SYMPOSIUM PAPERS

RTCM ASSEMBLY MEETING

APRIL 29-30 and MAY 1, 1970

SAN FRANCISCO, CALIFORNIA

VOLUME 2

MARITIME TELECOMMUNICATIONS

RADIO TECHNICAL COMMISSION

FOR

MARINE SERVICES

WASHINGTON, D. C.

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with the participation of

TUG COMMUNICATIONS, INC.

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THE

RADIO TECHNICAL COMMISSION FOR MARINE SERVICES

What it is - What it does.

The RADIO TECHNICAL COMMISSION for MARINE SERVICES (RTCM) is an organization in which government and industry cooperate in studies of existing and proposed systems of maritime telecommunications. These studies serve to determine suitability of the various telecommunications systems. Furthermore, appropriate cooperation often helps to foster new developments needed to meet changing maritime operational requirements.

As a coordinator of government and industry views on matters coming within its purview, the RTCM often is able to formulate recommendations for national and international action. All such official recommendations are presented as Special Committee reports. Membership in these committees is composed of experts in the particular subject to be studied. Before official distribution, all Special Committee reports are reviewed and approved by the Executive Committee.

The Executive Committee is composed of representatives from the following:

Department of the Army

Department of the Navy

Department of Commerce

Maritime Administration

Environmental Science Services Administration

Department of Transportation
U. S. Coast Guard

Federal Communications Commission

The Telephone Group
(Bell System and Independent Operating Companies)

The Lake Carriers' Association
(Representing Great Lakes steamship companies)

ITT Mackay Marine
(Communications interests)

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The Electronic Manufacturing Group
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(Representing recreational craft owners)

The American Waterways Operators, Inc.
(Representing major inland waterways operators)

American Radio Association
(Representing licensed radio officers)

American Pilots' Association
(Representing licensed pilots)

Papers contained in this volume were presented at the RTCM Assembly Meeting. They are the opinions of the authors, and do not necessarily represent the official views of the Radio Technical Commission for Marine Services.

FOREWORD

1970 marks 2 epochal events in the maritime world, and RTCM is proud to have been associated with both events.

The 1962 RTCM Assembly Meeting in San Francisco had as its theme "Shore Based Harbor Radar Surveillance and Guidance Systems." Now, in 1970, RTCM salutes the U. S. Coast Guard test Harbor Advisory Radar station, just placed in operation in San Francisco within the past few months.

The other epochal event is the National Navigation Plan. In 1957, RTCM Special Committee No. 35 (SC-35) reported on "Review Requirements for Maritime Long Distance Aids to Navigation." When the study for a national navigation plan was inaugurated in 1968, RTCM was requested to update its SC-35 report. Special Committee No. 60, "Electronic Aids to Navigation" tackled this project vigorously and within 6 months produced a timely report that has since been enthusiastically acclaimed. Registrants participating in this 1970 Assembly Meeting were fortunate in being able to obtain a preview of the complete United States National Navigation Plan.

This Assembly Meeting would not be complete without recognition of progress in other maritime telecommunications. Space Communications will become increasingly important as a means of expediting maritime telecommunications. But all these developments - harbor advisory radar, the National Navigation Plan, and space communications - can be traced back to their individual components, which often began as an individual paper given at an earlier Assembly Meeting.

No man can foretell the future, but if the past is prologue, one can expect that RTCM will continue to be a leader in the quest for better maritime telecommunications.

Symposium Papers

Volume 2

Maritime Telecommunications

Moderator: CDR H. G. Holmgren, Chief, Communications Branch
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Section

A Computer Simulation Model for the National Data Buoy HF Telemetry System

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1.0 INTRODUCTION

Man's physical environment drastically influences most of his daily activities, whether launching a journey to the moon or planning a week-end picnic. Yet, too little is known about the global environment or the natural phenomena which control it. Adequate theories and mathematical models now exist which have sufficient accuracy and detail to represent existing environmental conditions and to extrapolate to future conditions. The primary hindrance to the practical application of these techniques is the lack of up-to-date information describing roughly 80% of the earth's surface, mostly over, on, and under the oceans and their contiguous marine areas. If understanding of the earth's physical environment is to improve, and if reliable predictions of future conditions are to be possible, we must be able to describe existing conditions accurately, routinely, and in real time.

