, the larger the number, the greater the disturbance. Another measure is the A-index. It is based on the eight K-indices for the Greenwich day and thus characterizes the magnetic activity on a whole day basis. A-indices $\leq$ 05 are quiet; those $\geq$ 25 are disturbed. The storm index as used in the CRPL-J and Jp reports is a A-index for the most disturbed 24-hour period following the onset of a storm.

Sudden commencement or sc describes one type of beginning of magnetic disturbance. This type of disturbance is associated with solar activity and is usually not of extended duration.

Sudden Ionospheric Disturbances or SID are abrupt large increases in absorption in the D- or lower E-region of the ionosphere. They are of short duration, affecting sky-wave transmissions on the daylight side of the world only. SID are associated with solar flares. When observed as shortwave fadeouts on HF CW field strength recordings, they are called SWF. If observed by sudden cosmic noise absorption they are call SCNA; if observed on very low frequencies they may be recorded as either sudden enhancement of atmospherics SEA, sudden phase anomalies SPA, or sudden enhancement of signals SES; if observed by HF Doppler techniques they are known as sudden frequency deviations SFD.

Polar Cap Absorption Event (PCA) is a large increase in absorption occurring in the lower ionosphere over the polar regions. These events are associated with the arrival of a stream of solar protons with energies of 10 to 100 Mev. These streams originate at the time of some great solar flares. Within the polar caps the increased absorption is uniform and may be sufficient to black out the normal ionospheric frequencies. Outside the polar regions, radio propagation conditions are not affected by PCA events. These events begin on the average before a geomagnetic storm develops.

Solar Radio Noise —The observation of unusual solar "noise" at radio frequencies indicates the presence of a center of solar activity somewhere on the disk. Usually it is not possible to locate the active region unambiguously from the solar noise measurements alone. Three types may be mentioned in discussing sun-earth relationships:

1. Enhanced radiation - the general background radiation level of the quiet sun is increased. It usually reaches maximum at time of CMP of an active solar region.

2. Bursts - increased solar radio noise for a few seconds or less. The burst rate is indicative of the activity of the solar regions on the disk.

3. Outbursts - an increase in solar radio noise lasting from a few to many minutes. These often occur simultaneously with solar flares and SID.

Type IV outbursts are especially important. They are recognized on radio spectrographs as a high intensity burst lasting several minutes covering a broad band of frequencies, especially in the centimeter region of the spectrum.

APPENDIX C

CRPL-RWS-81
(Supersedes
CRPL-RWS-68)

CRPL RADIO WARNING SERVICES
Central Radio Propagation Laboratory
National Bureau of Standards
Boulder, Colorado - 80301

March 4, 1964

NOTE ON CRPL RADIO QUALITY SCALE

Since 1942 the CRPL and many other institutions working on radio propagation disturbances, have expressed "quality" of radio propagation conditions on a scale ranging from 1 to 9, with the following adjective equivalents:

1 - Useless	4 - Poor-to-fair	7 - Good
2 - Very poor	5 - Fair	8 - Very good
3 - Poor	6 - Fair-to-good	9 - Excellent

This scale has been used in the evaluation of conditions as well as in forecasts. The introduction of a 9-step scale in preference to the 5-step scale which is also widely employed in grading radio propagation conditions, may seem to imply that radio quality is thought to be measurable in more than 5 gradations. Except under special circumstances, this is not so. Usually not more than 5 steps can be distinguished by the typical operator of a radio circuit.

The 9-step scale, however, is needed in the derivation of quality ratings from combined reports. The reasons for this include:

(1) The 9-step scale is, in effect, "open ended". While most quality reports for a given circuit may lie, say, within the ranges 3 to 7, an operator can report the very unusually disturbed or the unusually quiet periods by digits 1, 2 or 8, 9 respectively. The extremes of the scale are used in the same way in CRPL forecasts.

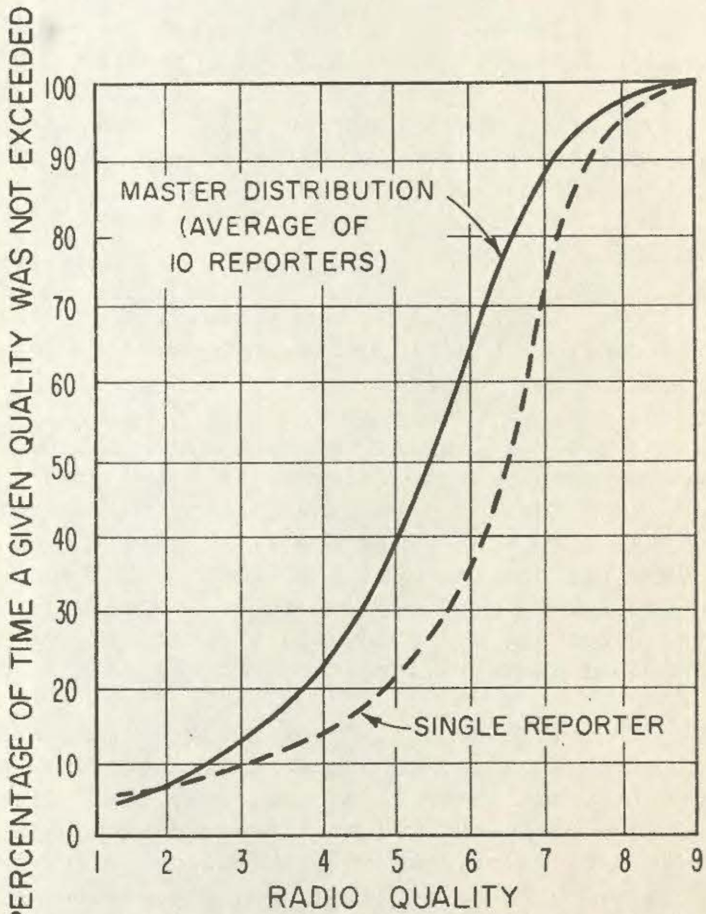
(2) With a 9-step scale, it is possible to compare ratings of similar circuits, with different average quality, without restricting the range of either. Thus a circuit which is normally "good" and perhaps never gets worse than fair, may be given ratings principally in the range 5 to 8. Another circuit on about the same transmission path may have less suitable equipment or severe requirements and thus be rated principally in the range 2 to 7. Experience has shown that neither of these circuits can be properly represented on a 5-step scale. In the first case the 5-step scale does not distinguish between the several grades of quiet conditions. In the second case a wide range of disturbed conditions must be lumped under a single quality figure. Only a few reporters would adjust the criteria for quality grade assignments so that the norm would fall near the center of the range.