The United States Coast Guard has undertaken an ambitious project to bridge this environmental information gap by instrumenting the oceans. The Coast Guard's National Data Buoy Development Project has begun the research, development, testing, and evaluation necessary to provide a national capability to deploy and maintain networks of automatic unmanned data buoys, operating reliably and routinely to measure and report important parameters describing the marine environment. These "data pictures" of the deep oceans, coastal waters, estuaries, Great Lakes, and possibly the Arctic, will be reported on a real-time basis for weather prediction, fish migration prediction, pollution monitoring, transportation routing, resource exploitation, and obvious national security uses. Archived information will further allow detailed environmental research and understanding, and possibly future control of the weather.

The concept of a network of data buoys collecting meteorological and oceanographic data from the oceans has been endorsed by a number of important national committees beginning in 1967 when the President's National Council for Marine Resources and Engineering Development, popularly known as the Marine Sciences Council, recommended establishment of a goal to implement networks of data buoys.

More recent examinations by groups of leading experts have endorsed the original decision by the Marine Sciences Council to begin data buoy development. The January 1969 report of the Commission on Marine Sciences, Engineering and Resources, selected the advancement of buoy technology and deployment of a pilot buoy network as one of the six activities deserving national priority. A special Task Force on National Technology Problems in November 1969 reviewed the Commission's recommendations along with other potential programs, and affirmed that the prototype buoy network was worthy of national emphasis.

The first specific funds appropriated for the National Data Buoy Development Project became available in January 1970, when $6.5 million were included in the Coast Guard Fiscal Year 1970 appropriation. Until then, the Coast Guard had supported the project office with re-programmed funds from other mission areas. For continuous, reliable operation, the National Data Buoy Systems must include not only the basic buoys and instruments to make and transmit the required measurements, but also the communications networks, data processing, maintenance vessels, shore facilities, spare parts, and trained personnel essential to keep the buoys and instruments operating. The required systems are highly complex and involve a mix of many different technologies and disciplines. Thus, to state the obvious, National Data Buoy Systems are natural for the systems approach, to integrate the many portions and components into an optimum, cost-effective whole.

The keystone to any successful undertaking of this complexity is careful planning, both as a guide for the development program itself and as justification for future budgetary requests.

2.0 COMMUNICATION PLANNING

Reliable collection of data from a network of buoys presents a complex communication problem. An initial investigation of communication alternatives revealed that neither the required communication satellites nor space frequency allocations were available for collecting the data via satellite relay. Satellite relay methods are being developed but they will not be addressed here.

In 1964 the World Administrative Radio Conference (WARC) allocated six high frequency (HF) bands for ocean data collecting, thus culminating a long and difficult struggle by those who had worked many years towards this goal. However, the WARC stipulated that a plan for the global coordination of these frequencies was required, and it requested that the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC) draw up the plan in communication with the International Frequency Registration Board (IFRB) and Member Nations. The WMO and IOC appointed a joint Group of Telecommunication Experts to work out the details of the plan. The group includes two U. S. citizens, Mr. T. deHaas of the Institute for Telecommunication Sciences and Mr. James Snodgrass of Scripps Institute of Oceanography.

Within the United States, the Coast Guard agreed to fund a study directed toward utilization of the newly assigned frequencies, and contracted with the Institute for Telecommunication Sciences (ITS) to conduct the study. One of the principal outputs of this study is a computer based simulation model of the HF communication system. This model, and the results of other portions of the study as well, has (1) been used to support the joint Group of Experts on Telecommunications, (2) served as evidence of work toward development of the required plan, and (3) been used in the planning and engineering design of the communication subsystem of the National Data Buoy System. The remainder of this paper will be devoted to describing this simulation model and its application to international and national planning of HF ocean data collecting systems.

3. 0 CHARACTERISTICS AND PREDICTION OF HF CIRCUIT PERFORMANCE

Successful communication beyond ground wave distances in the HF portion of the radio spectrum depends upon the transmitted signals being reflected to the receiving terminal by the ionosphere. The ocean data collection system using frequencies in this range will consist of a collection of circuits using such transmissions. A circuit as the term is used here will mean the communication link from a buoy to a cooperating shore station. The performance (say in terms of error rate for a digital transmission system) on one of these circuits in one of the allocated bands is a highly variable factor. Fortunately this performance is predictable, in a probabalistic sense, over a period of a month. That is, the percentage of days in a given month that a required performance level will be met or exceeded at a specified hour can be calculated. This percentage of days is frequently referred to as the circuit reliability for that hour and month and it can be thought of as being the product of two probabilities:

(1) the probability that the ionosphere will support (reflect) the signal at that hour, and
(2) if it is reflected, the probability that it will be strong enough to give the desired performance.

Both probabilities depend upon the condition of the ionosphere along the path.

The first factor, the probability of support, is essentially independent of circuit design parameters (e. g. , transmitter power level). It depends basically on the operating frequency, the angle of incidence on the reflecting layer, and the intensity of ionization. The higher the frequency and/or the steeper the angle of incidence, the more intense the ionization must be to reflect the signal. Thus for a given path geometry, i. e. , angle of incidence, the probability of support decreases with increasing frequency. For example, there may be only a 10% chance of a 22 MHz signal being supported, but a 95% chance for a 4 MHz signal. Because of the steeper angles of incidence associated with shorter paths, the probability of support tends to decrease with decreasing path length. The ionosphere is produced by solar radiation and the intensity of ionization depends on local time of day along the path, season, and general level of solar activity. The intensity, and hence probability of support, increases during daylight hours and during years of high solar activity. As a result, higher frequencies are more useful during these periods.

The second factor, the probability of adequate signal strength, depends upon (1) the ionization in the lower regions of the ionosphere along the path, (2) the geometry of the path, (3) equipment parameters and performance quality desired, (4) operating frequency, and (5) the radio noise and interference environment at the receiver site. HF signals are absorbed in passing through the lower regions of the ionosphere on their way to or from the higher regions where reflection normally takes place. The amount of this absorption increases with distance travelled through the lower regions and with the intensity of ionization present in them. Thus the signal strength and the probability of an adequate signal decreases on longer paths and during daylight hours, during the summertime, and during years of higher solar activity. The absorption is inversely proportional to frequency, that is, lowering the operating frequency increases the absorption. The probability of adequate signal strength then decreases with decreasing frequency, while the first factor, the probability of support, increases with decreasing frequency.

In general, the curve of reliability versus operating frequency for a given time and set of parameters tends to have a peak because of these opposing propagation related factors. The performance on frequencies below this peak is degraded faster due to absorption than it is improved due to a higher probability of propagation. Conversely, for frequencies higher than this peak, the probability of support drops faster than the probability of adequate signal increases.

The adequacy of the signal also depends on the radio noise level at the operating frequency. This noise may be man-made (such as ignition noise from automobiles), atmospheric (lightning discharges), galactic, or, in rare instances in these bands, noise in the receiver itself. As an example, high man-made noise levels associated with urban receiving areas would require greater signal strengths than those associated with rural areas. Signal strengths increase with transmitter power and antenna gain. Thus higher radio noise levels tend to narrow the choice of useful frequencies while higher transmitter powers and antenna gains tend to increase it by increasing the probability of an adequate signal.

A final consideration in factor two is the required signal-to-noise ratio (SNR) necessary to obtain the desired performance. In a data collection system, the major performance factor is the bit error rate. The higher the allowable error rate, the lower the required SNR and the more useful the frequencies with lower signal strength or, more accurately, with lower SNRs. It also depends on the type of modulation and coding employed.

To summarize, the frequency and value of the point of maximum reliability and the shape of the reliability versus frequency curve changes with geographic location, time of day, season, solar activity, equipment parameters, and required performance. The operation of an individual circuit should be on a frequency at or near this point of maximum reliability.

The simulation model that is described in section 6 uses computed values of circuit reliability to select shore stations and operating frequencies for each buoy and to evaluate overall performance of the telemetry system under varying conditions. These calculations are based on a computer program developed at ITS to predict the performance on individual circuits. It is described in a report by Barghausen, et al. (1969). It uses predictions of basic ionospheric parameters which are obtained from long term vertical incidence soundings, atmospheric and man-made radio noise measurements, and experimental and theoretical evaluations of modem performance. The use of this and similar programs in the analysis of individual circuits is well documented and has been described at previous RTCM assembly meetings (e. g., Robinson, 1969). The distinquishing feature of the simulation program that is described in this paper is that it is intended to be an aid in the design of a system that consists of a large number of such individual circuits.

4.0 BASIC SYSTEM OPERATION

The purpose of the communication system is to efficiently transfer the oceanographic and meteorological data collected by the ocean buoys to the shore where it can be processed and passed on to the ultimate users. These transmissions can be initiated by an onboard clock system or by an interrogation transmission from a shore station. The transmissions of a given buoy would be at the synoptic hours of 0600, 1200, 1800, and 2400 GMT on one of the six allocated frequency bands.