(3) The quality of propagation conditions on quite different transmission paths can be compared when quality reports are made on a 9-step scale. For instance there is an obviously real difference between the quality of conditions on an auroral zone transmission path and the quality of a middle latitude path. This can only be accounted for if the operators have a wide range from which to select their quality grades.

It will be noted that as many as 90 percent of the CRPL North Atlantic quality ratings and forecasts fall within the range 3 to 7, because on the average this is the range of reported quality ratings by communications agencies. In an average of reports on a 5-step scale, however, about 85 percent would fall in three grades. Thus the use of a 9-step is necessary to obtain the desired range of quality figures, and in addition it permits distinguishing of extreme conditions.

Calibration of CRPL Q-Scale. The scale of the North Atlantic Radio Quality Figures is based on the average experience reported by about 10 communication, both commercial and military, and monitoring agencies. These are asked to report the performance of their circuits on the 1 to 9 scale, having regard for the adjective equivalents of the quality grades. The distribution of all ratings by all these reporters in a period of, say, 12 months is regarded as the "master" distribution. In order to calibrate the quality scale of individual reporters, regardless of whether or not the reports are on the 1 to 9 scale, the distribution of quality grades reported by the individual is related to the "master" distribution for the same interval of time. Otherwise stated, the distributions are forced to agree at each percentile. This results in a conversion scale for reducing individual reports to the North Atlantic Q-scale. Because there is a significant diurnal variation in quality as reported to CRPL, separate distributions are derived for each six-hour interval of the day.

A typical "master" distribution is shown in Figure 1, and with it is the distribution of quality grades by one of the individual reporters which used the 1 to 9 scale and therefore helped determine the "master" distribution except at the extreme quiet end of the scale. This reporter consistently graded conditions less disturbed than average. Thus, while his reports are on the 1 to 9 scale, they must be adjusted downward for best agreement with the average of several such reporters. The individual distribution is thus forced to agree with the "master" distribution, and current indices for a given portion of the day are reduced by the corresponding conversion table to the Q-figure scale. It is assumed that the individual reporter maintains the same standards for assigning quality ratings in the period on which the conversion table is based and in the ensuing months or years. The validity of the quality figures is dependent on this consistency and on the ability of the compiler to recognize changes in the criteria of the reporter.



0000-0600 GCT JULY-DECEMBER 1960

The Q-scale is thus calibrated against the average experience of several operating communications agencies. If these are typical, the Q-scale with its adjective equivalence has some meaning. Each observer of radio propagation conditions, however, must determine the relationship between his own scale and the Q-scale either subjectively or by a statistical analysis such as has been described, and interpret the quality figures and forecasts accordingly.

North Pacific Radio Path -- The CRPL quality figures, Qp, are compiled by the North Pacific Radio Warning Service (NPRWS), the CRPL forecasting center at Anchorage, Alaska from measurements made at the station of field-strength and fading-rate characteristics on several suitable transmissions, on absorption characteristics as measured by riometer, and on reports of radio traffic data from the U.S. Air Force, Federal Aviation Agency and Radio Corporation of America. These data indicate propagation conditions for moderately long transmission paths in the North Pacific equivalent to Seattle-to-Anchorage or Anchorage-to-Tokyo.

The original data are reported on various scales and for various time intervals. The observations for each 8-hour or 24-hour period are averaged on the original scale. This average is compared with reports for the same period in the preceding two months and expressed as a deviation from the 3-month mean. The deviations are put on the 1 to 9 scale of quality which is assumed to have a standard deviation of 1.25 and a mean for the various periods as follows:

03-11 hours UT	5.33	19-02 hour UT	6.00
11-18	5.33	00-24	5.67

The 8-hour and 24-hour indices Qp are determined separately. Each index is a weighted mean of the data available for the period.

APPENDIX D

CRPL-RWS-88
(Supersedes
CRPL-RWS-75)

CRPL RADIO WARNING SERVICES
Central Radio Propagation Laboratory
National Bureau of Standards
Boulder, Colorado - 80301

March 12, 1964

Description and Interpretation of Radio Propagation Forecasts

The two radio propagation forecasting centers of the Central Radio Propagation Laboratory regularly issue three types of forecasts of radio propagation conditions. These forecasts apply to sky-wave propagation (usually within the frequency range 3 to 30 Mc) over certain particularly important radio paths. The North Atlantic Radio Warning Service forecasts apply primarily to transmission over paths such as New York to London or Washington to Paris; their forecasts will apply to a lesser extent on nearby paths like Boston to North Africa, Maine to Greenland, etc. The North Pacific Radio Warning Service forecasts are designed for paths like Tokyo to Anchorage, San Francisco to Fairbanks, or Anchorage to Seattle; however, they can be given special interpretation for other paths such as the shorter intra-Alaska circuits, but again with less reliability.

Each forecast statement gives the average quality expected in a specified 6, 8, 12, or 24 hour period. All times are Universal Time (UT or GCT). The CRPL radio quality scale is used in all forecasts expressed as a quality figure. The CRPL Q-scale can be described in words as follows: 1 - useless; 2 - very poor; 3 - poor; 4 - poor-to-fair; 5 - fair; 6 - fair-to-good; 7 - good; 8 - very good; 9 - excellent.

These forecasts must be interpreted in terms of each user's own experience. A forecast of "3" means that the conditions experienced should be relatively poor, but the operator must interpret this in terms of the expected performance of his circuit. If the forecast is correct, on no more than 5 or 10% of all days should radio propagation conditions be so poor. There may be, however, a systematic difference between the word-descriptions used by the operator and by the forecaster, and the operator must take this difference into account in interpreting the forecast. For instance, the operator may be used to calling conditions "very poor" when the forecaster calls them "poor", or the operator of another, perhaps more efficient, circuit may never see conditions as worse than "fair". The scale used by the forecast center corresponds to the average experience reported on typical circuits.