To illustrate the situation, consider a buoy located off the east coast of the United States. Assume that there are three shore stations in the system that are candidates to receive the data. Thus there are three circuits to consider, one to each of these stations. Furthermore, for each circuit there is a choice of the six frequency bands. Each of the frequencies for each circuit will generally have a different predicted reliability because the reflection areas, local times, and noise levels at the shore stations will be different. This results in a total of 18 possible station-frequency combinations for selection. The idea, of course, is to pick the pair with the highest predicted reliability.

Each of the six frequency bands can be divided into separate channels so that several transmissions can be accommodated simultaneously. As an example, each 3.5 kHz band can be divided into ten 300 Hz wide channels leaving 500 Hz for guard space. Thus, each buoy can be assigned a channel as well as a shore station and frequency, and each shore station could receive data from as many as ten buoys simultaneously. It is also possible to receive data at different times, but still within the allowable time limit following the synoptic hour. In other words, one buoy might be read out between 1800 and 1802, and another between 1802-1804, etc. These are called timeslots. If there were 10 shore stations, 10 channels, 10 timeslots, and the 6 allocated frequencies, there would be a total of 6,000 station-frequency-channel-timeslot (SFCT) combinations for data gathering. The object is to assign these combinations (resources) to buoys in such a way that the performance of the telemetry system is optimized. The overall telemetry system performance resulting from such assignments will be discussed in the following section.

5.0 TELEMETRY SYSTEM PERFORMANCE

The Total System Reliability for the telemetry system at a given synoptic hour can be defined as the percentage of data messages from all buoys that are received at the shore stations with acceptable error rates. This reliability is the expected value or average of all the individual circuit reliabilities. For example a given assignment of station-frequency-channel-timeslots might produce a total system reliability of 90% with individual circuit reliabilities ranging from 60% to 97%.

The Total System Reliability and the distribution of reliabilities is a function of a number of parameters. These include those associated with determining the reliability of individual circuits and those associated with the system as a whole. Some of these can be controlled by the system engineer and others cannot. The major parameters in these two categories are listed in table 1.

Under controllable parameters, the first three--buoy transmitter power output, antenna gains and patterns, and required S/N ratios--are the basic ones associated with designing individual circuits that were discussed in section 3. 0. The remainder are those associated with the overall system. Item 4 is the number and location of shore stations. Increasing the number of shore stations increases the number of alternative station-frequency combinations available for assignment. Since some of these may have higher reliabilities, the Total System Reliability may increase. Similarly, certain shore station locations may be more favorable than others. The next parameter, item 5 in the table, is the number and distribution of frequency bands and channels with which each platform is equipped. To decrease the complexity and cost of the buoy transmitter, they may be equipped to be able to transmit in only two or three frequency bands rather than all six. This decreases the reliability from what would otherwise be attainable because at certain times the best frequency would not be available. Increasing the number of channels per frequency band or the number of timeslots (item 6 in the table) permits greater flexibility in assigning noninterfering station-frequency combinations, and thereby may increase the Total System Reliability. Related to this is item 7, the method of making assignments of the resources. If the system capacity is limited so that several platforms are competing for the same assignments, then the method in which assignments are made will affect the Total System Reliability. Item 8 is the geographic distribution of moored buoys. Since circuit reliability depends heavily on the location of the path, the position of the moored buoys will affect the Total System Reliability just as the location of shore stations affects it in item 4. Finally there is item 9, the choice of transmission time. So far it has been assumed that the data would be sent at times near the four synoptic hours mentioned previously. For a system where this is not a requirement, it would be possible to increase the Total System Reliability by sending the data at times when propagation conditions are predicted to be best.

Under the column marked uncontrollable parameters are three items. The first is the time of year or season and the second is the level of solar activity. Since the buoys will be deployed for long periods of time, the circuit reliabilities and the Total System Reliability will vary with season and solar activity. The third item is the geographic distribution of drifting buoys. It may be cost-effective to deploy large numbers of low cost, unmoored buoys to gather data much in the same way as weather balloons are used. Since their location would change from day to day in at least a partially unpredictable manner, the Total System Reliability would also vary. It is these three uncontrollable parameters that make simulation necessary.

The computer program described in section 6.0 predicts the Total System Reliability as a function of these two classes of parameters. Predictions of Total System Reliability are useful in both the planning and operational phases of communication system development. During the planning or design phases it provides a meaningful index of performance for cost/effectiveness and tradeoff studies. For example, the establishment and operation of shore stations is a major factor in the cost of the communication system. Using the computer program, the change in performance resulting from a decrease in the number of shore stations can be evaluated. Similarly the effect of varying the power output of the buoy transmitters can be studied. The transmitter power is an important factor in determining the cost of the communication equipment on the buoy and it may have an impact on the buoy's primary power source as well. It may be possible to increase the number of shore stations to compensate for a more economical buoy transmitter power level, or vice versa, depending on the cost factors. The program provides the means for studying such tradeoffs over the expected range of the uncontrollable parameters.

After the buoy network is in operation, it will provide an objective method for assigning station-frequency-channel-timeslot resources to buoys on a routine basis, perhaps even at the international level. It will also be useful in evaluating actual performance as it is reported.

6.0 PROGRAM DESCRIPTION

The main program, SIMIGOSS, has three main sections: (1) PREDPRFM, the basic circuit performance prediction subroutine which is a modified version of the program described in the previously referenced work by Barghausen et al., (2) OPTIMAL, the subroutine which actually assigns a station-frequency-channel-timeslot to each buoy, and (3) SKEDULE, the subroutine which generates statistics and outputs the assignments. The inputs to SIMIGOSS are the data on each buoy (position, equipped frequencies, etc.), shore station locations, and other data such as transmitter powers and antenna types. The inputs to PREDPRFM are the ionospheric and radio noise data that were mentioned previously. OPTIMAL uses the calculations from PREDPRFM to select for each buoy at each synoptic hour, the station-frequency combination with the highest predicted reliability. Channel and timeslot assignments are used to avoid potential interference. If the channel and timeslot assignments are filled for the best station-frequency combination, the second best is tried, etc. The predicted reliability for the assignment is used in computing the Total System Reliability. The outputs are the assignments, i.e., the station, frequency, channel, and timeslot selected for each buoy, and summaries such as the Total System Reliability, signal strength distributions, distributions of reliabilities, and many others. Examples of some of these outputs are given in the next section.

7.0 SAMPLE OUTPUTS

To test the operation of the program, several simulation runs have been made. One run was made to simulate the international coordination problem and involved an assumption of several thousand buoys and instrumented ships of many nationalities and 18 worldwide shore stations. Other runs were made for a hypothetical national system consisting of 35 buoys distributed off the coasts of the United States. The shore stations were assumed to be 11 existing U.S. Coast Guard radio stations. The examples given here are for the 35 buoy network.

Runs were made for the months of June and December to represent the extremes of seasonal variations. Solar activity, as measured by the smoothed sunspot number, was assumed to be 59 and 49, respectively. These correspond to the values expected for these months in 1971. Other assumptions were that:

(1) 11-meter high discone antennas would be employed on the buoys,
(2) the shore stations would be equipped with antennas with 12 dB power gain and space diversity,
(3) an FSK modem with a 200 Hz bandwidth and a 100 bit/second transmission rate would be used,
(4) the maximum allowable error rate is one bit per 1,000 which results in a required signal-to-noise ratio of 38 dB, and
(5) the man-made radio noise environment at each shore station is typical of urban areas.

Four different buoy transmitter power output levels were considered (25, 50, 100, and 200 W).

A sample assignment is shown in figure 1. This particular sample is for June and a transmitter power of 100 W. The unlabeled line shows the geographic coordinates of the buoy (43°N, 68°W). The remainder of the printout is divided into four parts corresponding to the four synoptic hours. At the 0600 GMT synoptic hour, it shows that platform (buoy) number 1 has been assigned to station 5 (New Orleans) on frequency band number 2 (6 MHz), on channel 1 and timeslot 1. The predicted reliability for this assignment is 93% and the predicted signal strength at the shore station is -73 dBW. The location of the shore station is 29.95°N, 90.03°W and the distance from the buoy to the station is 2,434 km. Note that the buoy is assigned to three different shore stations over the four synoptic hours and that it uses three of the six allocated frequency bands.

Table 2 is a summary of the Total System Reliability for the two months and four power levels. The effect of increasing transmitter power is evident. It gives the system designer a feel for the improvement in performance that can be accomplished with increased power levels.

Figure 2 shows samples of computer prepared histograms of the individual circuit reliabilities that are used in calculation of Total System Reliability. These give additional information on the actual distribution of reliabilities.

Figure 3 is a set of histograms illustrating the frequency band utilization resulting from all assignments for the four power levels in June 1970. The 6, 8, and 12 MHz bands account for the great majority (80-85%) of the assignments. This implies that this percentage of the best assignments could be made if the buoys were equipped with only these three frequencies. The decreased complexity of the buoy transmitter, antenna, and matching circuits that this would allow must be balanced against the reduction in Total System Reliability that would result from not having the best frequency available about 15-20% of the time. This reduction in reliability can be predicted by rerunning the program with assignments restricted to these three frequencies.