Each user may go still further in converting the forecasts to his own particular situation. For example, when he receives a forecast of a "4", he may know from past experience that in order to maintain the desired level of communications efficiency he must change to the night operating frequency an hour earlier than usual, or possibly he will be able to pass traffic on only two channels of his four-channel equipment.

On the higher end of the scale, a forecast of "6" should correspond to normal conditions. A "7" would indicate better-than-average operation could be anticipated. The forecasts generally range from "2" to "7"; the ends of the scale (1, 8 or 9) are reserved for extreme conditions, which are rarely observed and even more rarely forecast.

The first type of forecast issued by the two forecasting groups is the advance forecast. This forecast is issued weekly. It includes a general forecast of intervals expected to be disturbed within the following 25 days and a detailed forecast of the expected quality of radio propagation conditions (on the CRPL quality scale) for each of the next 10 days. The forecast is distributed by mail, teletype and telephone. The teletype and telephone messages are, of necessity, brief but the mailed version (CRPL-J and CRPL-Jp reports) includes a review of propagation conditions, geomagnetic disturbances, if any, and the general level of solar activity during the past seven days. The factors which have affected the forecast, such as certain phenomena on the sun, are also described and special notes are frequently included. Special Disturbance Warnings (SDW) are issued (as desirable) between the regularly scheduled forecasts.

The second type of forecast is the 24-hour forecast or medium term forecast. This forecast is available by telephone and teletype and is issued daily. This forecast includes a statement concerning the expected level of geomagnetic activity and associated radio propagation conditions during the ensuing 24-hour period and a statement which suggests the range of operating frequencies on which the expected propagation conditions should be realized. The statements are designed to differentiate between nighttime and daytime propagation conditions. The propagation forecast, in this instance, is not expressed as a quality figure but rather as a class of conditions corresponding roughly to quiet, unsettled or disturbed.

The third type of forecast issued by the CRPL radio forecasting centers is the short term forecast. These are issued on regular schedules three and four times daily for the North Pacific and North Atlantic regions, respectively, and indicate the expected propagation conditions in the 8 and 6 hours immediately following issue. Each forecast statement consists of a letter and a number, e.g. N-4. The letter indicates the level of conditions prevailing in the 2-hour interval immediately preceding the forecast, and the number indicates the conditions expected in the forecast period. There are three possibilities for the letter--N, U or W. When an "N" is issued as part of the forecast statement, conditions were quiet in the 2-hour period preceding the forecast (quiet means in the range 6 to 9 on the CRPL quality scale); a "U" would mean conditions were unsettled (quality 5); and a "W" indicates that conditions currently are disturbed (quality 4 or lower). The number part of the statement is the forecast. The numbers are on the 1 to 9 scale defined above and must be interpreted in the manner described earlier.

The letter, a rating of current conditions, is included in the forecast statement to enable each user to interpret the forecast (the number) in terms of his own recent, or current, evaluation of conditions. For example, if an "N-5" forecast is issued and the operator is already, at the time of the forecast, experiencing what he would call unsettled (quality 5) conditions, then he should expect conditions to become even worse. The statement N-5 indicates that the forecaster expects a deterioration of at least one quality grade during the forecast period. The value of this scheme is obvious--the operator is concerned with expected changes in conditions and so is given information to tie in with his current experience. If the "5" had been issued without the "N" the operator would not have been prepared for a drop in quality since he was already experiencing what he called quality "5" conditions, although the consensus available to the forecaster rated conditions "normal".

Additional information concerning the radio forecasting services may be obtained from:

For the North Atlantic area:

North Atlantic Radio Warning Service (or NARWS)
National Bureau of Standards
P. O. Box 178
Fort Belvoir, Virginia 22060
(Telephone Washington, D.C., 780-1444, area code 703)

For the North Pacific and Alaskan areas:

North Pacific Radio Warning Service (or NPRWS)
National Bureau of Standards
P. O. Box 1119
Anchorage, Alaska 99501
(Telephone - SKyline 3-2211 or SKyline 3-7210,
area code 907)

APPENDIX E

CRPL-RWS-91
(Supersedes
CRPL-RWS-69)

NORTH ATLANTIC RADIO WARNING SERVICE
National Bureau of Standards
Box 178, Fort Belvoir, Va. 22060

March 18, 1964

Services Available from North Atlantic Radio Warning Service/AGIWARN
(Operated 24 hours a day - every day of the year)

The North Atlantic Radio Warning Service is a field station of the Central Radio Propagation Laboratory (Boulder, Colorado), under the National Bureau of Standards, U.S. Department of Commerce, whose primary function is the forecasting of radio propagation conditions over North Atlantic transmission paths. Under the auspices of the International Ursigram and World Days Service (IUWDS) it serves as the Western Hemisphere Regional Warning Center for providing solar-geophysical data and IQSY Alerts to scientific institutions in the western hemisphere. AGIWARN also serves as the World Warning Agency and is charged with the responsibility for assessing solar and geophysical phenomena and originating daily alerts in connection with the world-wide geophysical alert program for the International Years of the Quiet Sun, 1964-65 (IQSY). This daily alert is introduced into the World Meteorological Organization and AGIWARN communication networks and is given world-wide dissemination. Under the auspices of the Committee on Space Research (COSPAR), and supported in this endeavor by the National Aeronautic and Space Administration, AGIWARN also serves as a Satellite Regional Warning Center for introducing into the SPACEWARN network messages concerning launch announcements, orbital elements and tracking information for artificial earth satellites and interplanetary space probes.

The following tabulation is a listing of established messages distributed telegraphically from this office and contains a brief description of the information in each message. Many of the messages, possibly in slightly different form, are also distributed by mail (including air mail) and/or by telephone. Additional information concerning these services may be obtained from this office.