Many other outputs from the program are possible, but the ones just illustrated are the most useful in the current stage of the system design. An example of another output which has not yet been programmed, would be a summary of antenna takeoff angles for each frequency, and azimuthal bearings to assignments, so that the antenna requirements for each shore station can be determined. This would provide a basis for antenna design.

8.0 SUMMARY

The National Data Buoy Development Project has been undertaken by the U.S. Coast Guard to satisfy a critical need for additional marine environmental data. The concept of using a network of buoys to collect such data has been endorsed by a number of national committees and funds supporting the development were appropriated by Congress for Fiscal Year 1970. A reliable telemetry subsystem is essential to the success of the system as a whole. In this paper, a computer model developed at ITS for simulating the performance of a telemetry system using six frequency bands in the HF portion of the radio spectrum has been described. It is useful in both the design and operational phases of system development. During the design phase, it enables the systems engineer to efficiently make tradeoff studies among parameters over which he has control (e. g., transmitter power output, modem type, antenna gains and patterns, number and location of shore stations, and frequency assignments) for different levels of solar activity, season, geographic distributions of drifting buoys, and other factors over which he does not have control. During the operational phase it can be used for assigning frequency, station, and time resources and evaluating actual performance. Sample results obtained from studies of a hypothetical data buoy network have been given.

9.0 REFERENCES

Barghausen, A. F., J. W. Finney, L. L. Proctor, and L. D. Schultz (1969), Predicting long-term parameters of high-frequency sky-wave telecommunication systems, ESSA Tech. Rept. ERL-110 ITS 78 (U. S. Government Printing Office, Washington, D. C. 20402).

Robinson, J. W. (1969), Reliability and economic considerations in the selection of HF radio systems, Symposium Papers, RTCM Assembly Meeting, April 21-23, 1969.

Table 1. Summary of parameters affecting system performance

CONTROLLABLE	UNCONTROLLABLE
(1) TRANSMITTER POWER	(1) TIME OF YEAR OR SEASON
(2) ANTENNA GAINS AND PATTERNS	(2) LEVEL OF SOLAR ACTIVITY
(3) REQUIRED S/N RATIOS	(3) GEOGRAPHIC DISTRIBUTION OF MOBILE PLATFORMS
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(4) NUMBER AND LOCATION OF SHORE STATIONS	
(5) NUMBER AND DISTRIBUTION OF EQUIPPED FREQUENCIES AND CHANNELS ON EACH PLATFORM	
(6) NUMBER OF CHANNELS AND TIMESLOTS	
(7) ASSIGNMENT METHOD	
(8) GEOGRAPHIC DISTRIBUTION OF MOORED BUOYS	
(9) CHOICE OF INTERROGATION HOUR(S)	

Table 2. Summaries of Total System Reliability

Reliabilities in Percent for June, 1971

Time-GMT	Transmitter Power Output in Watts			
	25	50	100	200
0600	90	93	95	97
1200	90	94	96	97
1800	84	89	92	94
2400	88	92	94	96
Avg. Rel.	88	92	94	96

Reliabilities in Percent for December, 1971

Time-GMT	Transmitter Power Output in Watts			
	25	50	100	200
0600	92	95	97	98
1200	93	95	97	98
1800	91	94	96	97
2400	95	97	98	99
Avg. Rel.	93	95	97	98

Figure 1. Sample assignment.

LATITUDE = 43.00 LONGITUDE = -68.00

HOUR = 600 GMT

PLATFORM NO.	AREA NO.	STATION NO.	FREQ NO.	CHANNEL NO.	TIMESLOT	RELIAB PERCENT	SIGNAL -DBW	STATION LATITUDE	STATION LONGITUDE	DIST KM
1	1	5	2	1	1	93	87.0	29.95	-90.03	2434

HOUR = 1200 GMT

PLATFORM NO.	AREA NO.	STATION NO.	FREQ NO.	CHANNEL NO.	TIMESLOT	RELIAB PERCENT	SIGNAL -DBW	STATION LATITUDE	STATION LONGITUDE	DIST KM
1	1	3	3	1	1	91	93.0	36.72	-76.02	977

HOUR = 1800 GMT

PLATFORM NO.	AREA NO.	STATION NO.	FREQ NO.	CHANNEL NO.	TIMESLOT	RELIAB PERCENT	SIGNAL -DBW	STATION LATITUDE	STATION LONGITUDE	DIST KM
1	1	3	4	1	1	91	95.0	36.72	-76.02	977