I - Radio Propagation Forecasts

1. ADFOA (Advance Forecast North Atlantic Area) - Forecasts of radio propagation conditions over North Atlantic transmission paths; issued weekly (Wednesday), and supplemented whenever circumstances warrant. These are often applicable as advance predictions of impending geomagnetic disturbances. Although this service is distributed by teletype when rapid notification is desirable, primary distribution is by air mail (identified as the CRPL-J Series). This mail version carries also a review of radio propagation conditions, general solar activity and geomagnetic disturbances during the previous week. Telephone distribution also is made locally.

2. MTAFO (Medium-term Forecast Atlantic Area) - Forecasts of radio propagation conditions over North Atlantic paths for the next Greenwich day; issued daily at about 2000 Universal Time (UT or GCT). Distribution is accomplished by teletype and, locally, by telephone.

3. STAFO (Short-term Forecast Atlantic Area) - Forecasts of North Atlantic radio propagation conditions; issued every six hours for the subsequent six-hour period. These forecasts are distributed by teletype and, locally, by telephone and are broadcast by Radio Station WWV.

4. GEOCAST (Geomagnetic Activity Forecast) - General forecast of geomagnetic activity for the following Greenwich day, issued about 1900 UT each day. Distribution is by teletype; telephone may be used locally.

II - Solar-Geophysical Data Messages

1. WASHAGI (Data Summary Message) - Daily data message, sent telegraphically at about 1800 UT, which contains a summary of the most important solar activity and geophysical data collected during the previous 24 hours. These data, in synoptic code, include reports of outstanding solar flares and radio noise events, important absorption events, cosmic ray events, geomagnetic activity, sunspots, etc. Although the primary method of distribution is via teletype, mail distribution is available if rapid delivery is not required.

2. WASHFLAR (Important Flare Report) - Message issued immediately upon receipt at this office of a report (less than 24 hours old) of an importance 3 or 3 plus solar flare; also issued immediately if an importance 2 or 2 plus flare is reported while still in progress. This message is distributed by teletype to individuals or institutions who require rapid notification of the occurrence of these events. For other users, these flare reports are contained in the daily WASHAGI message. These reports are usually in coded form.

3. WASHION (Ionospheric data) - Daily message, issued telegraphically about 1800 UT, which gives the critical frequency of the local (Washington) ionosphere (F_2 layer) at six-hour intervals within the previous 24 hours. The message is in synoptic code.

4. WASHMAG (Geomagnetic Data) - Daily telegraphic message issued shortly after the end of each Greenwich day, providing indices of geomagnetic activity for the preceding 24 hours. The message, in coded form, contains a daily A-index and 3-hour K-figures. (Similar information, covering a slightly different time period, is provided in the daily WASHAGI message described above). These geomagnetic observations are made locally (Washington area).

III - Solar-Geophysical Alerts for IQSY Program

1. AGIWARN (IQSY ADALERT) - (Advance Geophysical Alert) - Regional Alert issued immediately upon receipt at this office of a report (usually from a Western Hemisphere observatory) of a significant solar flare; or of a significant cosmic ray increase or decrease; or after the recognition of the existence of a significant geomagnetic storm. These Alerts may be issued either on the basis of unusually high or extremely low solar activity or extremely quiet magnetic conditions. Distribution is primarily by teletype but may be accomplished locally by telephone.

2. IQSY GEOALERT (World-wide Geophysical Alert) - Alert message issued daily at 0400 UT. Positive alerts are issued following the occurrence of a cosmic ray increase; during a significant geomagnetic disturbance; upon determination of the existence of a significant warming in the stratosphere (currently confined to the northern hemisphere); during periods of an unusually high level of solar activity; in periods of extremely low solar or geomagnetic activity; or when a significant geomagnetic disturbance is expected to begin within the following 24 hours. When no positive alert exists, the word "nil" is employed. The primary distribution method for these Alerts is via the World Meteorological Network (WMO). In the United States this is accomplished through the Service C teletype network of the U.S. Weather Bureau. For those who require these Alerts but have no reasonable access to Weather Bureau (or WMO) circuits, direct telegraphic service is offered by AGIWARN when the Alert is positive. This direct service is initiated at about 1300 UT. Telephone service is available in the Washington area.

3. IQSY ADALERTPRESTO (Rapid Flare Alert) - Special Alert issued immediately on the basis of the probable occurrence of an important flare as indicated by recordings of 10 cm solar radio noise. This is intended as an extremely rapid warning system for cosmic ray studies. Whenever feasible, telephone or direct TWX service is employed for distribution.

4. IQSY STRATALERT (Winter Stratospheric Warming Alert) - Regional Alerts issued daily during the winter season (December 1 to April 30). The U.S. Weather Bureau is the originating agency for these Alerts in the Western Hemisphere. These coded messages are introduced into the Service C network of the Weather Bureau at about 1800 UT. Upon request, arrangements can be made for distribution telegraphically from AGIWARN.

IV - Artificial Earth Satellite Information

SPACEWARN - messages relating to launch information, orbital elements, ephemeris for optical observations and reports of tracking observations, distributed when appropriate to interested observatories or scientific organizations. Launching announcements are plain language messages which announce the launch of satellites from the United States or other countries. Messages containing the code word "SATOR" are coded messages carrying modified orbital elements for prediction purposes. These two types of message are released by an agency or agencies within the launching country and are introduced into the SPACEWARN network by AGIWARN for the benefit of Western Hemisphere stations. Currently SATOR messages are distributed in this hemisphere for US-launched satellites only. Telegraphic or mail distribution is offered. Messages containing the code words SATAT (for communication of the ephemeris for optical observations at individual stations) and SATEV (for reports of tracking observations) are special messages and usually are not handled by AGIWARN.

The above services are available currently at no cost to the subscriber if military (usually military establishments only) or government teletype systems can be utilized. If the subscriber's desires or communication facilities are such that commercial TWX or Western Union systems must be used, the services are then available at the cost of transmitting the messages (collect). Note that the government teletype channel operates on a daytime schedule, five days a week; night, weekend or holiday messages delivered by this system are held at AGIWARN until the following normal work day, except that upon request the weekend-holiday-night messages will be distributed at the normal time, collect, via TWX or Western Union.