HOUR = 2400 GMT

PLATFORM NO.	AREA NO.	STATION NO.	FREQ NO.	CHANNEL NO.	TIMESLOT	RELIAB PERCENT	SIGNAL -DBW	STATION LATITUDE	STATION LONGITUDE	DIST KM
1	1	4	3	1	1	89	93.0	25.62	-80.38	2236

FREQUENCY 1	4.260 MHZ
FREQUENCY 2	6.246
FREQUENCY 3	8.330
FREQUENCY 4	12.481
FREQUENCY 5	16.638
FREQUENCY 6	22.162

STATION 1	BOSTON
STATION 2	NEW YORK
STATION 3	NORFOLK
STATION 4	MIAMI
STATION 5	NEW ORLEANS
STATION 6	KODIAK
STATION 7	KETCHIKAN
STATION 8	WESTPORT
STATION 9	LONG BEACH
STATION 10	HONOLULU
STATION 11	SAN FRANCISCO

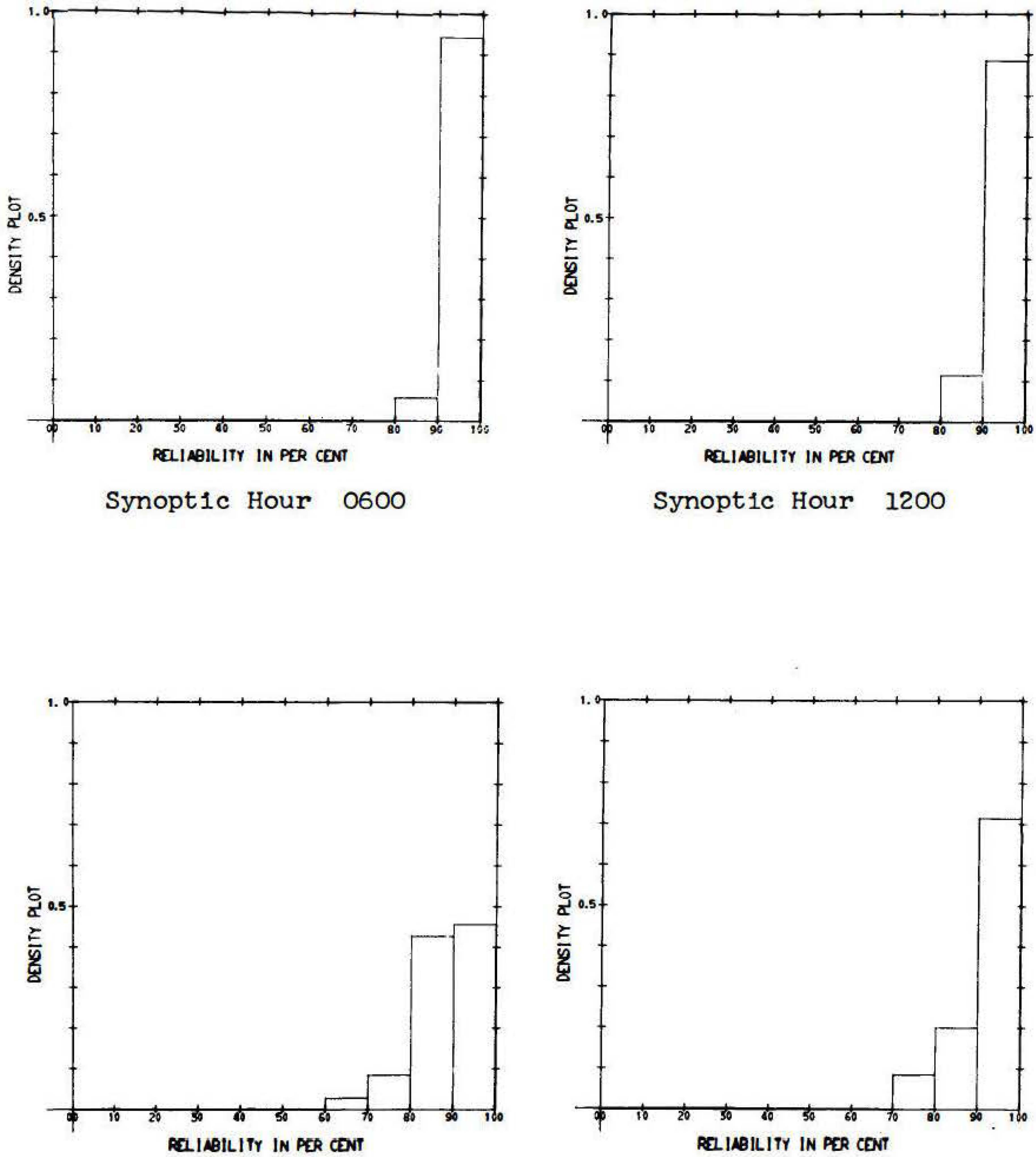

Figure 2. Histograms of reliability for a buoy transmitter power of 50 W in June 1971.

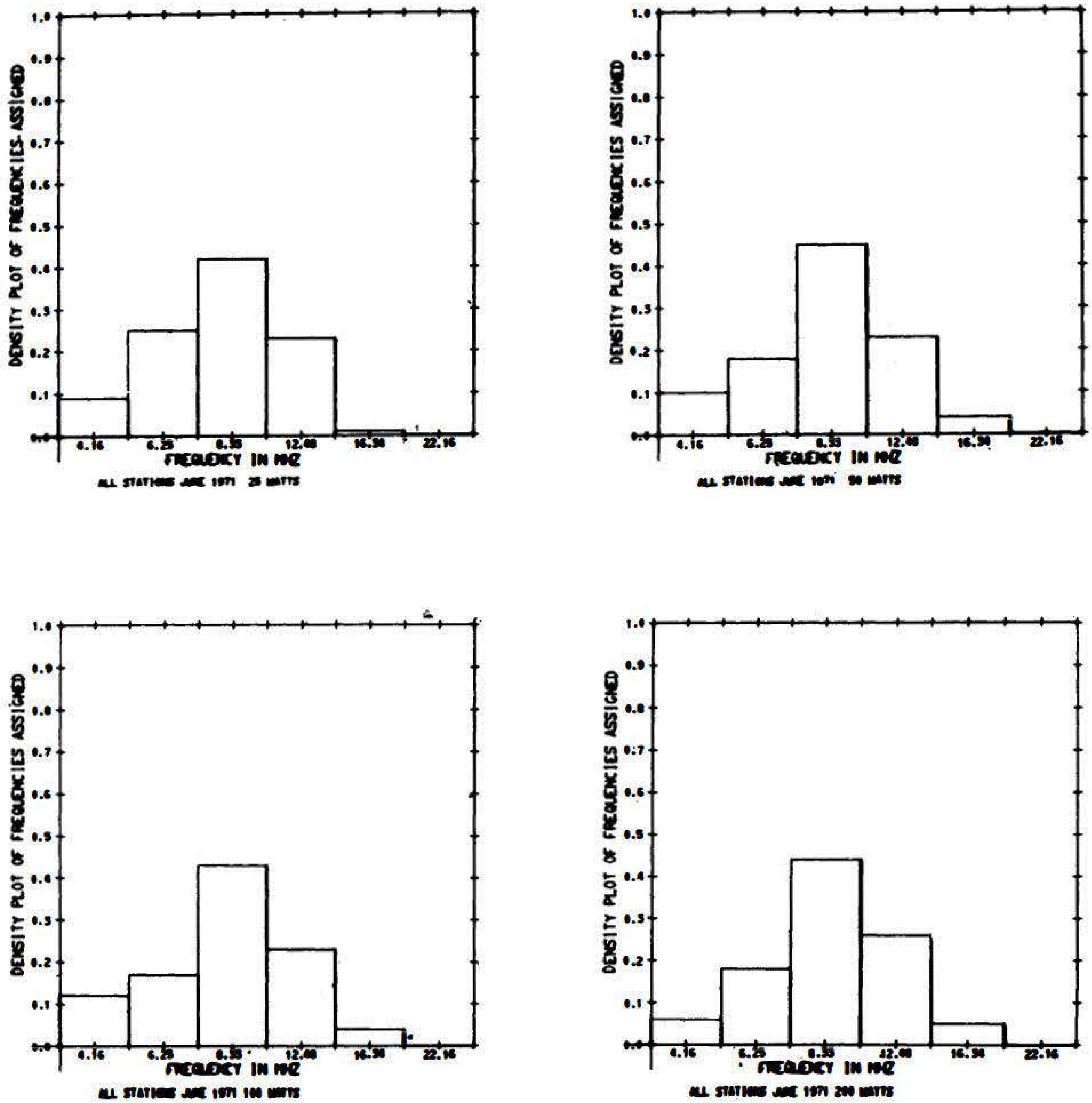

Figure 3. Histograms of frequency utilization for four transmitter power levels in June 1971.