Any of the following addresses may be used to transmit communications to this office by electrical means.

Telephone:	Alexandria, Va., Area Code 703, 780-1444 or 780-1436
Cable and Radio gram:	AGIWARN WASHINGTON
Telegraphic:	NORTH ATLANTIC RADIO WARNING SERVICE WUX WASH DC
TWX:	703-339-5771
Teletype:	AGIWARN BUSTAN FT BELVOIR VA.

APPENDIX F

CRPL-RWS-85
(Supersedes
CRPL-RWS-79)

CRPL RADIO WARNING SERVICES
Central Radio Propagation Laboratory
National Bureau of Standards
Boulder, Colorado - 80301

March 9, 1964

SHORT TERM RADIO FORECASTS

APPLICATION - These forecasts apply to propagation quality on radio transmission paths such as Washington to London for the North Atlantic Radio Warning Service or Anchorage to Tokyo for the North Pacific Radio Warning Service. In general, paths which reach higher latitudes will be more disturbed and paths in lower latitudes will be less disturbed.

TIMES OF ISSUE -

North Atlantic: They are issued four times a day at nominal six-hour intervals: 0500, 1200 (1100 in summer), 1700, and 2300 UT. Each forecast refers primarily to the six-hour period beginning one hour after the time of issue -- for example, the 0500 forecast refers especially to the 0600-1200 UT period.

North Pacific: They are issued three times a day at nominal eight-hour intervals: 0200, 0900, and 1800 UT. Each forecast refers primarily to the eight-hour period beginning an hour after the time of issue -- for example, the 1800 forecast refers especially to the 1900-0300 UT period.

FORM - The forecast statement consists of a letter and a number; the number is the forecast while the letter identifies the quality of radio propagation conditions prevailing at the time the forecast is issued. A typical forecast statement is "U-6" -- which means, "propagation conditions are now unsettled but radio quality is expected to improve to fair-to-good during the hours covered by the forecast".

NUMBER - The radio quality which is forecast for the coming period is expressed in the following quality grades:

1 - useless, 2 - very poor, 3 - poor, 4 - poor-to-fair, 5 - fair, 6 - fair-to-good, 7 - good, 8 - very good and 9 - excellent.

LETTER - The radio quality at the time of issue of the forecast is identified as follows:

W - disturbed (quality 1, 2, 3, or 4)
U - unsettled (quality 5)
N - normal (quality 6, 7, 8, or 9)

The letter describes the average quality in the two hours preceding the issue time -- 0300 to 0500, 1000 to 1200, 1500 to 1700, or 2100 to 2300 UT for the the North Atlantic Radio Warning Service; 0000-0200, 0700 to 0900, or 1600 to 1800 UT for the North Pacific Radio Warning Service.

DISTRIBUTION - Short term forecasts are telephoned by the Radio Warning Services to the local outlets of several communications services where they are further distributed by some of the services through their facilities. The North Atlantic forecasts are also broadcast by the NBS Standard Frequency Radio Station WWV on 2.5, 5, 10, 15, 20, and 25 Mc; the announcement is given in International Morse code every five minutes. A new forecast is first broadcast promptly after each time of issue, and is repeated every five minutes until the next forecast is issued. The North Pacific forecasts are broadcast by the NBS Standard Frequency Radio Station WWVH on 5, 10, and 15 Mc; the announcement is given in International Morse code every five minutes. A new forecast is first broadcast at 0239, 0939, and 1839 UT, and is repeated every five minutes until the next forecast is issued.

MEANING OF THE NUMBER-FORECAST - Each user must interpret the forecast in terms of his own experience with previous forecasts and with the guidance provided by the letter-identification. In this way he should be able to judge the amount of outage or other disturbance effects to be expected with each quality grade. For a given forecast number these effects will vary widely according to the service, transmission path, type of equipment, and available frequencies. In general, one can expect normal or high maximum usable frequencies (MUF) when the quality forecast is 6 or greater, though "multipath" trouble is still possible. With quality grades of 4 or less, normal or low MUF can usually be expected, together with low signal or severe fading.

Quality grades are interpreted in a number of ways: relative amounts of outage time, number of "hits", traffic speed which can be maintained, relative signal strength, relative intelligibility, or a subjective combination of two or more of these.

Remedial measures to be taken during propagation disturbances depend greatly on the service involved. Transmission quality may sometimes be improved by deviating from habitual frequency usage; in any event unusual frequency changes at unusual times may be expected. Frequency or space diversity, if available should be used. In some situations, slower traffic speeds will provide more efficient operations. Relaying traffic by low latitude routes will successfully circumvent all but the most severe disturbances.

MEANING OF THE LETTER-IDENTIFICATION - One of the purposes of the letter in the forecast statement is to indicate when significant changes may be expected to take place in propagation conditions. For instance, if conditions are normal when the forecast is issued but a severe disturbance is expected, the forecast statement would be "N-3". The letter also serves to relate the quality scale of the forecasters to that of the user. Since standards of various kinds of services vary widely, the user may need to compare his own quality rating in the specified 2-hour period with that of the forecasting center.

SPECIAL FORECASTS - Occasionally radio conditions will deteriorate unexpectedly. Under these circumstances special short term forecasts may prove helpful to communications agencies. Such forecasts are issued by the North Atlantic Radio Warning Service for telephone customers in the Washington, D.C. area only, but they are <u>not</u> broadcast by WWV. They are issued only when the need is apparent earlier than two hours after the regular forecast was issued. The special forecast gives the quality of conditions at the time of issue and a revised forecast for the remainder of the 6-hour period. Similar telephone revisions are made by the North Pacific Radio Warning Service which are <u>not</u> broadcast by WWVH.

USCOMM-NBS-BL

NOTE: All times are given in Universal Time (UT or GCT).

APPENDIX G

CRPL-RWS-84
(Supersedes
CRPL-RWS-73)

NORTH ATLANTIC RADIO WARNING SERVICE
National Bureau of Standards
Box 178, Ft. Belvoir, Virginia - 22060

March 6, 1964

DESCRIPTION OF RADIO PROPAGATION FORECAST SERVICES
(North Atlantic Area)

A. Advance Forecasts -- The series of reports described below is available to operational addresses by mail or airmail on request. Telegraphic summaries are provided by special arrangement -- normally on a collect basis if commercial communications channels must be utilized.

1. CRPL-J report -- issued each Wednesday -- includes:

   a. General forecast listing the intervals, within the following 25 days, expected to be disturbed in terms of whole-day radio reception quality indices.

   b. Detailed forecast of radio propagation conditions for the first 10 days after issue, reporting the quality of reception expected for each day on the CRPL 1 to 9 scale of radio quality which is defined in C below.

   c. Discussion of current solar activity as related to the forecast.

   d. Review of propagation conditions during the past seven days based on 10 immediately available reports; this review summarizes conditions by listing the whole-day and six-hour quality indices for each day.

   e. Notification and brief review of geomagnetic disturbance which occurred during the past week; also an analysis of these and earlier storms, which gives an indication of severity, probable association with solar activity whenever possible, and other information suggesting the likelihood that the disturbance should be expected to recur 27-days later.

   f. Chart showing the history of geomagnetic and radio disturbances during the past five 27-day recurrence cycles.

2. Special Disturbance Warnings (SDW) -- These forecasts are of two types. Both are issued on an irregular schedule, as required, and both are in effect for the date given and the remaining days

of the forecast week, and occasionally beyond the forecast week if this is considered appropriate for the forecast. Both are issued by postcard, telegram and telephone.

a. The first type of SDW is to predict a disturbance which was not foreseen at the time of issue of the last CRPL-J report. If an outstanding solar phenomenon has been reported and is expected to be followed by a radio propagation disturbance this type of SDW will be issued. Anticipation of such a disturbance normally would not have been possible in the regular CRPL-J.

b. The second type of SDW is to advise of a disturbance which has already begun, but which was not predicted by an earlier CRPL-J or SDW. In many instances this may be preceded by a SPECWARN message issued as a special plain language forecast covering an unforeseen disturbance which appears to be imminent or which has just recently begun -- this type of SPECWARN message, distributed only by telegram and telephone, is issued when it is not feasible to issue an SDW immediately.

These advance forecasts are based on the tendency of geomagnetic and radio disturbance to recur at 27-day intervals, and on statistical relationships between activity on the sun (for example, solar flares) and unusual conditions in the earth's ionosphere. the 27-day recurrence tendency is currently the primary basis for forecasts as we approach sunspot minimum. The forecasts are intended to apply especially to radio transmission in the North Atlantic area. They may therefore differ in detail from other advance forecasts of the NBS-CRPL Radio Warning Services -- radio propagation forecasts issued by the North Pacific Radio Warning Service at Anchorage, Alaska, and the geomagnetic forecasts issued from the NBS Central Radio Propagation Laboratory for general users of shortwave radio.

Although the advance forecasts of radio propagation conditions are not primarily intended as forecasts of geomagnetic activity, they may be interpreted as such. The forecasts are based upon anticipated geomagnetic conditions, and forecasts of disturbed radio conditions (quality 4 or lower) thus suggest a strong likelihood of geomagnetic disturbance during intervals so forecast.

B. Medium Term Forecasts -- Word statement type forecasts covering radio propagation conditions on North Atlantic paths the following Greenwich day are available daily at 2100 UT (2000 during the summer). In addition to general statements concerning radio reception, the forecasts include general information concerning Optimum Traffic Frequency (FOT) and

Lowest Usable High Frequency (LUF) during the forecast period. The statements are prepared in such a manner as to give consideration to local times of day, i.e., daytime, nighttime, day-to-night transition and night-to-day transition. These forecasts are distributed by teletype and telephone.

C. Short Term Forecasts -- Forecasts are issued four times daily, at 0500, 1200 (1100 summer), 1700, and 2300 UT, giving estimates of radio quality expected during the six-hour period beginning about one hour after time of issue. They are distributed by teletype and telephone and are broadcast every five minutes by NBS station WWV (2.5, 5, 10, 15, 20 and 25 Mc) in International Morse Code. Each forecast is broadcast unchanged until the next regular forecast is issued.

The forecast statement consists of a letter and a number. The letter is an identification of current radio quality -- it identifies propagation conditions on North Atlantic transmission paths at the time of issue and may be expressed in one of three grades: N - normal, U - unsettled, and W - disturbed. The number is the forecast -- it gives the expected quality on the CRPL 1 to 9 scale of radio quality which is defined as follows: 1 - useless, 2 - very poor, 3 - poor, 4 - poor-to-fair, 5 - fair, 6 - fair-to-good, 7 - good, 8 - very good, and 9 - excellent. "N" corresponds to Q6 to 9, "U" to Q5, and "W" to Q1 to 4. A typical forecast statement is "U4", i.e., "Conditions are now fair and are expected to be poor-to-fair (moderately disturbed) in the next 6 hours.

NOTE: The above forecasts apply only to radio propagation quality as affected by ionospheric conditions. They refer to typical long-distance radio transmission paths such as New York - London or Washington - Reykjavik. Radio disturbances have their greatest effect on transmission along paths crossing the auroral zone and their least effect, or none at all, on paths in lower latitudes. The forecasters assume that the most suitable radio frequencies for communications (as given, for instance, by the CRPL "Ionospheric Predictions") are available to the operator and that they are in use. Typical effects of disturbances are rapid fading, low signal strength, complete blackout. Interference from adjacent frequency channels is usually regarded as not being a disturbance effect. Because of disturbed conditions, it may be necessary to make unscheduled changes in operating frequency in order to obtain the best communications possible. If a frequency near the predicted OWF (optimum working frequency) is customarily in use on undisturbed days, the first choice in attempting to maintain communications during a disturbance, as a general rule, is the next lower available frequency. If this does not work, then higher than normal frequencies should be attempted since in the beginning phases of a disturbance intense sporadic E may support communications, at least erratically, on frequencies higher than those useful during quiet conditions. As the disturbance becomes severe, all radio frequencies may be blacked out.

Sudden ionospheric disturbances, i.e., brief simultaneous fadeouts in the entire high frequency spectrum on paths on the daylight side of the earth (called SID or, more properly, SWF) are not predicted by either of the above forecasts or the broadcasts from WWV. Fadeout warnings are available, however, as described in Section D below.

D. Fadeout (SWF) Warnings -- Warnings for brief shortwave fadeouts are available daily on request. The warnings express the probability that one or more such fadeouts will occur during the daylight hours of the following day. There are three grades of warning. Grade 1 - slight chance, Grade 2 - fair chance, and Grade 3 - good chance. With the decrease in activity at this solar cycle epoch SWF are much less frequent than at the maximum of the solar cycle.

E. Special Services -- Information on current radio propagation conditions and general information on ionospheric disturbance and forecasts may be obtained 24-hours a day from the North Atlantic Radio Warning Service. Telephone: Washington, D.C., 780-1444. TWX: (703) 339-5771. Government Teletype -- Military communications agencies: AGIWARN BUSTAN FT. BELVOIR VA: other: NARWS FT BELVOIR VA or AGIWARN FT BELVOIR VA.

NOTE: All times are given in Universal Time (UT or GCT).

USCOMM-NBS-BL

APPENDIX H

CRPL-RWS-86
(Supersedes
CRPL-RWS 72)

NORTH PACIFIC RADIO WARNING SERVICE
National Bureau of Standards
Box 1119, Anchorage, Alaska, 99501

March 10, 1964

DESCRIPTION OF RADIO PROPAGATION FORECAST SERVICES
(North Pacific Area)

A. Advance Forecasts -- A series of reports, as described below is available to operational addresses by mail or airmail on request. Telegraphic summaries are provided by special arrangement.

1. CRPL-Jp report -- issued each Wednesday -- includes:

   a. General forecast listing the intervals, within the following 25 days, expected to be disturbed in terms of whole-day radio reception quality indices.

   b. Detailed forecast of radio propagation conditions for the first 10 days after issue, reporting the quality of reception expected for each day on the CRPL 1 to 9 scale of radio quality which is defined in B below.

   c. Discussion of current solar activity as related to the forecast.

   d. Review of propagation conditions during the past seven days based on a few immediately available reports; this review summarizes conditions using the whole-day and eight-hour quality indices for each day.

   e. Notification and brief review of geomagnetic disturbance which occurred during the past week; also an analysis of these and earlier storms, which gives an indication of severity, probable association with solar activity whenever possible, and other information suggesting the likelihood that the disturbance should be expected to recur 27-days later.

   f. Chart showing the history of geomagnetic and radio disturbances during the past five 27-day recurrence cycles.

2. Special Disturbance Warnings (SDW) -- These forecasts are of two types. Both are issued on an irregular schedule, as required, and both are in effect for the date marked and the remaining days of the forecast week. Occasionally, Special Disturbance Warnings will be effective beyond the forecast week if it is considered appropriate for the forecast. Both are issued by postcard, telegram, and, if warranted by telephone.

   a. The first type of SDW is a prediction which was not foreseen at the time of issue of the last CRPL-Jp report. This type of SDW will be issued if an outstanding solar phenomenon has been reported which is expected to be followed by a radio propagation disturbance. Usually anticipation of such a disturbance would not have been possible in the regular CRPL-Jp.

b. The second type of SDW is to advise that a disturbance is in progress but was not predicted by an earlier CRPL-Jp or SDW. In many instances this may be preceded by a SPECWARN message which is a special, plain language, forecast of an unforeseen disturbance which appears to be imminent. The SPECWARN message is distributed only by telegram and telephone.

Advance forecasts are based on the tendency of geomagnetic and radio disturbance to recur at 27-day intervals, and on statistical relationships between activity on the sun (for example, solar flares) and unusual conditions in the earth's ionosphere. The 27-day recurrence tendency will be the primary basis for the predictions during the next two or three years during sunspot minimum epoch. The forecasts are intended to apply especially to radio transmissions in the North Pacific Area. They may therefore differ in detail from other advance forecasts of the NBS-CRPL Radio Warning Services -- the radio propagation forecasts issued by the North Atlantic Radio Warning Service at Ft. Belvoir, Virginia and the geomagnetic forecasts issued from the NBS Central Radio Propagation Laboratory for general users of shortwave radio.

B. Short Term Forecasts are issued daily at 0200, 0900 and 1800 UT and are for the periods 0300-1100, 1100-1900 and 1900-0300 UT, respectively. Whenever the forecasters expect radio propagation conditions on the east path (Anchorage to Seattle) will be different from those on the west path (Anchorage to Tokyo), separate forecasts will be made for the two paths. They are distributed by telephone in the Anchorage area and by telegram by special arrangement. The forecasts for the general North Pacific area are broadcast on NBS radio station WWVH, Maui, Hawaii (5, 10 and 15 Mc) in International Morse code every five minutes after the time announcement and the station identification. The 0200 forecast is first broadcast at 0239 UT and every five minutes through 0900 UT. The 0900 forecast is first broadcast at 0939 UT and every five minutes through 1809 UT. The 1800 forecast is first broadcast at 1839 UT and every five minutes through 0209 UT. The short term forecasts are available also at most FAA stations in the North Pacific and Alaskan areas.

The forecast statement consists of a letter and a number. The <u>letter</u> is an <u>identification</u> of current radio quality -- it indicates the quality of propagation conditions on North Pacific transmission paths at the time of issue, expressed in three grades: N - normal, U - unsettled and W - disturbed. The <u>number</u> is the forecast -- it gives the expected quality for the following 12-hour period on the CRPL scale of radio quality: 1 - useless, 2 - very poor, 3 - poor, 4 - poor-to-fair, 5 - fair, 6 - fair-to-good, 7 - good, 8 - very good, 9 - excellent. "N" corresponds to Q6-9, "U" to Q5 and "W" to Q1-4. A typical forecast statement is "U4", i.e., conditions are now fair (unsettled) and are <u>expected</u> to be poor-to-fair in the next 12-hour period.

NOTE: The above forecasts apply <u>only</u> to radio propagation quality as affected by ionospheric disturbance. They refer to typical long-distance radio transmission paths such as Anchorage-Seattle, Tokyo-Anchorage or San Francisco-Fairbanks unless specified. Radio disturbances have their greatest effect on transmission along paths crossing the auroral zone and their least effect, or none at all, on paths in lower latitudes. The forecasters assume that the most suitable radio frequencies for communications (as given, for instance, by the CRPL Ionospheric Predictions) are available to the operator and that they are in use. Typical effects of disturbances are rapid fading, low signal strength, complete blackout. Interference from adjacent frequency channels is usually regarded as not being a disturbance effect. Because of disturbed conditions, it may be necessary to make unscheduled changes in operating frequency in order to obtain the best communications possible. If a frequency near the predicted OWF (optimum working frequency) is customarily in use on undisturbed days, the first choice in attempting to maintain communications during a disturbance is the next lower available frequency. If this does not work, then higher than normal frequencies should be attempted since in the beginning phases of a disturbance intense sporadic-E may support communications, at least erratically, on frequencies higher than those useful during quiet conditions. As the disturbance becomes severe, all radio frequencies may be blacked out.

Sudden ionospheric disturbances, i.e., brief simultaneous fadeouts in the entire high frequency spectrum on paths on the daylight side of the world (called, SID, or more properly, SWF) are not predicted by the above forecasts or the broadcasts of WWVH, but fadeout warnings are available as described in Section D below.

C. Separate Path Forecasts -- Beginning March 16, 1964, forecasters will provide separate short term forecasts for the Anchorage to Seattle and Anchorage to Tokyo radio paths. These forecasts will be given using the same letter and number format as is used for the general North Pacific area short term forecast. The separate path forecasts will be distributed only to telephone customers in the Anchorage area.

D. Optimum Frequency Forecasts -- Forecasters will provide, upon request on a trial basis, the estimated in and out times for two frequencies each on the Anchorage to Seattle and Anchorage to Adak radio paths (Seattle 12 and 5 Mc/s, Adak 10 and 6 Mc/s). These will be provided three times daily to the users who receive the forecasts by telephone. This information should serve as a guide for MUF-LUF use of the various frequencies allocated to the user.

E. Fadeout (SWF) Warnings -- Warnings for brief shortwave fadeouts (SWF) are available on request at about 0200 UT each day. The warnings express the probability that one or more such fadeouts will occur during the ensuing daylight hours. There are three grades of waring: Grade 1 - slight chance, Grade 2 - fair chance, and Grace 3 - good chance. The decrease in solar activity at sunspot minimum epoch makes the occurrence of SWF rare at present.

F. <u>Special Services</u> -- Information on current radio propagation conditions and general information on ionospheric disturbances and forecasts may be obtained during normal duty hours, 0700 to 2300 150° WMT, (or by special arrangement) from the North Pacific Radio Warning Service. Telephone: Anchorage SKyline 3-2211 or SKyline 3-7210. Teletype address: BUSTAN ELMENDORF AFB ALASKA.

NOTE: All forecast times are given in Universal Time (UT or GCT).

APPENDIX I

CRPL-RWS-80
(Supersedes
CRPL-RWS-67)

March 3, 1964

CRPL RADIO WARNING SERVICES
Central Radio Propagation Laboratory
National Bureau of Standards
Boulder, Colorado 80301

FORECASTS OF SUDDEN IONOSPHERIC DISTURBANCES OF THE SHORT-WAVE RADIO FADEOUT (SWF) TYPE

The CRPL Radio Warning Services make available general forecasts on the chance of occurrence of SWF -- the radio fadeouts or sudden ionospheric disturbances which affect all daylight high-frequency radio circuits for periods lasting from a few minutes up to about an hour. The SWF forecast will be issued only when there is a recognizable chance that a SWF will occur on the following day. There are three grades of warnings:

Grade 1 -- small but appreciable chance
Grade 2 -- fair chance
Grace 3 -- good chance

The forecast is available at the forecasting centers every afternoon at about 4:00 PM local time. It is given to telephone and teletype recipients on the next following radio disturbance forecast. The forecast is expressed in plain language -- for example, "There is a fair chance that a SWF will occur July 22." It must be emphasized that the SWF Warning refers to the chance that a fadeout will occur and not to the importance of a SWF that might be observed.

BACKGROUND

Now that the solar cycle is approaching minimum activity, the occurrence of flare producing solar regions is very rare. Associated SWF, however, still may be a significant factor in the operation of long-distance radio communications. These shortwave fadeouts affect radio transmission paths which are, at least partially, in daylight at the time of the flare. Radio communications are abruptly interrupted by the sudden and large increase in absorption which is called SWF. On the average, communications may be impossible for twenty to thirty minutes, after which normal field strength is gradually recovered. SWF are most noticeable on the lower of the normal frequencies in use and on paths that pass close to the sun's subsolar point.

In general, no steps should be taken by the radio operator to obtain communications on normal ionospheric frequencies while a SWF is in progress, other than to remain on the highest of the assigned frequencies which would normally be in use at that time of day. The radio signals will again be propagated normally as soon as the ionosphere recovers from the effects of the solar flare. If an LF link is in operation, it is likely that intelligible communications will be possible on LF throughout the SWF.

These daylight fadeouts are not considered in the weekly CRPL-J or Jp Radio Propagation Forecasts nor in the short term disturbance forecasts.

The bases for the forecasts are summarized below. Note that there is no attempt to forecast the time of any individual SWF. The forecasts give an indication of the likelihood of one or more SWF occurring at some time during the day specified.

Grade 1: There is a flare-producing region on the sun; therefore a SWF may occur tomorrow even though to date no SWF has been associated with this solar region.

Grade 2: (fair chance): A brief SWF has been observed today; since the solar region is likely to remain somewhat active for at least another day, there is a fair chance a SWF will occur tomorrow.

Grade 3: (good chance): A prolonged SWF or several brief SWF were observed today; therefore the solar region is very active, and there is a still better chance a SWF will occur tomorrow.

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS