MARINE WEATHER DISSEMINATION SYSTEMS STUDY v. 5.

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16. Abstract

Systems objectives for advanced alerting and dissemination systems for recreational boatmen are established. Parametric data are presented as a baseline for future initial design efforts on systems to disseminate weather and environmental information to marine users and to alert them to impending hazardous conditions. Areas are identified in which further data are required for systems analysis and design.

The work described was performed in the final phase of a study aimed at improving the dissemination of weather information to marine users and at establishing guidelines for future Coast Guard research and development efforts in this field.

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FOREWORD

This is the last of four interim reports to be prepared by Computer Sciences Corporation for the U.S. Coast Guard during the course of a Study of How Best to Utilize Coast Guard Communication Facilities for Weather Dissemination to Marine Users. The study was performed under Contract DOT-CG-00,579-A, which was awarded to CSC on August 31, 1970, and completed August 16, 1971.

The study is divided into four phases:

- Task 1 - Familiarization of the study team with existing marine weather dissemination systems, and the characterization of these systems in terms of their facilities, policies, and procedures.
- Task 2 - Measurement of effectiveness of existing and planned weather dissemination systems, following the development of standards and criteria against which to measure this effectiveness.
- Task 3 - Formulation of recommendations for changes in the facilities, policies, and procedures of the U.S. Coast Guard and other government and nongovernment agencies considered necessary to improve the dissemination of weather information to marine users.
- Task 4 - Generation of guidelines for future USCG research and development effort in the area of weather dissemination and alerting techniques in terms of operational constraints, performance requirements, and cost data

CSC wishes to acknowledge the assistance of CDR B. F. Hollingsworth, USCG, as Technical Representative to this study and also of LCDR E. Jones and CWO R. J. Williams in making data available for the study. CSC would also like to take this opportunity to thank Mr, Max Mull, Mr. William J. McKee, Jr., and

Mr. Warren Hight of the National Weather Service, NOAA, for their valuable assistance.

It should be noted that the conclusions presented in this report are solely those of CSC and do not necessarily reflect the views of the Coast Guard or the National Weather Service.

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SUMMARY

This report examines the system requirements and operational constraints of an advanced environmental information dissemination and alerting system to serve the recreational boatman. The format of the report is a baseline study document for possible future Coast Guard research and development in this field.

The first section of the report establishes a set of system objectives to guide any future initial design efforts. The objectives are developed through an in-depth examination of the operation of the system in its two basic modes - information dissemination and hazard alerting, and the discussion draws heavily on information gained during the initial phases of the study. The set of objectives is stated in Paragraph 1.5.

Section 2 addresses areas in which specific data are required to perform system parametric and trade-off analyses. Data is presented on the cost of user reception equipment, radio frequency availability, radio propagation phenomena, and potential audience size. Areas in which data is unavailable or in which further analysis is required are identified and possible techniques for satisfying the requirements are suggested.

The report concludes that much data is needed regarding the system user - the recreational boatman - before system design can proceed beyond the initial concept stage. Information needed includes:

- Location and distribution of boatmen during boating operations.
- Relationship between sea surface phenomena and their distribution, the size and type of vessel, and the resultant hazard.
- Expenditures which each type or class of boatman is prepared to make to obtain the service offered to him.

It is further concluded that to be effective the system must integrate the functions of information dissemination and alerting while permitting separate access to each function where required, and that the major system mode must use radio propagation techniques to fully satisfy the objectives established.

SECTION 1

SYSTEM OBJECTIVES

1.1 INTRODUCTION

Ideally, a weather information dissemination and alerting system to serve the recreational boatman should have the following characteristics:

a. The provision of up-to-date relevant weather and other pertinent environmental information to all boatmen as needed.

b. The ability to alert the boatman to imminent severe weather conditions or other potentially hazardous environmental phenomena in a timely manner.

c. High reliability of service coupled with a low probability of false alarm.

Although these characteristics describe an ideal system in a general manner, they are qualitative and must be specified to fully define the system objectives. Some characteristics may be satisfied in a number of ways, and a selection must be made among these alternatives before proceeding to a definition. Finally, it is unlikely that optimal service could be provided to every type of user by a single system; some degree of compromise will probably be necessary to optimize the service for the maximum number of users.

Recognizing these factors, the following paragraphs examine the operation of the system in its two basic modes - dissemination and alerting - in order to proceed logically to the establishment of a set of system objectives.

1.2 ENVIRONMENTAL INFORMATION DISSEMINATION

1.2.1 Information Content

The vast majority of recreational boatmen make excursions of relatively short duration, typically 2 to 6 hours. Consequently, their requirements are best served by frequently updated observations of prevailing conditions and short-term forecasts for their areas of operation. These requirements were stated explicitly by a large number of boatmen in surveys conducted or reviewed during Task 2 of this study.

1.2.2 Information Updating

The information which is disseminated should be current if it is to maintain credibility. Many boatmen criticize existing services because the information is frequently "out-of-date" or "old," and therefore leaves them unsure as to whether it accurately represents the current and immediate future conditions. The time of origination of each message should be included in the transcript and should be updated periodically, even though the message itself may not have changed.

The interval between updates must be tailored to the local weather characteristics, particularly to the weather development time. In areas where squalls are known to develop in 30 minutes, for example, messages must be updated at least every 15 minutes during periods of potential squall activity. During quiescent periods messages might be updated less frequently but should contain a paragraph stating that no storm activity is forecast during a specified period and should include the time at which the message will next be updated.

1.2.3 Message Repetition Rate

To maximize the availability of the service to the user, the information must be broadcast continuously or at frequent intervals. The activities of most recreational boatmen are such that the maintenance of a listening watch on a weather information channel would interfere with normal recreational pursuits; consequently, the average user may attempt to access the system irregularly at any time during his boating activity. To be of maximum benefit, the system must be available immediately or within a very short time of attempted access by the boatman. The value of this type of service has been clearly indicated by the response to the National Weather Service's continuous VHF broadcasts and to Coast Guard trial broadcasts at 1 and 2 hour intervals.

1.2.4 Transmission Range

A conflict exists between utility and cost in the determination of message transmission range. A system which maximizes range in order to minimize the number of transmitting sites required (and thus reduce costs) may provide coverage over an area within which significantly variant weather conditions pertain. On the other hand, if each transmitting site covers only that area throughout which uniform conditions exist, an unacceptably large number of such sites may be required.

In practice the selection cannot be made solely on the basis of system requirements, but will be heavily constrained by the physical phenomena associated with the transmission mode. Visual and audio propagation techniques, for example, are strictly limited in range. The range achievable by radio transmission techniques, on the other hand, is primarily dependent upon the broadcast frequency, and this in turn is constrained by frequency allocation restrictions.

Achievable transmission ranges by various means of propagation are known or are amenable to computation. However, the requirements of the user in terms of the permissible variability in weather phenomena throughout the area covered by a single message or message segment are not well defined. <u>This information must be made available to properly optimize a weather dissemination system</u>.

A compromise solution is possible in which a single transmitting site broadcasts a sequence of message segments, each pertaining to a section of the total service area. In this manner, each segment may be tailored to cover an area throughout which the conditions or weather phenomena may be considered uniform from the user's point of view. The number of segments which may be contained in a single message is limited by the minimum segment duration necessary to contain the required information and the maximum message duration permissible to maintain the desired repetition rate. Consideration must also be given to the attention-span of the user.

1.3 HAZARD ALERTING

1.3.1 The Need for an Alerting System

Because the system is to serve the recreational boatman, the audience may be classified as "inattentive;" a user occupied in recreational pursuits is unlikely to monitor the information source continuously (see Paragraph 1.2.3) and will probably attempt access in a fairly irregular manner. It is clearly desirable, therefore, to provide some means of alerting the user to potentially hazardous conditions. A system which simply makes available information concerning the hazard cannot, with confidence, be relied upon to reach the user in a timely manner. To ensure the receipt of urgent information, the system must be capable of attracting the user's attention so that he may initiate self-protective procedures and/or seek further information concerning the hazard.

1.3.2 The Meaning of the Alert

Alerting the user to a potential hazard is of limited value unless some information concerning the nature of the alert is available. Such information may be inherent in the alert itself or may be available from a complementary information source within the system. Alternatively, the user may obtain supplementary information from a source not directly associated with the alerting system.

The normal human reaction to a warning, such as a siren or a flashing beacon, is a series of questions:

1. What is the nature of the phenomenon about which I am being warned?
2. Does the phenomenon pose a potential threat to me?
3. What is the severity of the hazard?
4. Where will the hazard manifest itself?
5. How long before the hazard manifests itself?
6. What is the probability that the hazard will, in fact, manifest itself at the postulated level of severity?
7. What action should I take to minimize the hazard?

If the user is unable to answer questions 1 and 2 from information contained in the alert or from supplementary sources, he will probably take no action. Failure to answer any or all the other questions may result in inappropriate action, which might be ineffective or might even increase the hazard which the user seeks to avoid.

It is important, therefore, that careful consideration be given to the informational aspects of any alerting system. This is particularly true in the case of a system designed to serve the recreational boatman, since the level of hazard posed by a particular phenomenon will vary from user to user as well as in time and space. The following paragraphs consider some of the ways in which the necessary information may be made available to the user.

1.3.3 Coded Alerts

It is feasible to arrange for an alert to contain inherent information about the nature and/or severity of the hazard by a system of coding. Essentially, a number of alert signals are available, each signifying different conditions to the user.

In the case of visual signals the coding may take the form of different colors or arrangements of lights, or may be achieved by the frequency or sequence in which one or more lights flash. Visual signals may be more sophisticated than this, of course, by combining shapes and colors (as in flags or pennants) or ultimately written signs.

At some point the display ceases to be a signal and actually becomes a message. There is no clear boundary between the two; a sequence of flashes may be used to transmit intelligence (Morse code). For the purposes of this discussion it is convenient to restrict coded signals to those which do not use the common visual communications medium, the written word. Thus any symbol or combination of symbols may validly be considered as an alerting signal.

However, as the complexity of the signal increases, restrictions are imposed upon its utility. These restrictions are usually manifested as reductions in range of visibility and attention-getting capability and as an increase in the user skills necessary to interpret the signal. In practice the number of signals is limited by the degree of training and dedication of the observer or by the degree of exposure or experience of the user. Thus it is possible to use a relatively large number of traffic signs because they are frequently observed and their meaning learned and remembered. Where exposure, training, and dedication are low, the number of signals must be reduced. The Coastal Warning Display System uses only four symbols, for example.

Audio signals are even more limited due to the lack of a perception corresponding to "shape." Moreover, the audio models which the human brain is capable of storing are less detailed than its visual models. There is a corresponding progression from symbol to message as with visual signals; however, utility limits alert signals to tones, sequences of tones or combinations of tones (chords).

In practice the number of signals or symbols which may be used by an untrained inexperienced observer is limited to less than six visual and two or three audio variants. In general, where a more refined structure is required it is necessary to transfer to the informational mode using the spoken or written word.

Although this discussion has been limited to audio or visual signals, the arguments generally hold true for signals propagated by electromagnetic means since the final translation is invariably into one of these types (viz. radio or television). However, the reception of signals by radio (Figure 1-1a) may extend the range of possibilities somewhat by relegating the role of translator to the receiving device. In this manner a complex signal may be used to initiate a simple alert message (such as the single word "storm") to indicate different types or levels of hazard (Figure 1-1b). Alternatively, the receiving device may be used to address the warning to a subset of the total user set or audience (Figure 1-1c). Combining the functions of b and c in Figure 1-1d permits the system to tailor the alert to the appropriate user and to provide him with some information as to its nature. The degree of selectivity attainable in this manner, however, is subject to limitations of prediction confidence and equipment cost.

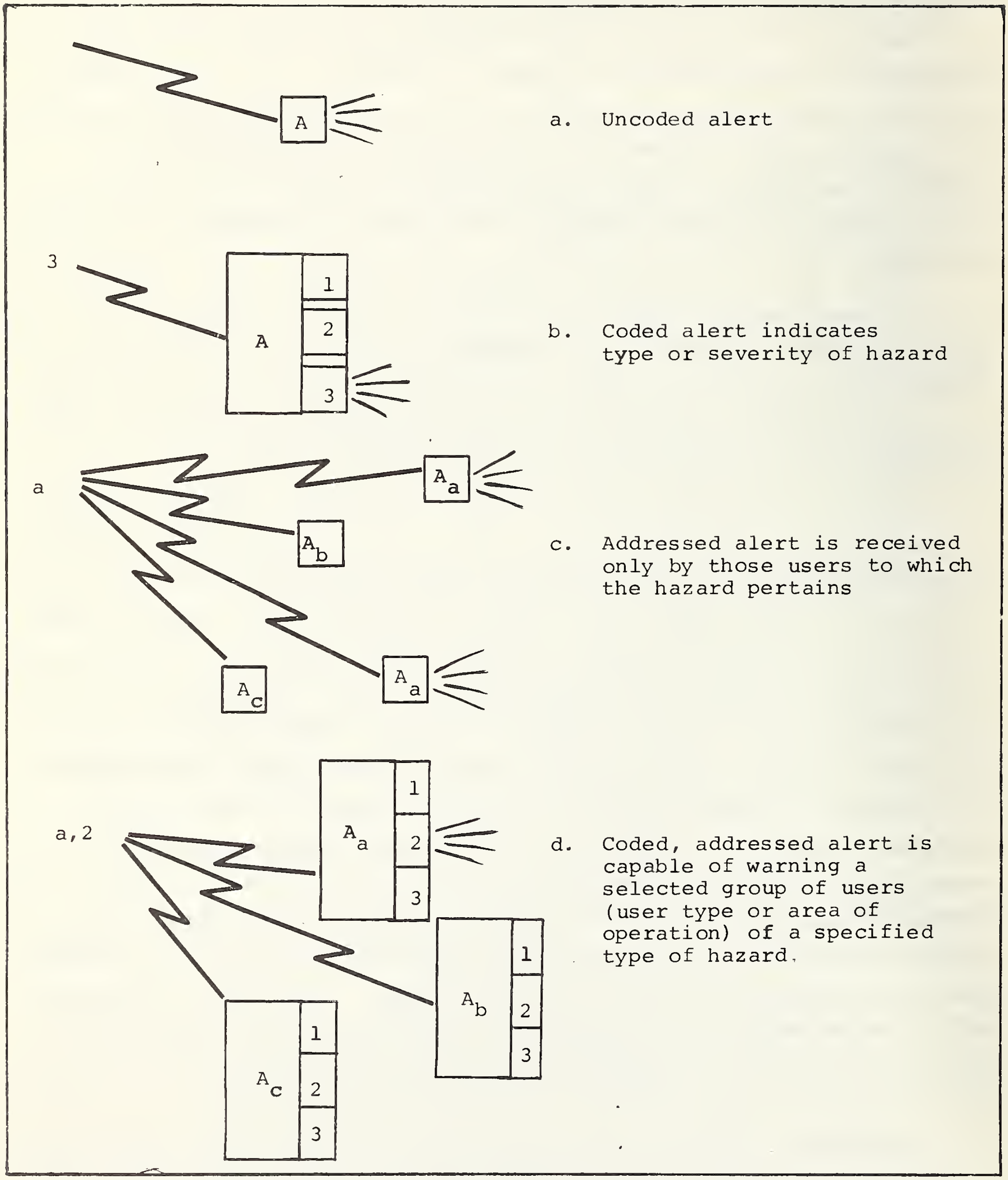

Figure 1-1. Alert-Coding Schemes

1.3.4 Alert/Information Schemes

To overcome the difficulties and limitations associated with coded alerts, many alerting systems operate on the principal of "gating" or unlocking an information source. The alerted user is exposed to this source and is given the required information concerning the alert. A simplified verison of this scheme simply alerts the user to the possibility of a hazard, and the user then seeks further information from an independent source.

These configurations are represented schematically in Figure 1-2 as they might be applied to a recreational boating weather information/alerting system. In Figure 1-2a the alert is received in the absence of any information, the alert-only mode. The user in Figure 1-2b seeks information from an independent device upon receiving the alert. In Figure 1-2c the alert device activates a receiver to which it has been connected; in Figure 1-2d the alert device performs the same function but is an integral part of the information-receiving device.

Configuration d corresponds to the commercially available alert-monitor type receiver. The advantage of configuration c lies in the potential saving in user cost by modifying a suitable, existing receiver and purchasing only the alert device. The potential advantage of configuration b is more significant; it permits the listener to use a lower stability (and lower cost) receiver than that necessary for configurations c and d, since he can perform a simple manual tuning action upon receiving the alert. In configurations c and d the device must be of high stability so that it is tuned into the information dissemination source upon activation. Configuration b also permits the user to access one or more of a number of information sources which might be available.

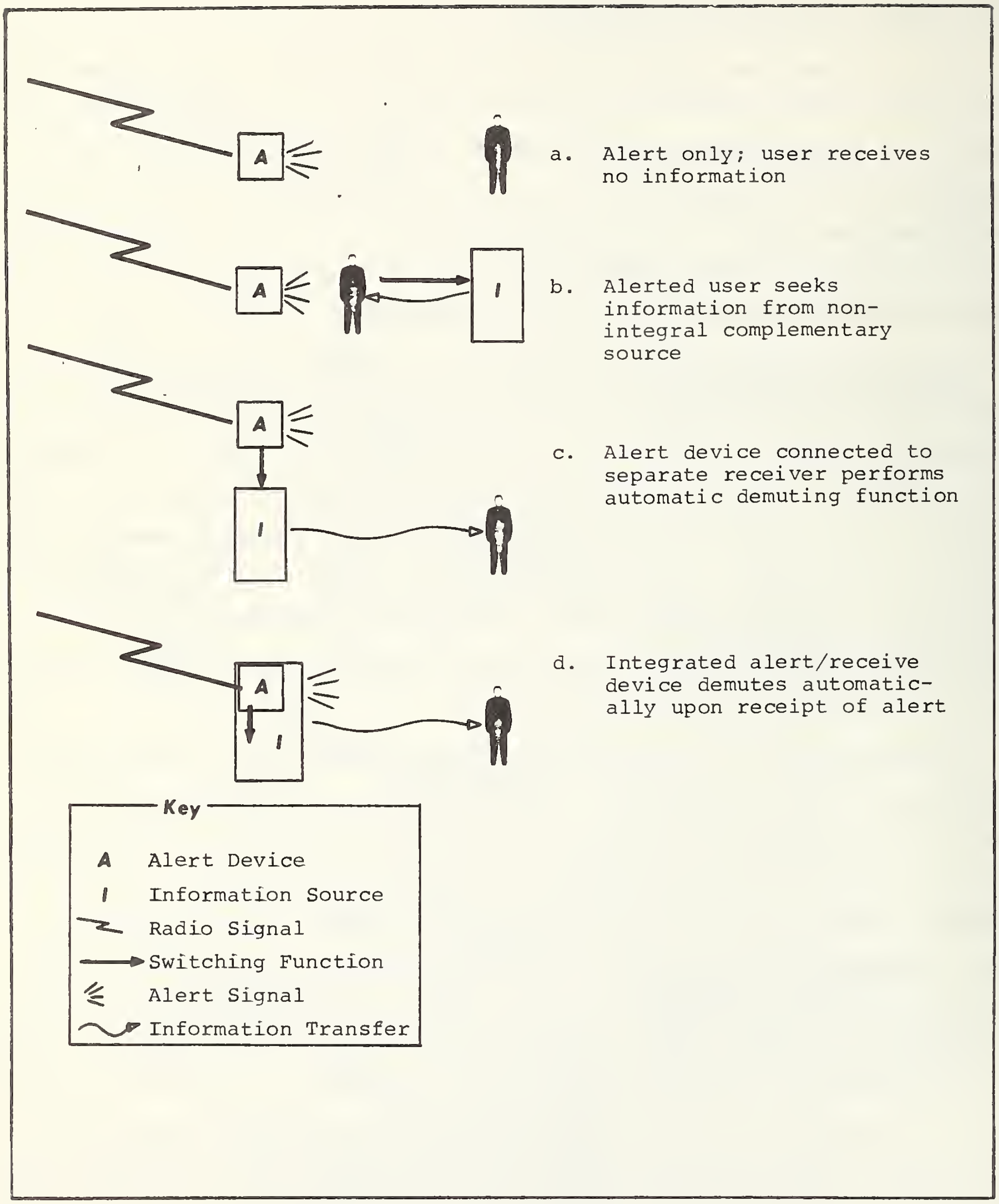

Figure 1-2. Alert/Information Schemes

1.3.5 National Alert System Studies

The philosophies of alert management and the techniques for disseminating alerts and emergency information have been under study for some years by Federal interagency groups.

During World War II, radio alerting was associated with national emergency activation as CONALRAD. The CONALRAD system, however, was an alerting signal among broadcasters, and was not designed for individual reaction. Warning of a national emergency continues as a civil defense mission of the Office of Civil Defense, under the Department of the Army. In recent years there has been increasing recognition of the need for public alerting as related to natural disasters and area jeopardy. About 6 years ago, national level studies of warning techniques were initiated to examine technical systems for alerting and warning including direct reception by the public. Several approaches were examined including two-tone reed relays, holding and signal tones, and a digital selective approach which provided an address capability.

However, the policy implications and operational questions in implementing a national system were not adequately addressed by these earlier studies. In 1971, additional examination of home warning and individual alerting was undertaken by government representatives with FCC liaison. Policy guidance is expected from the Office of Telecommunications Policy when the results of these studies are available. In addition to policy and system concept studies, technical examination of a possible solid state approach is being conducted with contractual assistance.

A brief summary of some of the studies undertaken during the last 10 years is given in Appendix A. Criteria for issuance of an alert by the National Weather Service are described in OML-71-8, included as Appendix B.

Day-to-Day Emergency Operation

§ 73.971 Day-to-day emergencies posing a threat to the safety of life and property; use of Attention Signal.

(a) The Emergency Action Notification Attention Signal may be transmitted for the following purposes by all standard, FM and television broadcast stations, at their discretion, in connection with day-to-day emergency situations posing a threat to the safety of life and property:

(1) Activation of State program distribution interconnecting systems and facilities for the origination of emergency cueing announcements and broadcasts by the management of the State Network Primary Control Station in accordance with previous arrangements and agreement of the State Industry Advisory Committee in day-to-day emergency situations in the public interest. These include both situations where the time element is short, and those which develop slowly. (For example: Tornado warnings or tornado sightings; toxic gases threatening a community; flash floods; widespread fires threatening populated areas; tidal waves; earthquakes; widespread commercial electric power failures; large scale industrial explosions and fires; tornado watches, hurricane watches, and hurricane warnings; civil disorders; heavy rains—developing dangerous flood conditions; icing conditions—developing dangerous road hazards; heavy snows—developing blizzard conditions; appeals for medical assistance and facilities; appeals for emergency food and housing; call-back of off-duty police personnel; call-back of off-duty fire personnel; call-back of off-duty military personnel.)

(2) Activation of Operational Area interconnecting systems and facilities for the origination of emergency cueing announcements and broadcasts by the management of the Primary Broadcast Stations for the Operational Area in accordance with previous arrangements and agreement of the Operational Area Industry Advisory Committee and the State Industry Advisory Committee in day-to-day emergency situations in the public interest. (Examples set forth in subparagraph (1) of this paragraph.)

(b) Stations originating emergency communications under this section shall be deemed to have conferred rebroadcast authority, as required by section 325(a) of the Communications Act, on other participating stations. Neither the notice and certification of consent called for by §§ 73.121(b), 73.291(b), 73.591(b), and 73.655(b), nor prior Commission approval as otherwise required by §§ 73.121(d), 73.291(d), 73.591(c), and 73.655(c) in the case of aural-TV cross-service rebroadcasting, is necessary under these circumstances.

Figure 1-3. F C C Regulations Covering Day-To-Day Alerts

1.4.2 Visual Transmissions

Transmission of weather information over significant distances by visual means is not considered practical. However, the issuance of alerts and simple alert codes by visual means is feasible and is, in fact, currently in use (Coastal Warning Display System).

Though the coding capability of visual signals is high when compared to audio signals, the distances over which they can successfully be transmitted is severely limited. It is estimated that the pennants of the Coastal Warning Display System can be seen reliably at distances no greater than one mile, and then only under optimal conditions. The night display signals (red and white lights) can be seen at greater distances at night under ideal conditions (estimated at 2-2½ miles) but would lack visibility during the day.

Specially designed range-lights used for navigation at approaches can be seen at about 2 miles during daylight. The cost of these units is greater than $2,000. Ultimately, ranges of up to 20 miles are attainable by specially designed lights such as lighthouses and off-shore light structures. The cost of these devices is extremely high, however. Lighthouses built in the early 1800's cost between $15,000 and $20,000, and the cost of modern structures runs into millions of dollars.

The limited information capability and high cost of this mode of transmission precludes its use in an extended range situation. It is recommended that consideration of visual alert transmission be limited to short-range applications in a supplementary role, either as land-based or buoy-mounted installations, in areas of high boating activity.

1.4.3 Audio Transmissions

Effective transmissions of both alerts and environmental information are feasible by audio means, although this mode is also limited in range capability. Alerts in the form of sound signals (such as sirens, fog-horns, etc.) have traditionally played an important role in the protection of life at sea and could conceivably continue to do so at distances of up to one or two miles.

Voice information can be transmitted by sound wave propagation over considerable distances under carefully controlled conditions. In an experiment conducted for the U.S. Army in 1950, a 1-kW amplifier was used to drive a specially designed horn to achieve highly intelligible voice transmissions over a distance of a mile. A major limitation to the system was that it generated pressures which exceed the threshold of pain at distances as great as 1/4 mile. This phenomenon precludes the use of such a technique at sea level, which otherwise might provide the required coverage in highly populated areas by mounting the transmitter on buoys.

1.4.4 Aerial Applications

Some of the problems attendant to the use of audio and visual signalling may be alleviated by elevating the propagation source. For example, flying short weather information messages as trailing banners behind light aircraft or using high-intensity voice transmission units on board helicopters have been suggested as possible means for alerting boatmen not equipped to receive radio transmissions.

These procedures undoubtedly have merit as emergency measures in areas of high boating activity. However, the costs involved in their implementation and the logistics of providing coverage over the required areas must be carefully examined to determine their relative merit. It is recommended that such measures be considered tactical and not strategic, and that they not be considered as the predominant means of transmission for a recreational boating alert and dissemination system.

1.4.5 Radio Transmissions

In contrast to the preceding transmission modes examined, radio propagation techniques are generally troubled by too great a range for this application rather than too short, and by the requirement for some form of transducer to intercept the radio signal and convert it into a sensible form.

Nevertheless, this is the mode which appears to be most applicable to the system under study, and is the one which is the preferred mode for broadcasts and communications in this field. The relevant parametric and phenomenological data pertaining to this technique are discussed in detail in Section 2.

1.5 SYSTEM OBJECTIVES

The requirements and constraints outlined in the preceding paragraphs may be reflected in the following set of postulated system objectives:

- The system shall make available to the maximum practicable number of recreational boatmen, weather and other environmental information relevant to their immediate area of operation, vessel size, and sailing habits.
- The information shall take the form of current observations of local conditions and short term (2 to 8 hours) forecasts in parameters of greatest interest and in terminology readily understood by the average boatman with no meteorological knowledge.
- The information shall be broadcast continuously (consecutive repetition of short messages) or at frequent regular intervals no greater than 15 to 20 minutes.

- The information shall be updated frequently in relation to prevailing local dynamic weather characteristics; the time at which the most recent update was made shall be included in the transcript, this item to be changed at the update interval even though the message content may not have been altered.
- The system shall be capable of alerting all recreational boatmen subject to a postulated hazard from weather or other environmental phenomena, addressing the alert, as feasible, only to those areas and/or those boatmen affected by the postulated hazard.
- The system shall be capable of recognizing and assessing a potential hazard and broadcasting an alert as rapidly as possible, but in any event in no longer period than 5 minutes.
- The alert subsystem shall be integral with an information source to enable the alerted boatman to assess the nature and severity of the postulated hazard; it shall also be compatible with nonintegral reception equipment permitting the user to interrogate a complementary information source where necessary or desirable.
- The system shall use equipment and transmission techniques which ensure the utmost reliability of operation; the system shall be designed to minimize the probability of false alarm, due either to equipment malfunctions or information error.
- The system shall be designed to minimize user cost, compatible with meeting the system requirements; the use of systems which do not require reception equipment, however, (audio, visual, etc.) shall be limited to short range supporting roles in areas of high boating activity.

SECTION 2

SYSTEM PARAMETRIC AND TRADEOFF DATA

2.1 USER COSTS

2.1.1 General

The potential user cost in participating in a weather information/alerting system is limited to the cost of suitable reception equipment, since all other costs of such a public service system are likely to be borne by the organization(s) providing the service.

Even with this limitation, however, the potential cost to the user varies over a wide range. If it were feasible to implement a system using only audio or visual transmission techniques, the cost to the user would be zero, since no equipment would be required.

Although supplementary service in one or both of these modes may be attractive, it is improbable that the total system requirements could be satisfied by these means. At least a portion, and probably the greater portion, of the system will utilize radio propagation techniques requiring the use of radio receiver equipment of some kind. Even then, the cost will be zero to users already owning compatible equipment. However, for the majority of users, equipment cost will be of primary concern and will largely dictate the size of the audience using the system.

2.1.2 Receiver Costs

Although the desirable technical receiver characteristics contribute to an efficient overall system, the receiver is purchased by the user only as a means of access. The user often views its purchase cost only in terms of initial expenditure, and in the absence of national receiver minimum performance standards, may not associate cost-effectiveness in terms of performance. A public service system such as a weather dissemination/alerting system accordingly is obligated to consider receiver characteristics of all users, and thereby tends to be limited by receivers having less than optimum characteristics.

Figure 2-1 shows representative cost ranges of receivers and transceivers by general operational categories. Although a relationship between cost and some performance parameter (such as sensitivity or selected figure of merit) might be considered more useful than the presentation in Figure 2-1, such an approach was rejected for a number of reasons. Performance specifications for the lower-cost receivers in the public broadcast band are not generally available and do not appear to be related in a significant manner to the cost of the device. The multiplicity of relevant parameters and the variance between those for receivers operating in different modes (e.g., amplitude vs. frequency modulation) make the selection of a significant parameter, or of a figure of merit dependent on all parameters, difficult. Finally, the value of special features such as alert-devices and frequency synthesizers is impossible to present parametrically. It is felt that grouping the receivers according to function and special features provides the most meaningful basis against which to consider cost.

The cost data in Figure 2-1 was gathered from retail catalogs, manufacturer's brochures, and from a compilation made by the National Weather Service. The prices shown are all subject to change (usually upward) and it is recognized that the list from which they were gathered is not exhaustive, but the ranges indicated for each group of devices is representative of the price range of that group. A compilation of the devices with manufacturer, type number or name, price and (in some cases) salient characteristics, is given in Appendix C.

The price of portable AM broadcast band receivers was found to lie in the range \$5 to \$17. Although a number of receivers with AM-band only capability cost more than this, the extra cost is

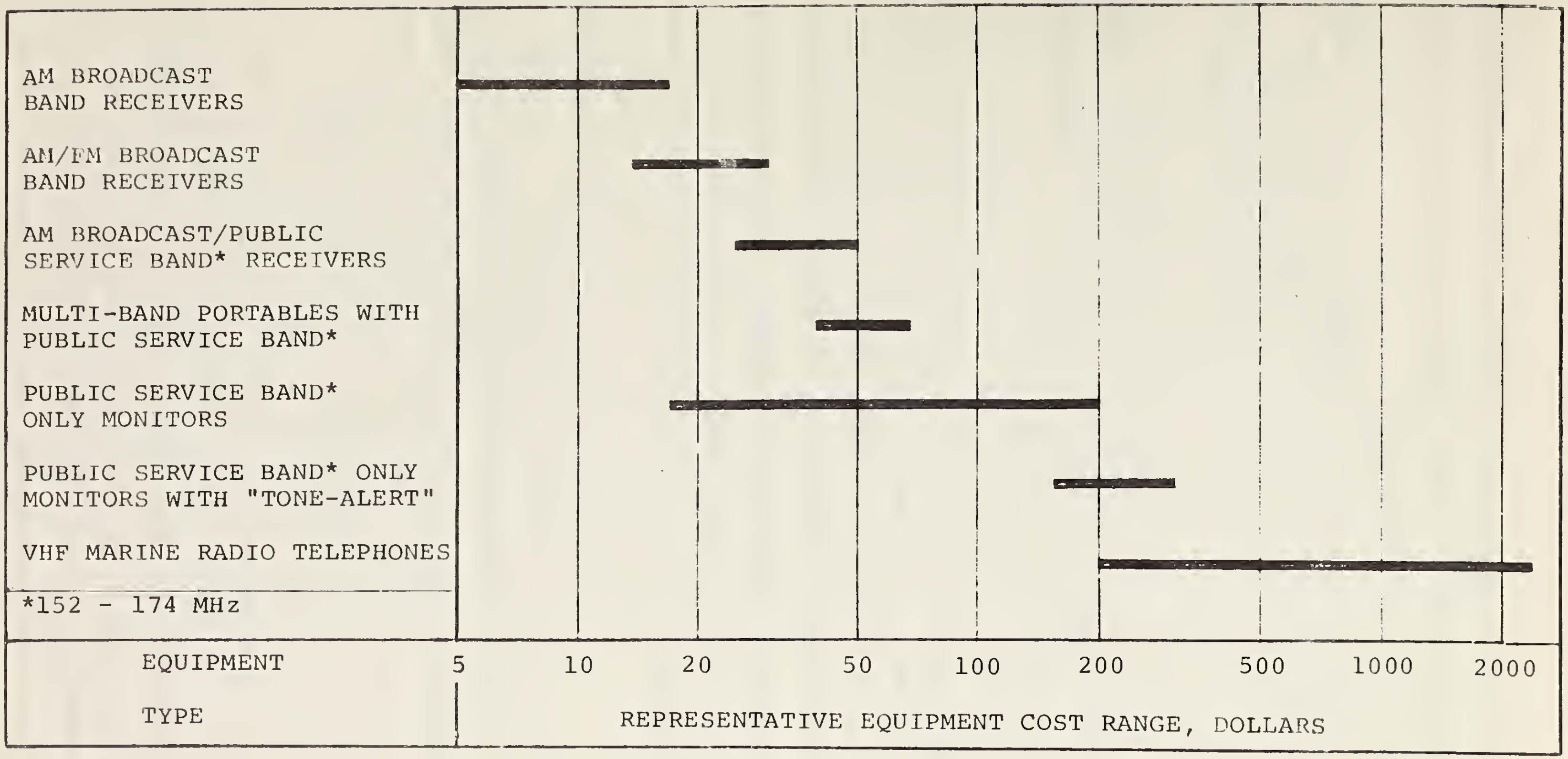

Figure 2-1. Receiver Cost Data

usually associated with higher quality audio reproduction and the devices are somewhat larger than normal "portables" often including the provision for 117V operation.

Portable receivers designed to operate in the FM and AM broadcast bands generally fall in the $13 to $30 price range. Only a small number of receivers is designed for FM reception only, and in any case these types fall into the same price range.

Lying in the $25 to $50 range are devices capable of receiving in the AM broadcast band and in the 152-174 MHz public service band. In some of these the AM circuitry is used as an intermediate frequency stage during FM conversion.

Portable receivers designed to operate in three or more bands are popular. A number of these include the 152-174 MHz band and are designated as Multi-Band Portables with public service band on Figure 2-1. Their costs lie in the range of $35 to $60.

Devices which are designed to receive only in a special-purpose band are often classed as "monitors" to distinguish them from transceivers capable of two-way communication in the same band. The price range for this type of device is much larger, extending from $17 to $200. The $17 device represents a tunable receiver of high sensitivity but only moderate selectivity. At the other end of the scale is a relatively high quality receiver which can be tuned across the band and also offers six switchable crystal-tuned channels. In between are fixed crystal-tuned receivers and tunable receivers of high stability. The wide range of devices available in this category attests to its popularity.

In contrast, public service band monitors equipped with tone-operated alert switches lie in a fairly constrained price range of $150 to $300. The relatively small sales volume of this type of device undoubtedly accounts in part for the higher price range, but the requirement for high frequency stability is a major factor.

Since the receiver is tuned to a station and then left on stand-by until demuted by an alert signal, it is imperative that the frequency drift of the device be small. This dictates the use of fixed crystal-tuned circuits or exceptionally high quality tunable devices, both of which are more costly than circuits of manually-tuned receivers. Additional cost is incurred due to the incorporation of the alert sensor and switch.

The last category presented in Figure 2-1 is that of VHF marine radiotelephone equipment. These transceivers may be used in a receive only mode to intercept any transmission in the maritime mobile band at 156.25 to 157.45 MHz and 161.775 to 162.012 MHz. Many are also amenable to channelization or tuning at 162.55 MHz to intercept the National Weather Service transmissions on this and adjacent frequencies. This type of device currently costs from \$200 to \$2400. Improvements in selectivity and channel capacity account for the increases to approximately \$600. The further increase to \$2400 results primarily from the inclusion of a frequency synthesizer which provides reception capability for all marine frequency channels, both United States and foreign.

2.1.3 Potential Reductions in Cost

Regulatory changes presently taking effect will be responsible for a dramatic increase in the number of VHF marine radiotelephones manufactured during the next five years (see paragraph 2.5).

The increase in production has already resulted in significant reductions in the price of this equipment, and with continued growth it is expected that the lower end of the price range may fall to \$100 to \$150. At the other end of the scale, although the \$2500 class provides optimum features for both the user and overall systems effectiveness, few operators may consider expending this amount for recreational boating. Through education and appreciation of communication values on the other hand, the aircraft operator pays from about \$695 to \$3936 for his communications transceiver.

The $3,936 category includes all channels, and has been estimated by one manufacturer as being amenable to fabrication for about $1,200 if coupled with a large scale (100,000 units) market. If the same principles of cost reduction by quantity production of a standardized model for marine application is assumed, the current $2,500 VHF all-channel transceiver could be available at a price of $800 (68 percent reduction). It should be noted, however, that production engineering may require two to three years to achieve this cost target.

The cost of "tone-alert" monitors is also believed to be susceptible to reduction. The essential requirement for this type of device is a stable receiver section. A popular crystal-tuned receiver (without the alerting feature) costs about $50. Manufacturers of alert-type receivers, when questioned, were unable (or unwilling) to isolate the cost of the alert device. However, CSC circuit design specialists estimate that such a feature could be incorporated for $5 to $10 depending upon the reliability and sophistication of the circuitry used. A reduction in the price of the receiver itself to $35 or $40 would mean that an integrated alert/receive device might feasibly be produced in the $40 to $50 range.

A reduction in price of VHF monitors may be possible due to greatly increased production, but is not likely to be significant. The distributor of the $17 tunable receiver claimed that the price of this device represents "minimum markup" on a unit which is already purchased in "considerable quantities." He conceded that some reduction in the selling price might result from a significant increase in sales volume, but indicated that such a reduction would be small, "perhaps one or two dollars." It seems unlikely, therefore that the cost of this type of receiver could be brought much below $15.

The manufacturer of a crystal-tuned VHF receiver at about $50 claimed that the portion of his product sold with 162.55 MHz crystals (NWS VHF Weather Radio frequency) represented only a small portion of the overall market for this device. The majority of the receivers, he said, were channelized for police, fire and civil defense frequencies, so that even a large increase in the number sold for weather reception would have little impact on the total sales volume. He declined to give actual figures for sales, total or marine. Despite this, electronic equipment sales data indicate that under severe competition, formerly "safe" items are often cut 20% to 25% in price. This seems to be as large a decrease as could reasonably be expected in current prices, and would set the lower limit for this type of stable, VHF monitor at $35 to $40.

Little reduction is to be expected in the price of broadcast band receivers, as this is a maximum volume, highly competitive market. A large variety of such devices is already available, however, in the quite moderate range of $5 to $20.

2.2 FREQUENCY CONSIDERATIONS

2.2.1 General

In selecting a frequency for marine weather dissemination, the following factors should be considered as desirable objectives:

a. The frequency selected should be one which could be subject to standardization for marine weather alerting and/or dissemination.

b. The frequency should be assignable on an exclusive use basis for marine information or marine broadcast purposes.

c. The frequency should be within the tuning ranges of common equipments available to marine users, and preferably within, or immediately adjacent to, internationally allocated frequency bands for maritime services.

d. If the frequency for an alerting system is different from that used for dissemination, the alerting frequency may share on a secondary basis because of its short duration and intermittent nature. Further, it may differ among geographical areas provided it is operator selectable; however, all alerting frequencies should fall within a similar electrical tuning range.

e. The frequency selected for dissemination should permit voice emission and tone signalling.

f. The selected frequency should have propagation characteristics compatible with the system coverage and range objectives.

Although the last of these, the propagation characteristic, is clearly the predominant technical system design parameter, consideration must also be given to the political aspect of frequency availability. In the following paragraphs the frequency spectrum in the range of interest is examined in the light of the above criteria. For convenience, the discussion gives separate consideration to the public broadcast bands and to those frequencies currently designated for marine, weather, and public safety services.

2.2.2 Public Broadcast Frequencies

Radio frequencies in the standard broadcast band (535 to 1605 kHz) meet some of the technical objectives. However, telecommunications policy limits this band to commercial broadcasting stations as licensed by the FCC. Weather broadcasting by a government broadcast station would neither be in consonance with national telecommunications policy nor the Communications Act of 1934 as amended. Mutual arrangements by which existing broadcasters provide dissemination service are feasible. This topic was discussed in detail in the report on Task 3 of this study. The possibility of using existing broadcast stations to transmit alerting tones is provided for by FCC. Rules and Regulations 73.971, and could be arranged by coordination steps through the FCC. It is noted that emergency alert planning has designated a two-tone national concept using 853 and 960 Hertz. Broadcast stations serving coastal or boating areas could provide alerting signals of short duration superimposed on existing broadcasts.

The frequency band utilized for FM entertainment broadcasting meets some requirements, but as in the case of the AM broadcast band, utilization by government stations involves major policy obstacles. The wide availability of FM receivers merits consideration of participating programs with commercial licensees, however. The possibility of using educational FM frequencies (88 to 92 MHz) involves policy implications that would require mutual agreement with educational groups, but might be feasible in view of the non-entertainment nature of a weather/alerting service. Again, the wide availability and considerable ownership of FM receivers makes the consideration of such an operation very attractive.

Even if the political obstacles to implementing a system in this band could be overcome, there would remain the question of frequency availability. It might be possible to allocate specific, unused frequencies in certain regions, but it is improbable that the same frequency could be made available in all areas.

Where no frequency is available, two possible solutions might be found in "piggy-back" operations. The first of these is the use of a Subsidiary Communications Authorization (SCA). Commonly used to broadcast commercial-free "elevator music," the SCA program frequency modulates a 67-kHz carrier which in turn modulates the broadcasting station's main carrier (Figure 2-2). Use of a specially designed detector permits isolation of the SCA program content. Use of an SCA-carried weather system would pose both political and commercial problems. In addition, the low modulation level of the SCA signal (about 15%) and the required adapter circuitry would necessitate the use of sensitive, specially designed reception equipment with attendant high costs.

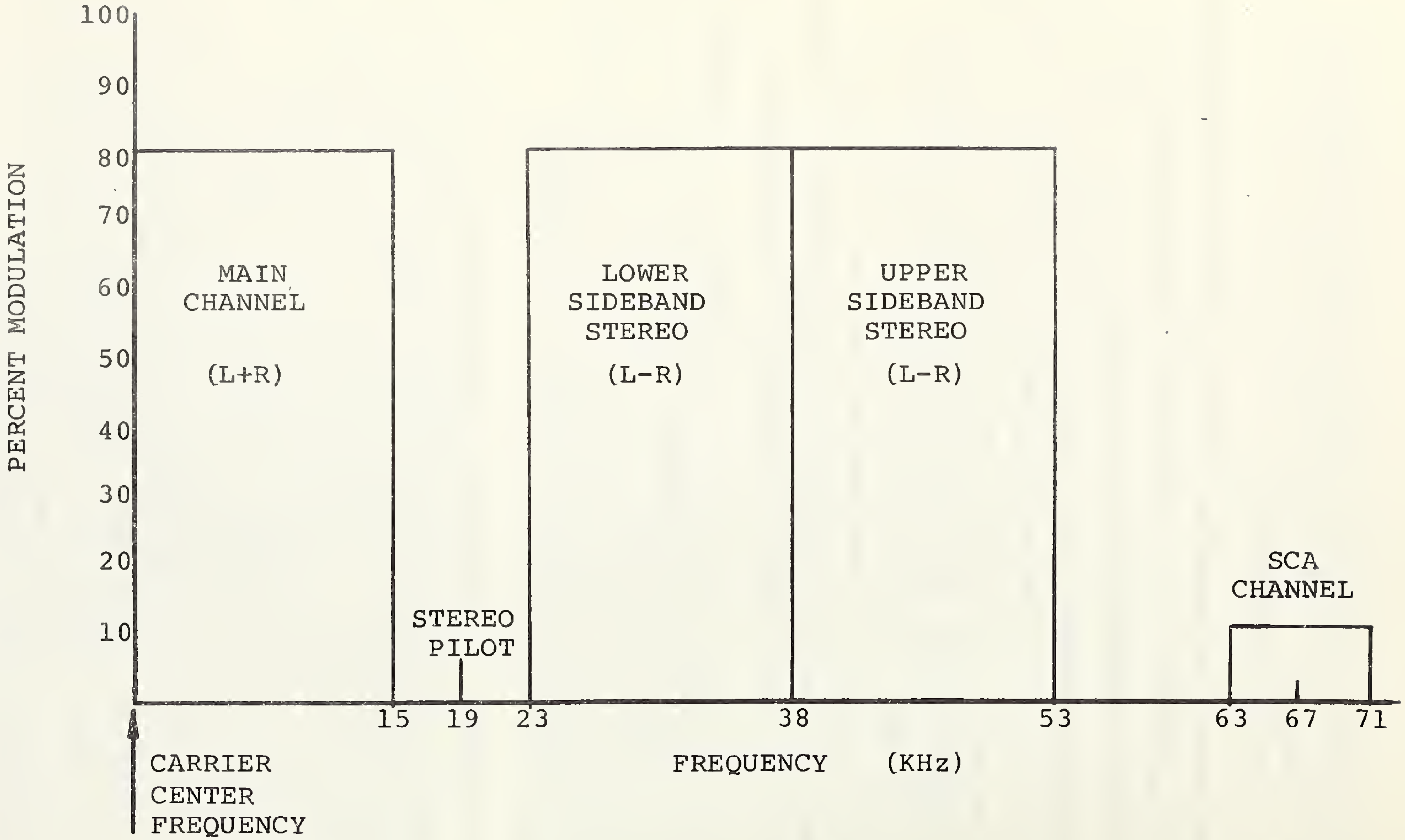

Figure 2-2. FM Stereo Broadcast Channel Spectrum with SCA Modulation

The second possibility is that of sharing a "stereo" channel with a monaural FM broadcaster, one channel being the regular entertainment program and the other carrying weather and environmental information. The reception of either channel would not require a stereo receiver, since only one channel would be monitored instantaneously; however, a special device would be necessary to separate the two channels, precluding the reception of the entertainment channel by regular FM equipment, a serious drawback.

Although the "½-stereo" concept was conceived as a means of riding piggy-back on an existing channel where alternate frequencies are not available, it may have application in a system using dedicated FM frequencies. The stereo concept could be used to provide environmental information on one channel and entertainment or other nonessential material on the other, to make the service attractive to the user and to encourage participation. The reception device would be monaural but would have to be capable of separating A+B and A-B channels, a switch function selecting one or the other. Thus the user might elect to use the entertainment channel generally with the option of switching to the continuous weather channel as required. The system could be arranged to override the entertainment channel in the event of an alert, interrupting the program with a warning and then carrying environmental information on both channels for the duration of the alert. The cost of the reception device and the added expense of the stereo transmission equipment would, of course, be predominant considerations in the implementation of such a system.

2.2.3 Marine and Government Frequencies

Frequencies in the spectrum vicinity of the existing 2 MHz maritime band utilized for amplitude modulated voice communications are not considered suitable for expanded weather broadcasting services. The present congestion on these frequencies requires removal of all possible localized operations, and national implementation of this policy is in progress. Further, the propagational characteristics make localized services questionable, particularly at night.

Frequencies in the high frequency spectrum are subject to wide variations in range characteristics and congestion at high power transmissions. Further, frequencies in the region 30 to 80 MHz are too removed from receivers normally available to boatmen and are also subject to severe congestion on a national basis. The frequency area between FM broadcasting and maritime VHF is heavily congested with aeronautical and land mobile services.

The general position of the VHF marine allocations in the radio spectrum is shown in Figure 2-3. The spectrum space allocated to maritime mobile in the United States is shown by hatch lines. The international allocations affording priority to maritime mobile are shown at the left of the scaled graph. Two frequency areas should be noted in particular for later discussion. These are in the small segment excluded from non-government maritime operations in the vicinity of 157 MHz, and the maritime mobile band in the 161 to 162 MHz area.

The frequency assignment plan by which functional communications are managed in the VHF maritime mobile band is shown by frequency order in Figure 2-4. All channels have been designated in accordance with nationally coordinated planning. The adoption of a 25-KHz channel plan was effective 1 January 1971, although all receivers currently in use do not provide adequate adjacent channel rejection on a 25 kHz basis.

The frequency of 156.750 MHz has been designated for environmental broadcasts in this plan. This frequency is limited in its utility for broadcasts by two factors. The first is related to its proximity to 156.800 MHz, the Distress, Safety, and Calling channel. The requirement to continuously monitor 156.800 is subject to interference from any transmissions at the site on 156.750 MHz,

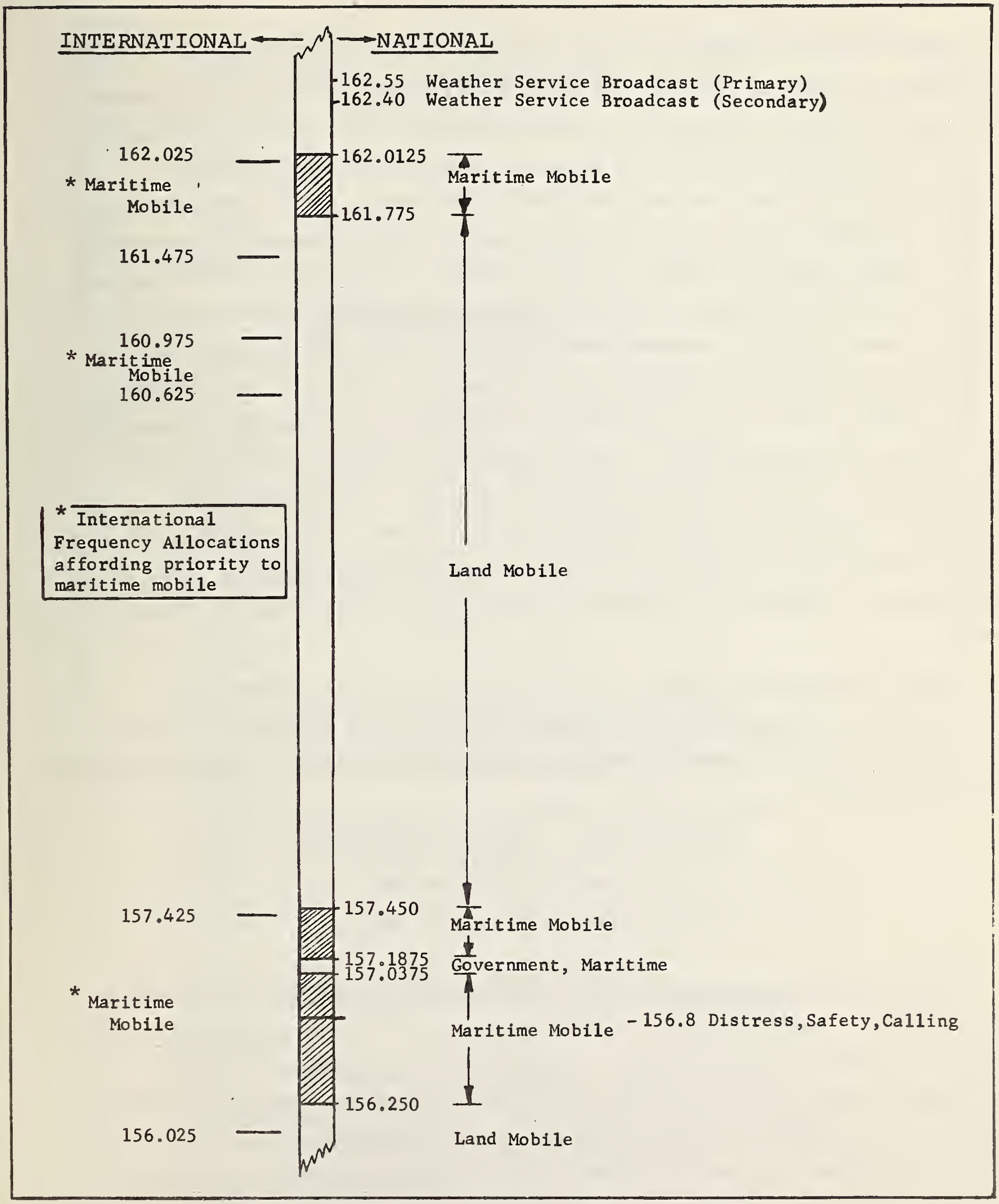

Figure 2-3. Frequency Allocations Close to VHF Maritime Bands

and would require that the local transmitter be physically separated by some distance. This is estimated as being at least 800 feet, but site engineering measures may reduce this requirement. The characteristic of receivers aboard many vessels further complicates the regular and continuous use of the environmental frequency for weather broadcasts. The present selectivity is not sufficiently narrow in all cases to separate transmissions on the calling frequency from weather broadcasts. The second factor stems from the adoption of power limits as a means of controlling adjacent channel interference. The application of strict power limits also adversely affects the coverage capability for weather dissemination. As a result of these factors, the utilization of 156.750 MHz has been limited. Although the frequency was intended primarily for government broadcasts, it is available for nongovernment environmental assignments upon application, subject to nonuse by government stations for that area.

The frequencies shown in Figure 2-4 as "Government" are available for Coast Guard operations subject to coordination by the Interdepartment Radio Advisory Committee (IRAC). The frequency channels are:

157.050 MHz	157.125 MHz
157.075 MHz	157.150 MHz
157.100 MHz	157.175 MHz

Designation of one of these channels for weather broadcasts would satisfy the frequency requirements and is in consonance with objectives previously stated. However, the proximity to the intership channel (157.025 MHz) and continued existence of receivers with inadequate filter characteristics suggests that the specific channel selected should not be adjacent to 157.025 MHz.

162.000	Public Correspondence, Coast Stations
161.975	"
161.950	"
161.925	"
161.900	"
161.875	"
161.850	"
161.825	"
161.800	"
157.425	Commercial, Intership
157.400	Public Correspondence, Ship Stations
157.375	"
157.350	"
157.325	"
157.300	"
157.275	"
157.250	"
157.225	"
157.200	"
157.175	Government
157.150	"
157.125	"
157.100	"
157.075	"
157.050	"
157.025	Commercial, Intership & Ship to Coast
157.000	Port Operations, Intership & Ship to Coast
156.975	Commercial, Intership & Ship to Coast
156.950	"
156.925	Noncommercial, Intership & Ship to Coast
156.900	Commercial, Intership & Ship to Coast
156.875	Commercial, Intership
156.850	State Control, Ship - Coast
156.825	
156.800	Distress, Safety and Calling
156.775	
156.750	Environmental, Coast to Ship
156.725	Port Operations, Intership & Ship to Coast
156.700	"
156.675	"
156.650	Navigational, Intership & Ship to Coast
156.625	Noncommercial, Intership
156.600	Port Operations, Intership & Ship to Coast
156.575	Noncommercial, Ship to Coast
156.550	Commercial, Intership & Ship to Coast
156.525	Noncommercial, Intership
156.500	Commercial, Intership & Ship to Coast

Figure 2-4. VHF Marine Band Frequency Assignment Plan

156.475	Noncommercial, Ship to Coast
156.450	Commercial Intership & Ship to Coast, and Noncommercial Intership
156.425	Noncommercial, Intership & Ship to Coast
156.400	Commercial, Intership
156.375	"
156.350	Commercial, Intership & Ship to Coast
156.325	Port Operations, Intership & Ship to Coast
156.300	Intership Safety
156.275	Port Operations, Intership & Ship to Coast

Figure 2-4. VHF Marine Band Frequency Assignment Plan (Continued)

Similarly, if 157.175 MHz is utilized, the possibility of interference from vessels transmitting to public correspondence coastal stations may create interference to weather reception by other vessels in the area. The impact of power limits would require careful Coast Guard evaluation as to means of providing extended range operation.

An alternative plan which alleviates power restraints is the consideration of a frequency in the vicinity of 162 MHz. (See Figure 2-3). Maritime operations of frequencies 161.800 to 162.000 MHz involve transmissions from coastal stations to vessels, a type of transmission consonant with marine weather dissemination. By associating marine weather transmissions in a similar frequency range with this category, optimum frequency utilization is feasible and interchannel interference avoided at the receiving terminal aboard vessels. The frequencies immediately below 161.775 MHz are assigned to land mobile users in a severely congested area already the subject of national concern. Frequencies immediately above this frequency are allocated to government use, and include National Weather Service transmissions at 162.55 MHz (primary) and 162.40 MHz (secondary). This segment of the spectrum meets the desired objectives, and is within tuning capability of existing marine transceivers or monitoring receivers currently manufactured.

By using a frequency immediately outside the maritime band, national arrangements for additonal power are more feasible, where desired. This would permit selected sites on major approaches or the Florida Straits to operate in extended range modes similar to fixed stations in the aeronautical service. That is, both transmitter power, antenna arrays, and heights could be arranged to increase range. Although it is not proposed that this frequency should be used at all stations, it would at least provide design flexibility for this purpose. The frequencies which appear most desirable are 162.025 to 162.40 MHz.

The least desirable alternative, but one which meets the technical objectives, requires national frequency suballocation action to assign a frequency in the band affording priority to maritime mobile, but currently utilized by land mobile. This is the band 160.625-160.975 MHz.

Frequencies above the ranges discussed above are of decreasing applicability because of equipment design and radio propagation factors.

2.3 RADIO PROPAGATION CONSIDERATIONS

2.3.1 General

System design objectives relating to radio propagation commonly seek to achieve the highest percentage of reliability in overcoming all losses over a given service area or path. However, in considering a weather dissemination system to be related to specific geographical areas, even low percentages of probability for extended range beyond the service area may be of concern. Radio propagation characteristics vary with frequency across the radio spectrum, and provide the means to control generally the distance over which the transmission propagates. However, in the frequency ranges which support skywave modes of propagation, these characteristics may vary hourly, seasonally, and anually. A desired systems objective where range limited control is desired can be assured to some extent only by using frequencies and antennas which are line-of-sight to the radio horizon.* This characteristic is achieved in the frequency band of about 100 MHz and higher. The propagation characteristics supporting this conclusion are summarized in the paragraphs which follow.

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*Neglecting occasional ducting, which may extend the range for limited periods in certain directions.

2.3.2 Propagation Characteristics

Frequencies in the medium frequency (2 MHz) maritime channels are propagated by ground waves with variable components of skywave propagation. The range for voice communications is governed by atmospheric noise at night and receiver noise in daytime, except in the vicinity of thunderstorms. Noise levels vary by time, season, and location and the extremes of variation represent a difference of 40 dB. However, radio interference is so severe in many areas that range is limited more by interference than by propagation considerations. Because of the great variation in the effects of noise, the range for controlled area of coverage is most difficult to predict under all conditions. This subject has recently been reviewed by SC-11 of the RTCM and Dr. Willis of ITS. It is concluded that localized weather dissemination on 2-MHz marine channels is subject to range vagaries which limit controlled service area approaches.

In the high frequency band, the use of maritime subbands to ensure localized, range-limited application is difficult because of practical limitations in controlling the number of hops and ionospheric layer heights. Although the ground wave coverage may be restricted, the skywave mode may create significant signal levels at considerable distances. Sporadic E layer propagation may exist to about 100 MHz, and is not predictable except under specific situations.

The characteristics of radio propagation affecting selection of a weather dissemination frequency are subject to complex factors which may be defined accurately only under specific criteria for the time, location, and technical characteristics. However, to illustrate the nature of propagational influence, Figure 2-5 shows in a general and approximate manner the relationship between propagation frequency and transmission range.

NOTE: THIS FIGURE IS NOT INTENDED TO BE USED TO DETERMINE RANGE. IT IS INTENDED ONLY AS AN ILLUSTRATION OF GENERAL RADIO FREQUENCY PROPAGATION BEHAVIOR.

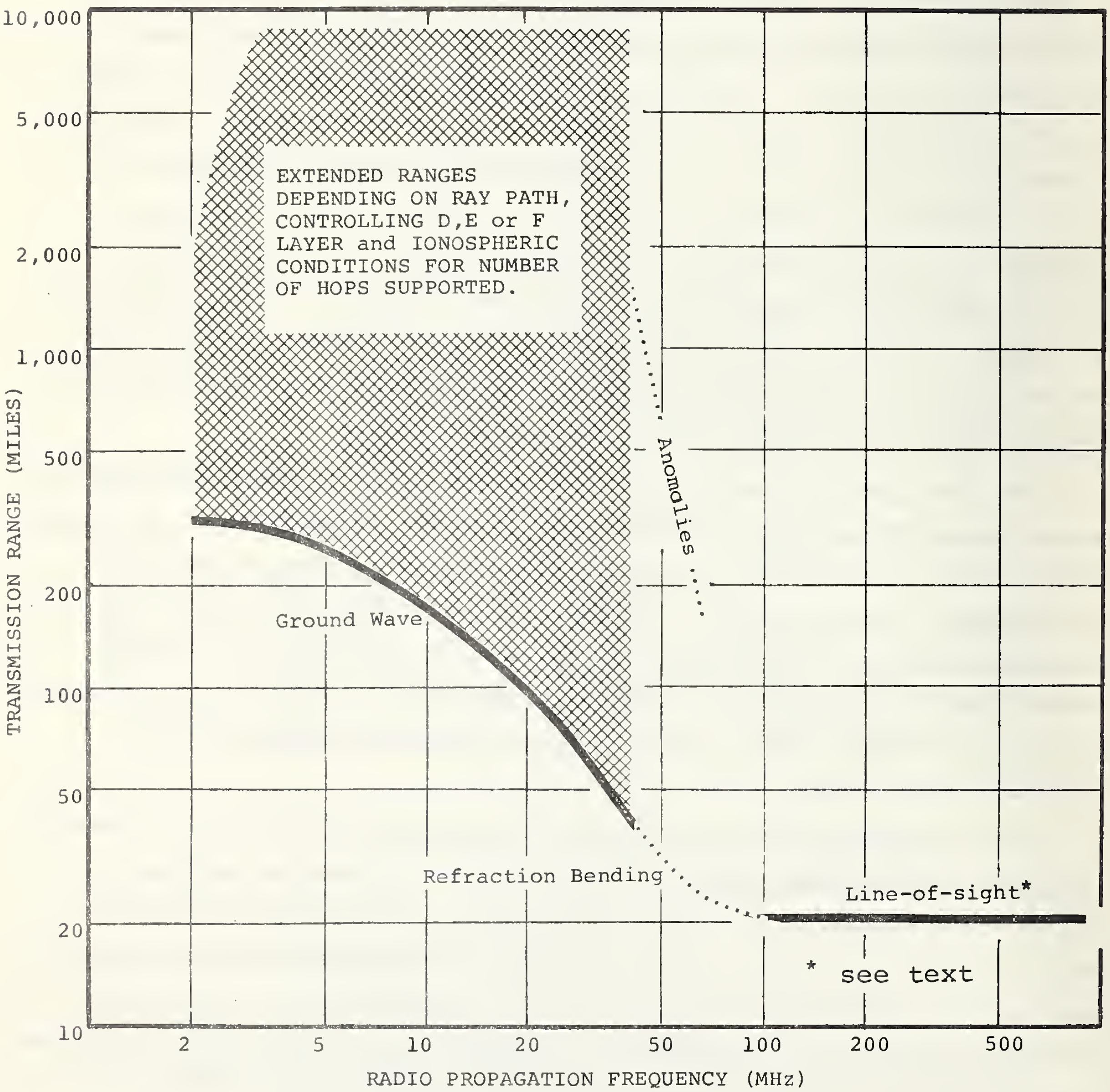

Figure 2-5. Propagation Range as a Function of Frequency

The ground wave distance in the frequency range 2 to 40 MHz may be controlled by transmitted power for a given environment. However, the sky wave component may propagate over extended distances as shown. From 40 to 100 MHz, erratic transmission ranges may result from propagation anomalies.

Limited coverage of a localized service area is feasible above 100 MHz, such as in the 156 MHz VHF Marine Band. The line-of-sight distance shown in the figure is based upon an assumed coastal station antenna height of 175 feet, and a maritime mobile antenna height of 30 feet.

At frequencies higher than approximately 300 MHz, the cost of equipment begins to rise significantly as a result of design phenomena and a smaller market. The range of frequencies from 100 to 300 MHz, therefore, appears to offer the most desirable propagation characteristics for a system in which range-limited control is required.

2.4 GEOGRAPHIC COVERAGE

2.4.1 Coverage Requirements

A system designed to serve all recreational boatmen should ideally cover all geographic areas in which such users operate. As a first approximation, and in the absence of specific information on the distribution of the users, consideration would be given to covering the entire coastal and inland regions, i.e., waters within 25 miles of the shore, including bays, lakes and major rivers.

Considerable benefit in terms of reduced system cost will accrue to a system which concentrates its coverage on those areas habitually operated by recreational boatmen. A system engineering approach to such a design would establish a cost-benefit factor associated with the number of users served and the cost of implementing the system and would then proceed to a design which maximizes the cost-benefit factor. The objective of such an approach would be to provide the highest level of service attainable within predetermined cost constraints.

The data required to perform such an analysis is not currently available, however. During the Effectiveness Measurement phase of this study in Task 3, CSC was able to identify only one source of objective, quantitative data describing the actual numbers of boatmen operating in specific areas. This data was generated during the development of the Boating Statistics Information System and was restricted to areas in the 5th District (Maryland, Virginia, South Carolina, and the District of Columbia).

Qualitative data describing the relative levels of activity from area to area are available from Coast Guard personnel, who maintain a close and intimate relationship with the boating community. In certain areas, subjective numerical data are available as a result of on-site boat counts, surveys, etc.

Valid statistical data are maintained by many state authorities which describe the numbers and types of boats registered in that state. However, because the registration is filed under the residence address of the owner, it is not possible to relate these data to actual area of boating operation, since the owner may maintain his boat at some distance from his residence (even in another state, in some cases), or may transport his boat by trailer to a number of different operating locations. Even if such data could be used, its availability and quality is varied since some states maintain only minimal records.

The approach taken by the BSIS is to determine areas of habitual operation of a carefully selected sample of boatmen by telephone questionnaire. The raw data is then carefully weighted using statistical prediction methods to yield projected population figures for each area.

In order to determine which areas should be covered by the system and which areas may be left unserved at minimum loss to the user population, the type of information outlined above must be obtained using the BSIS or some similar system. In the absence of such data, any attempt to design a selective coverage pattern for the system will have to be made in a partially subjective manner.

2.4.2 Coverage Adjustment

Assuming that the necessary analytical techniques and data are available to determine selective coverage patterns, some method of tailoring the actual coverage to the requirements will be necessary.

The average provided by any line-of-sight propagation technique may be approximated with reasonable accuracy by a circle of radius equal to the propagation range. Anomolies cause the actual coverage to depart from this ideal, sometimes significantly, but the model is adequate as a first approximation. This pattern is far from ideal in terms of providing controlled area coverage, as some degree of overlap between adjacent propagation sites is required (Figure 2-6). This results in problems associated with interference between adjacent signals and requires that measures be taken to reduce these problems, such as alternating transmissions in time or transmitting on different frequencies from each site.

Some degree of pattern control may be achieved through the use of directional antennas (Figure 2-7a), with possible attendant gains in received signal strength. However, the degree of control which can be exercised by this technique is limited.

A more powerful technique for achieving controlled coverage consists of using a large number of relatively short-range propagation centers suitably located (Figure 2-7b). The centers might take the form of transponders relaying a centrally-disseminated signal. The location of the transponder devices will be influenced

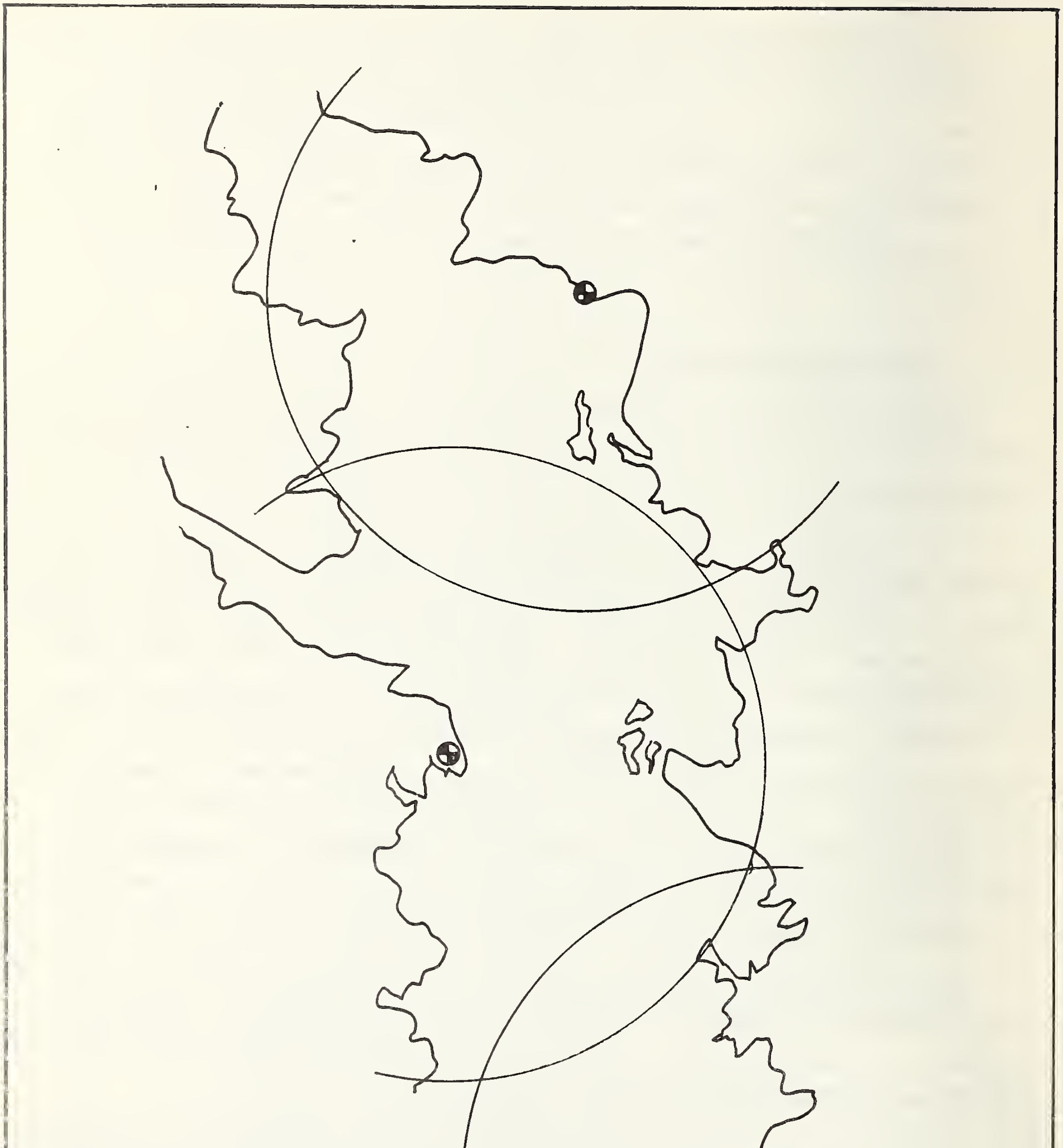

Figure 2-6. Service Area Overlap to Complete Coverage

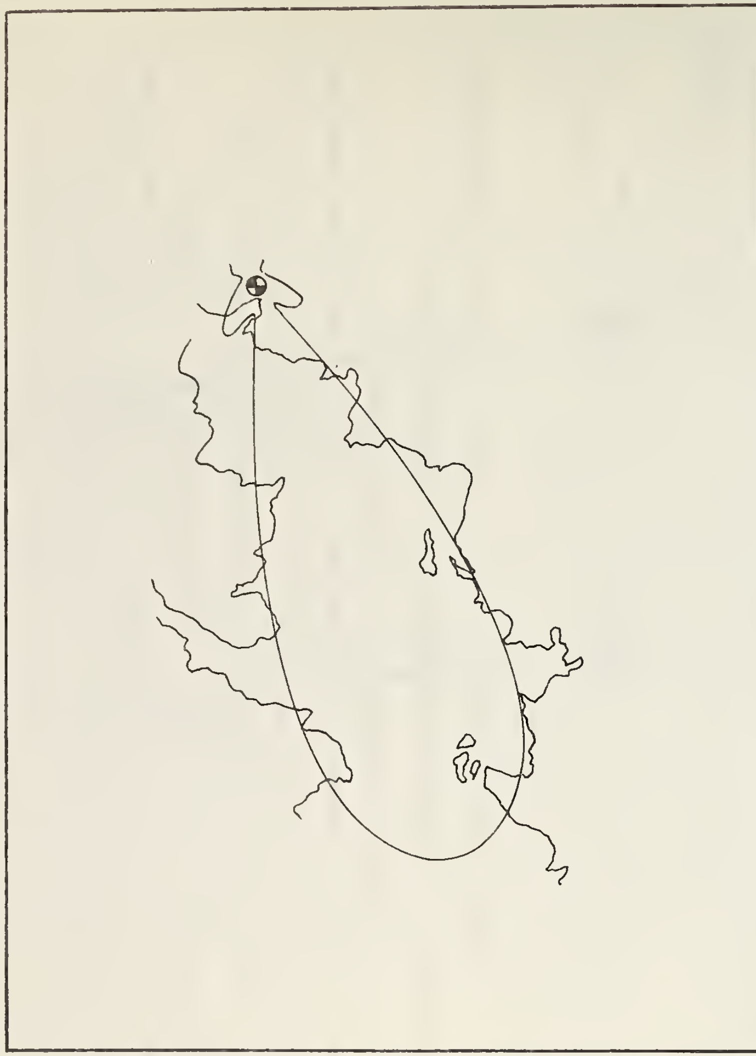

Figure 2-7a. Tailored Coverage by Antenna Pattern Control

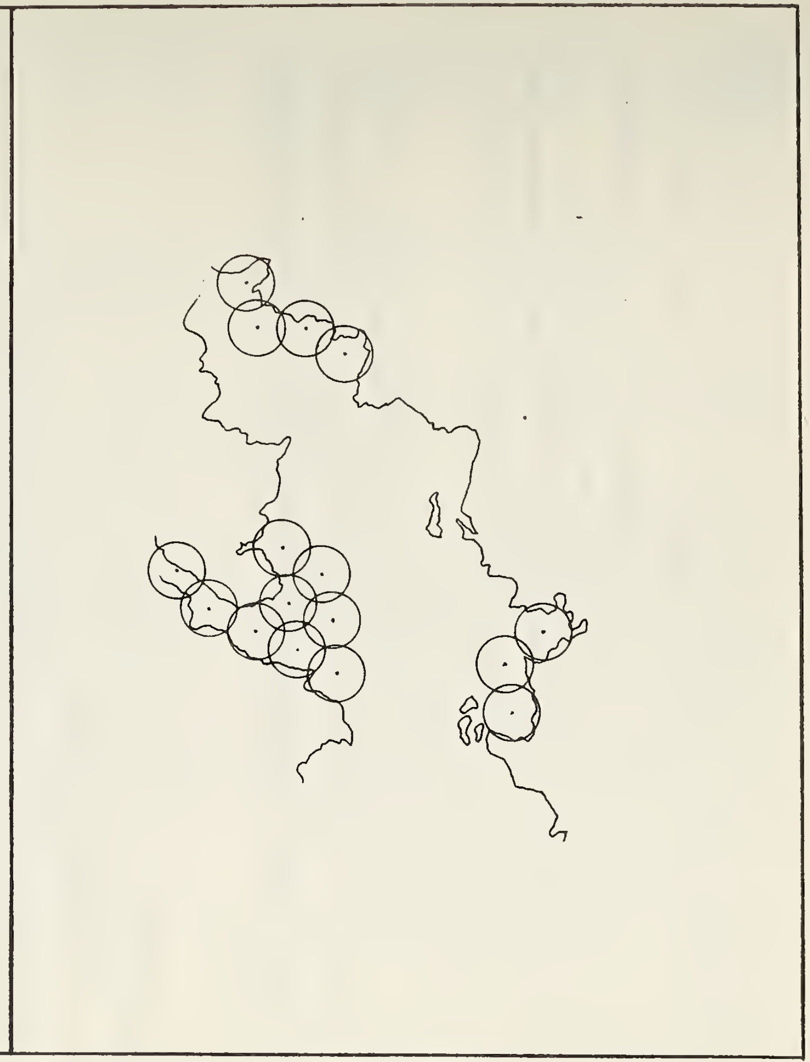

Figure 2-7b. Tailored Coverage by Use of Transponder Network

by the availability of suitable sites such as small islands, buoys, etc. This arrangement would be more costly both to implement and maintain than more conventional arrangements. Of even greater concern, however, is the interference problem which this arrangement poses; for although the interference may be effectively reduced by having adjacent sites transmit on different frequencies, at least three frequencies are generally required with attendant implications of high cost to the user.

A selection between the techiques used cannot be made in the absence of a specific system plan. In practice, a combination of all three techiques might effectively be employed in meeting local system requirements.

2.5 POTENTIAL USERS

2.5.1 Boating Population Growth

As a preparatory step in assessing the potential use of a future recreational boating weather information and alerting system, it is necessary to examine the total boating population and the way in which it will change in the future. This analysis was performed during Task 3 of this study, but the results are repeated for the convenience of the reader.

Figure 2-8 depicts the growth of the total boating population as an extrapolation of Coast Guard statistics from 1965 to 1969. Since the graphic technique employed is less accurate than rigorous numerical methods, upper, lower, and median growth rates have been estimated both for the number of registered boats and for the Boating Industries Association estimate of the total number of boats in the U.S. Superimposed on the extrapolated curves are the official figures for 1970. The close agreement with the predicted numbers lends confidence to the estimation technique.

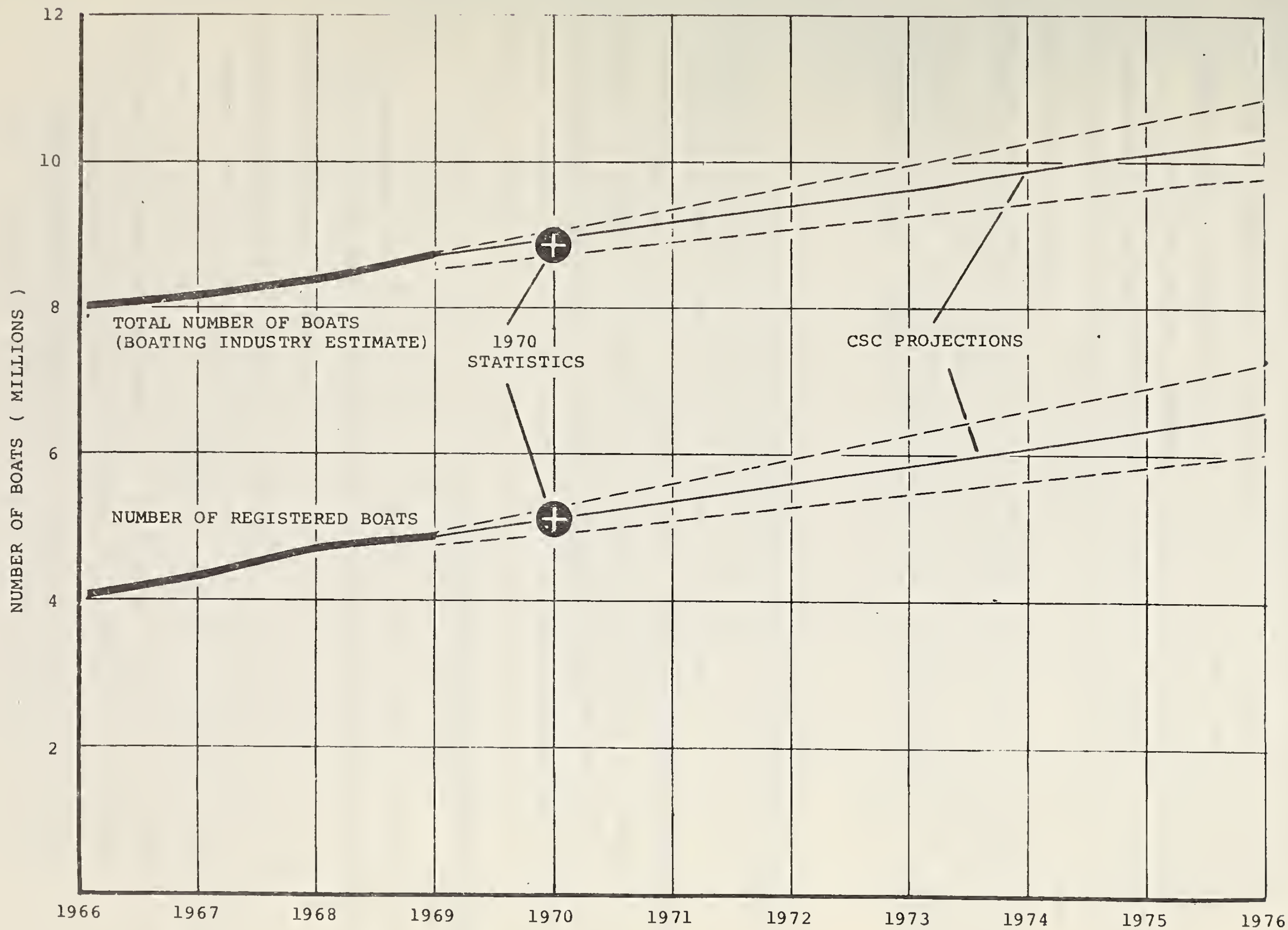

Figure 2-8. Growth in Number of Boats Projected From Coast Guard Statistics.

For this study it is the estimated total number of boats (rather than registered boats) which is of interest. The predictions in Figure 2-8 indicate that this number will grow from the presently estimated figure of approximately 8.8 million to between 9 and 10 million in 1973 and between 10 and 11 million by mid-1976. Coast Guard statistic indicate that of this number, about 65% will be between 16 and 25 feet in length. These divisions are chosen to correspond to the accepted boat classifications of Class A and Class 1, respectively. There is evidence which susgests that this separation is less than ideal because a large percentage of all boats are close to 16 feet. In other words, the majority of Class A boats are at the upper end of the scale, close to 16 feet and many Class 1 vessels are at the lower end of this scale, again close to 16 feet

If this implication can be validated by analysis of existing statistical data, it would suggest that a more meaningful categorization might be useful in assessing audience distribution for system analysis and design. The breakdown selected should, in fact, be based on the population distribution by length, choosing length categories which represent zones of standard deviation from the peak population length.

2.5.2 Audience Size/Cost Relationship

In addition to vessel type categorization, it is necessary to characterize the boatmen in terms of equipment or potential equipment ownership. Ideally, the percentage of the boating population prepared to spend X dollars on reception equipment should be known. The possibility of relating this factor to the size of boat owned and/or operated would also be most useful.

Unfortunately, the data on these factors is extremely limited and poorly qualified. Although a number of surveys have sought to establish these or similar figures, the questionnaires have been poorly designed and the samples improperly defined. This represents another area in which a specific need exists for statistically valid data. It is recommended that such data be sought through implementation of the BSIS of a similar system.

It is possible to determine one point on the "percentage population vs dollars to be spent" curve, however. Statistical data is available concerning the users of marine radio telepnones and a prediction of growth was made from this data in the Task 3 Report.

An analysis of FCC marine mobile license data* for applications made since 1966 shows a linear growth in the total number of applications (MF and VHF) of about 8,500 per year (Figure 2-9). A license, when granted, remains valid for 5 years so that the number of licensed operators in any year is the cumulative number of applications for the previous 5 years. This means that the rate of growth of the number of licensed operators is five times the annual growth, or approximately 42,500 a year.

The projected growth in the number of marine radio-telephone licenses is depicted in Figure 2-10, which shows an increase from the current figure of 245,432 to approximately 543,000 by 1977. Under the new FCC rules, all of these will be equipped with VHF transceivers. This number represents a growing percentage of the boating population which is prepared to spend between $200 and $600 on communications equipment. This group generally represents the extreme in spending, and it may be assumed from these data that no more than approximately five percent of the boating population is prepared to spend more than $200 on this type of equipment.

The most important figures, however, are at the other end of the scale. What we really need to know is how much 90% of the population is prepared to spend on equipment designed to receive weather information and alerts? An approximation of this figure is an important

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*Item 11, Appendix C, Volume 3

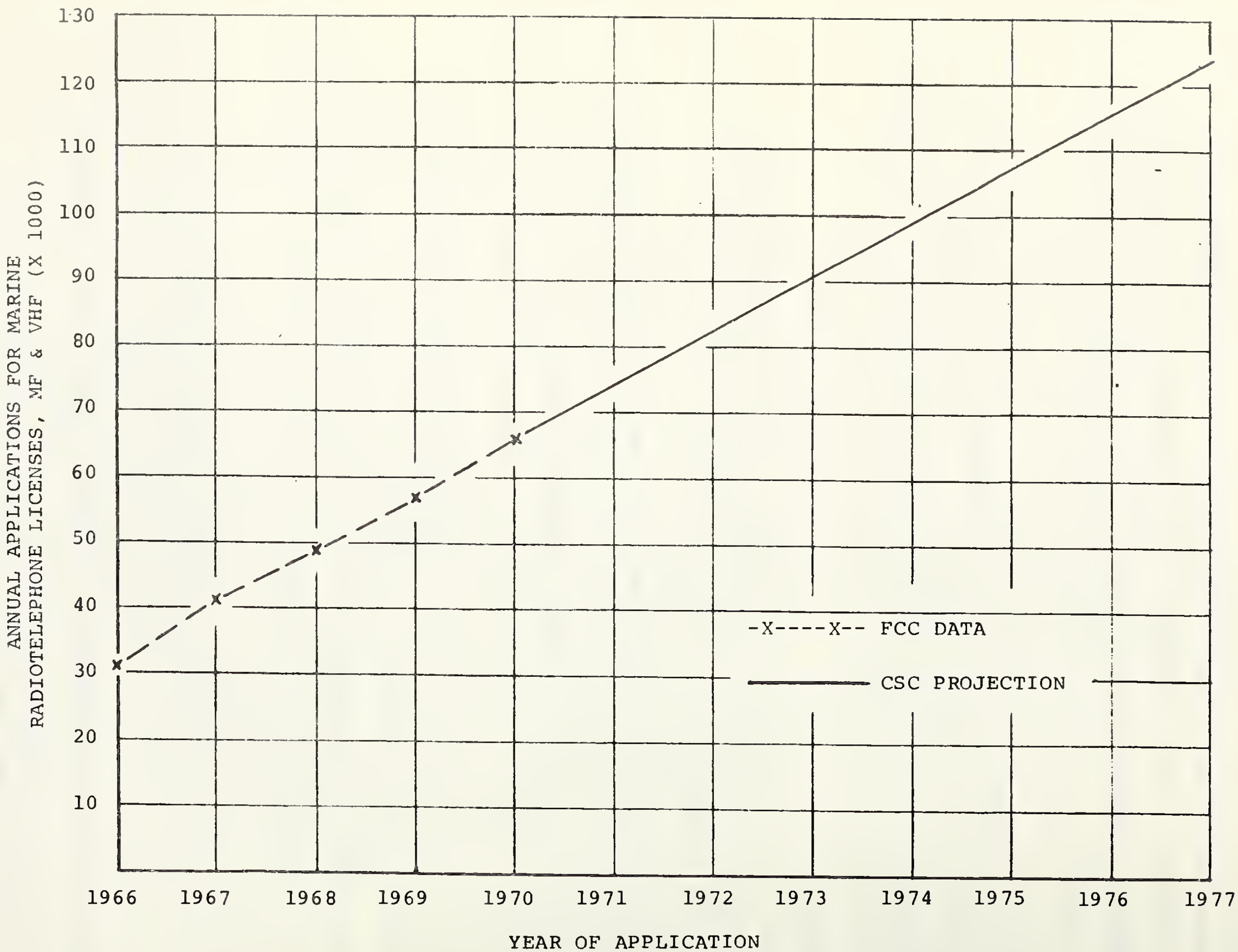

Figure 2-9. Rate of Increase in Marine Mobile Licence Applications

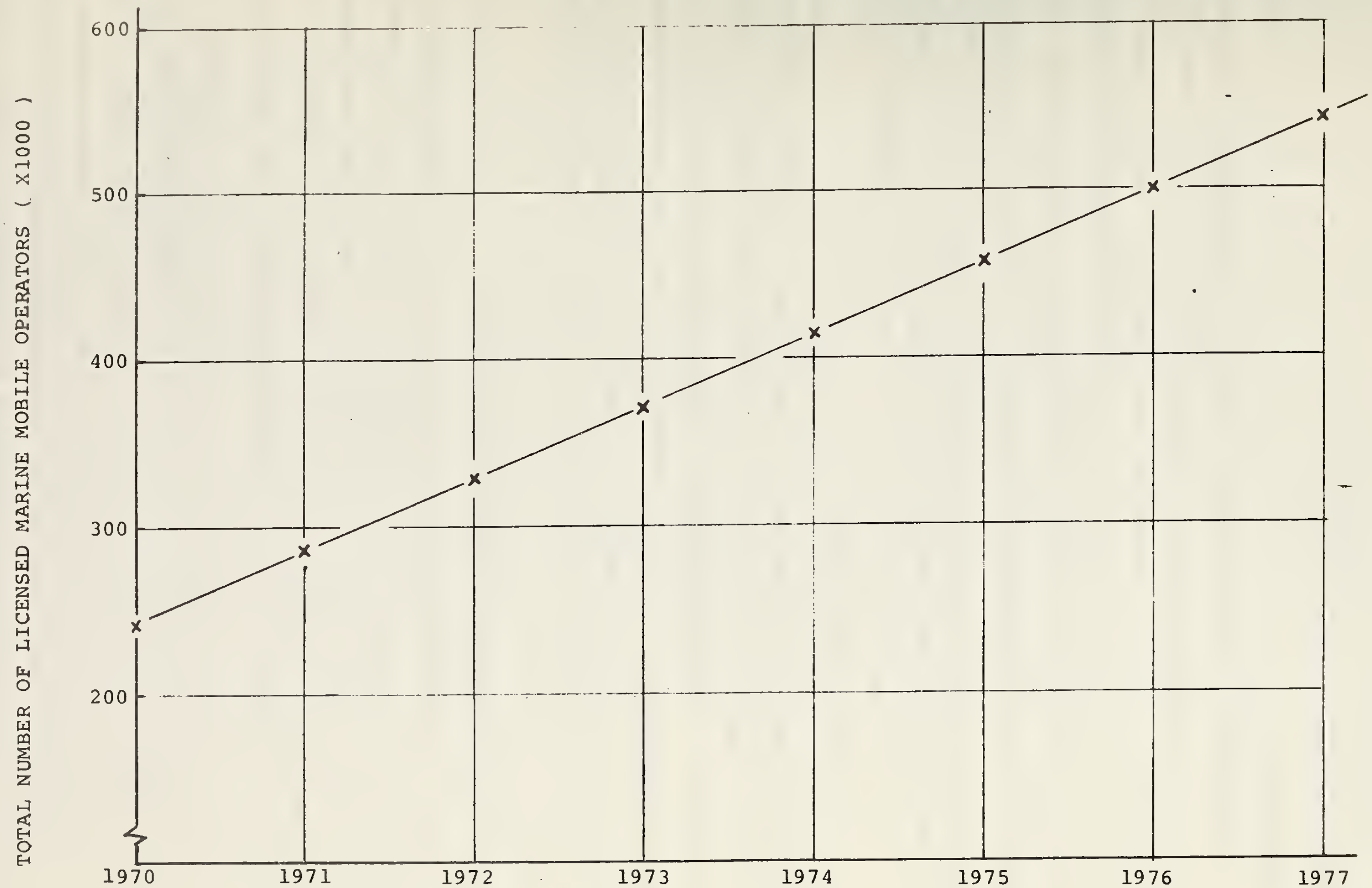

Figure 2-10. Projected Growth in Total Marine Mobile Licenses.

prerequisite to further study in this area, but cannot be determined without extensive effort either in reduction of existing data or by the acquisition of new data.

2.6 COMMUNICATIONS LINK TRADEOFFS

2.6.1 General

In a dedicated communications system a potential exists for tradeoffs between transmitter power and receiver cost to minimize total system cost and/or maximize performance. Within practical constraints, increasing transmitter power will permit the attainment of a given service level with less sensitive, and perhaps cheaper, receivers. Increasing receiver sensitivity, on the other hand, will tend to increase the cost of the receiver inventory but will permit lower transmitter power and reduce costs at the transmitting site(s). An optimum combination may be sought, therefore, which will minimize the total system cost.

Although such an optimization technique appears attractive, two factors limit its application to a recreational boating information dissemination and alerting system; the distribution of costs between disseminator and user, and the effects of the noise environment. Both factors arise as a result of the "non-dedicated" nature of the system, and are discussed separately in the following paragraphs.

2.6.2 User/Disseminator Cost Relationship

Because the system under discussion will be operated as a user-oriented service rather than a dedicated system, the user will be expected to bear the cost of the necessary reception equipment. Since the costs are shared, therefore, between disseminator and user, there can be no meaningful "system-minimum cost" in the usual sense.

Relieved of the receiver-cost burden, the disseminator could, of course, seek to minimize the costs of transmission and let the user costs escalate. Such a measure would largely defeat the objectives of the system, however, since rising user cost implies a smaller number of users and a corresponding reduction in system effectiveness (see Volume 3, Systems Effectiveness Measurement).

The cost-effectiveness relationship for the proposed system is, therefore, dominated by user-dependent factors and requires careful examination. It is evident that a simple power/sensitivity tradeoff to optimize system cost is not applicable to the system under consideration, and that a more complex approach is necessary to determine optimum values for these parameters.

2.6.3 Noise Environment Effects

For a dedicated system transmitting on a single frequency to a set of standard receivers, an increase in power of the transmitted signal will, within normal constraints, result in an improvement in the received signal. In general, increased power leads to an enhancement in service level.

However, this relationship does not necessarily hold for a system using a mix of receivers, a factor which was examined in a recent study (reference 2) in which some technical aspects of the use of the Land Mobile Radio Service spectrum are considered. The effects of various kinds of modulation, channel separation, transmitter power and physical separation of adjacent channel transmitters were evaluated; combinations of these parameters were also considered. It was concluded that narrow band FM with channel spacing of 20-30 KHz represents the optimum modulation and channel spacing in a mobile environment. The study also concluded that if increased transmitter power is used to overcome the additional degradation of noise, the intermodulation products generated between adjacent channels as well as the transmitter harmonic and spurious levels increase in power and tend to desensitize receivers tuned to adjacent channels. The net effect is that the effective service range tends to be reduced or at best remains the same, even though increased costs are incurred in the form of higher transmitter power and/or larger numbers of transmitter sites.

It would appear than, that although service on specific channels can be improved by increasing the effective radiated power of the transmitter, and/or increasing the receiver sensitivity, the net effect on users of adjacent channels would be a degradation of their effective range and signal quality. Based on this, it can be seen that attempts to optimize service in the maritime mobile bands must be considered from a system viewpoint, rather than from a single channel viewpoint.

2.6.4 Link Performance Data

It is clear from the foregoing considerations that link trade-offs for this type of system must be based on a carefully developed cost-effectiveness relationship. One element of such a model must be a parametric relationship of audience size to receiver cost. As was stated in Paragraph 2.5.2, this relationship cannot be developed without an extensive effort either in reduction of existing data or by the acquisition of new data.

The other primary element of such a model is that relating communications range to transmitter and receiver characteristics. The mechanisms for deriving this relationship were developed during Task 2 of this study and are detailed in Volume 3, Systems Effectiveness Measurement.

During the course of Task 2, field and laboratory measurements were undertaken to characterize a cross section of receiver types known to be quite widely distributed among the boating population. The purpose of the analysis was to derive a family of curves relating signal field strength and receiver performance. The detailed report of these tests was published in the Task 2 report and is included herein for reference as Appendix D. The same report addressed itself to the evaluation of the performance limitations imposed on receivers due to the external and man-made noise environment in which the receivers are expected to operate. This is also included for reference as Appendix E.

The pertinent conclusions reached may be summarized as follows:

For acceptable audio signal to noise ratio at the output of "average" quality receivers of the following types, the input signal field strength required was determined to be:

- For commercial AM portable receivers, 1200 μv/m
- For commercial FM portable receivers, 450 μv/m
- For small portable VHF receivers, 700 μv/m

Factoring in the results of the noise analysis led to the following general conclusions. Marine radiotelephones operating in the 2 MHz band would tend to be limited in range and performance by external noise levels. Portable AM, FM, and NWS VHF receivers tend to be range limited due to the quality of the receivers. Installed types of VHF marine telephones with sensitivities greater than 4 μV would be range/performance limited by their sensitivity rather than external noise.

To illustrate the relationship between transmitter power, antenna height and receiver sensitivity in typical FM link situations, the following comparison may be considered:

Transmitter Power (Watts)	Antenna Height (Feet)	Receiver Sensitivity (μv/m)	Link Range (Miles)
50	85	4	20
330	300	650	20

It can be seen that similar ranges are acheived with widely different link parameters, the former representing a Coast Guard VHF-FM transmission to a typical installed marine radiotelephone, the second representing a National Weather Service VHF broadcast at 162.55 MHz to an average quality VHF portable monitor.

SECTION 3
CONCLUSIONS

3.1 SYSTEMS OBJECTIVES

The systems objectives developed in Section 1.0 validly reflect the needs and requirements of the majority of recreational boatmen, and should form the basis for future systems design and development in this field. The objectives were based on extensive work performed during the initial phases of the weather dissemination study and also drew heavily on experience gained by the project team during contacts with the boating community. As such, they represent a blend of both objective and subjective evaluations.

3.2 TRADEOFF DATA

The parametric relationships needed to perform system tradeoff analyses are addressed in Section 2.0 along with applicable data. Modeling elements and data sets which are required for the analyses but which are not currently available are identified and methods suggested for their acquisition. These include

- Audience Size/Receiver Cost Relationship

  Information describing user attitudes towards the cost of participating in the system and attempting to establish the percentage of the recreational boating population prepared to spend a given amount on equipment is required. Surveys designed to elicit such information must consider the education of potential users to the hazards of weather and the benefits of the proposed system.

- Spatial Distribution of Users

  Improved management of existing state data or specially designed programs of data collection and reduction are required to establish numbers and distribution of boatmen on specific bodies of water. The recently developed Boating Statistics Information System provides an excellent means for obtaining such information.

* Relevance of Surface Phenomena

To accurately evaluate the level of hazard presented by weather phenomena and to establish criteria against which to issue alerts to different segments of the community, specific information relating surface phenomena (wave height, fetch, wind speed, etc.) to hazard level for different sizes and types of boats is needed.

The variation of these phenomena in time and space must also be characterized to the extent possible using current knowledge if a properly optimized dissemination network is to be designed.

In all other areas it is considered that the necessary information is available or is already being adequately investigated by other organizations (e.g., NIAC studies of alerting technology).

3.3 SYSTEM DEVELOPMENT

The implementation of an advanced environmental information dissemination/alerting system must proceed through systems analysis and development phases to ensure that prescribed objectives are met and that the system provides optimum service and maximum effectiveness.

It is suggested that the following procedure be adopted:

a. Acquisition of Data

Data which is required for a valid analysis must be collated and techniques for its acquisition developed where necessary (Paragraph 3.2).

b. Systems Analysis

The development of modeling techniques and parametric relationships will permit tradeoffs to be performed and candidate systems selected. Initial analyses could probably be undertaken in parallel with the data acquisition phase to identify other areas in which data may be required.

Candidate systems might include a dedicated, Coast Guard operated system of dissemination and alerting as well as a system operating through commercial radio stations using restricted or nationally-addressed alerting schemes. Either system might incorporate real-time data transfer from automated stations (buoys) through the disseminator or by direct user-access.

c. Program and Hardware Development

Selected system techniques may require the development of hardware (such as an alert device) for testing and pilot production. Simultaneous program development will entail the selection of test procedures, pilot program site(s), and program implementation requirements.

d. Pilot Test

Validation of the selected system may be explored through a pilot test program and careful evaluation techniques. Preliminary design may benefit from an analysis of the dissemination program currently being coordinated by the Coast Guard in the First District, in which a number of commercial broadcast stations are participating.

APPENDIX A

REPORT AND RECOMMENDATIONS OF THE NATIONAL INDUSTRY ADVISORY COMMITTEE STUDYING EMERGENCY ALERTING OF THE GENERAL PUBLIC

APRIL 8, 1971

NATIONAL INDUSTRY ADVISORY COMMITTEE

Special NIAC Working Group
Studying the use of
Standard, FM and television
broadcast stations for
emergency alerting of the
general public

Transmission Standards Sub-Group
Interconnecting Facilities Sub-Group
Field Test Sub-Group

REPORT AND RECOMMENDATIONS

Report covering Proof-of-performance tests of the two-tone signalling system proposed by the Transmission Standards Sub-Group.

Recommendations for the adoption and implementation of a two-tone Attention Signal.

APRIL 8, 1971

SUMMARY AND RECOMMENDATIONS

The Report which follows reviews the studies of the Special NIAC Working Group on Emergency Alerting of the General Public, the development of a proposed two-tone signalling system, the specification and purchase of equipment to test the proposed two-tone system, and the results of proof-of-performance tests of the system conducted from June through December 1969.

The Report concludes with a recommendation from the Transmission Standards Sub-Group of the Special NIAC Working Group that the following signalling system parameter be proposed by NIAC to the FCC for immediate adoption and early implementation for the Third Method and the Fourth Method of the Emergency Action Notification System:

> Tone Frequencies - The two audio signals shall have fundamental frequencies of 853 and 960 cycles-per-second and shall not vary over ± 0.5 cycles-per-second.
>
> Harmonic Distortion - Total Harmonic distortion of the audio tones shall not exceed 5%.
>
> Level of Modulation - Each specified audio tone will (with no other modulation) modulate the transmitter at 40% ± 5%. (The modulation level of each tone shall be calibrated individually.)
>
> Time Period for Transmission of Tones - The two tones with the characteristics specified above will modulate the transmitter at the specified level for a period not less than 20 seconds or longer than 25 seconds.

It is further recommended by the Transmission Standards Sub-Group that in so adopting the above Attention Signal and Transmission Standards the FCC should place receiver manufacturers on notice that a receiver designed to utilize the two tones for demuting or alerting should contain circuitry to introduce a timed delay of a minimum of 8-seconds in the activation or demuting process. The purpose of this timed delay is to prevent the receiver from falsely responding.

Further, it is recommended that the activation process in muted radio and television receivers should take place before the sixteenth second of tone reception to assure that a listener can audibly hear the tones for a period of from four (4) seconds to nine (9) seconds. This is consistent with the recommended time period for transmission of the two tones.

It is further recommended that the FCC take such measures as are necessary to inform receiver manufacturers that the responsive circuitry installed in all standard, FM and television broadcast receivers must be held to close tolerances, otherwise the efficiency of the system will be jepordized.

BACKGROUND

January 18, 1963 the Assistant Secretary of Defense (Civil Defense) proposed that a study be made by the Federal Communications Commission on the use of standard, FM and television broadcast stations in emergency alerting of the general public. In response to this proposal the FCC appointed a Special National Industry Advisory Committee Working Group to study the existing Emergency Action Notification System and to submit recommendations for changes thereto.

The inadequacies and inherent limitation of the carrier-break and tone "Attention Signal" were recognized, particularly the application of the "Attention Signal" to demute radio and television receivers designed for use in emergency alerting of the general public. The Special NIAC Working Group was therefore requested to study the revision of the carrier-break and tone "Attention Signal" looking toward the dual problem of Emergency Action Notification of Standard, FM and television broadcast stations and emergency alerting of the general public. Recognizing the numerous policy, philosophical, and operational problems involved, covering a broad range of management and technical considerations, the Special NIAC Working Group, insofar as possible, provided for participation by all interested elements of the non-Government communications industry, with representation by recognized principals of the communications industry.

The FCC issued Public Notices to the effect that the National Industry Advisory Committee (NIAC) was conducting such a study and invited any interested party to submit proposals for a revised standardized signalling system and "Attention Signal," with a closing date of June 18, 1963. This date was later extended to September 5, 1963. Thirteen entities submitted proposals for consideration by the Special NIAC Working Group.

Following the closing date of September 5, 1963 for submission of proposals, a detailed analysis was made by the Working Group for each proposal received. Closed circuit demonstrations of most of the proposed systems were conducted for the Working Group by each proponent.

As a result of further analysis and deliberations a decision was made by the Working Group that proposed systems utilizing the carrier-break principle would be eliminated from further consideration and that the systems proposed by four proponents should be field tested. The systems proposed by the following were selected by the Working Group for field testing: Philco, General Electric, CBS "Homealert", and Zenith.

A Field Test Ad Hoc Committee issued a report dated April 3, 1964, covering field tests conducted on the above proposed four systems. On May 15, 1964 The Systems Analysis Ad Hoc Committee released its comparative Analysis of the systems tested.

Following the field tests a NIAC Transmission Standards Sub-Group was appointed by the Defense Commissioner of the Federal Communications Commission, and assigned the task of examining the field test data and recommending a single transmission standard. This Sub-Group, under the Chairmanship of Mr. John H. DeWitt, Jr., Station WSM, Nashville, Tennessee, proposed a transmission standard which would utilize~~s~~ a two-tone "Attention Signal."

Specifications proposed by the Transmission Standards Sub-Group for a two-tone Attention Signal and Transmission Standards are as follows:

> <u>Tone Frequencies</u> - The two audio signals shall have fundamental frequencies of 853 and 960 cycles-per-second and shall not vary over $\pm$ 0.5 cycles-per-second.
>
> <u>Harmonic Distortion</u> - Total Harmonic distortion of the audio tones shall not exceed 5%.
>
> <u>Level of Modulation</u>* - Each specified audio tone will (with no other modulation) modulate the transmitter at 40% $\pm$ 5% or a total of 80% $\pm$ 10% for the two tones.
>
> <u>Time Period for Transmission of Tones</u> - The two tones with the characteristics specified above will modulate the transmitter at the specified level for a period not less than 20 seconds or longer than 25 seconds.

* The Working Group recommended that the words "or a total of 80% $\pm$ 10% for the two tones," be deleted and that a footnote be used to explain that the modulation monitor will not read 80%.

<u>DESIGN AND PRODUCTION OF TEST EQUIPMENT</u>

The Office of Civil Defense contracted with the Zenith Radio Corporation to produce 300 combination AM/FM receivers and 50 television receivers containing circuitry responsive to the proposed two-tone Attention Signal. In addition, 30 two-tone signal generators were ordered to enable standard, FM and television broadcast stations to transmit the "Attention Signal" according to the above proposed specifications.

The contractor for the test receivers was provided specifications for size, weight, sensitivity, frequency range, stability, operation and storage within certain temperature ranges, antenna configuration, audio power output, A.C. power voltage, and among other things, the electrical control requirements for muting and demuting. To safeguard against "false responses," the working group specified that the receivers for this test should contain circuitry which would withhold the demuting action of the receiver for at least 8 seconds after the start of the tones but which at the same time would assure that the demuting action took place before the 16th second of tone had been reached. The contractor selected 12 seconds as the time delay before switching. Considerable latitude is available to any manufacturer in the development and production of receiver circuitry to provide protection against false responses, latching or unlatching, audio level, and other features desired by the general public.

The contractor was authorized to exercise his own judgment in the selection of frequency sensitive components (audio devices responsive to 853 and 960 cycles per second) as long as the receiver would demute or become activated in accordance with the above specifications. A section of the contractors summary final report (3. Design History) is attached as Exhibit A since it contains data useful to receiver manufacturers.

Receivers specified by the Special NIAC Working Group for this proof-of-performance test were designed and constructed by the contractor, with circuitry responsive to the proposed two-tone "Attention Signal" and transmission standards. Although the two-tone signal can be heard on any receiver which is tuned to a station transmitting the two tones, responsive circuitry to be designed by the manufacturer is required in a receiver if it is to operate in a muted condition, and become demuted upon receipt of the proposed two-tone signal. The test receivers procured for use by the Special NIAC Working Group were designed to respond and automatically turn-on after they have "looked at" the two-tones for a period of twelve seconds. When the receivers respond, they automatically "latch" and turn the loudspeaker to full volume and remain at full volume until manually remuted or set for normal listening volume. This latching feature does not constitute part of the transmission standard. However, as explained later it is a feature that could be added by any receiver manufacturer.

Preproduction prototype receivers for the two-tone system were placed on continuous test at the Federal Communications Commission Laboratory during the period January, 1967 to December 1967. No false responses or major receiver malfunctions were observed during this time period. Delivery of production equipment commenced in late December, 1967.

DESCRIPTION OF TEST EQUIPMENT

At the outset of the field test project the Defense Commissioner recommended to the Committees that the equipment purchased for field tests of the two-tone system sould be as much like ordinary equipment as possible. The two-tone signal generators should be constructed consistent with the quality and stability found in other equipment used at broadcast stations. The receivers (AM/FM & TV) were to be modified home receivers ordinarily offered at regular retail outlets. Pictures of the AM/FM and Television test receivers and their schematics are shown in Exhibit B through E. The responsive circuitry in these schematics is that used with the defective resonant reed relays. See Figure 6 of Exhibit A for the modified responsive circuitry. The two-tone generator is pictured in Exhibit F with a schematics shown in Exhibit G. Technical Characteristic of Receivers and the tone generator are shown in Exhibits H and I.

The basic requirements for a selective signalling system such as proposed by the NIAC are (1) that a radio and television broadcast station must be capable of transmitting the two-tone "Attention Signal," (2) that a broadcast receiver must be tuned to the frequency or channel of the station which is capable of transmitting the two-tone "Attention Signal" (3) that the receiver contain frequency selective circuitry enabling it to respond to the two-tone "Attention Signal," (4) that the receiver will respond or react by turning itself on when the two-tones are received from the broadcast station, and (5) that the receiver will not falsely react or turn itself on at times when the two-tones are not being transmitted. Operation of the receiver is simple. When the receiver is connected to a 117 volt 60 Hz power receptable it is turned on at all times. There is no AC-power shut-off switch as is usually associated with the volume control. When the switch on the volume control is in the switched-off position the receiver is turned on but the loud speaker is muted. After the two-tones have been received for a period of about 12 seconds the radio is switched to full volume. The two-tones are then heard for about 8-10 seconds to let the listener know an important announcement is forthcoming. In order to remute the receiver the remute button (See Exhibits B and C) is pushed momentarily. If it is wished, at any time, to listen or to view the receiver at normal volume one has only to turn the volume control to what ever listening level is desired. In the event the receiver is adjusted for normal or low listening level and the two-tones are received the volume will switch to maximum after about 12 seconds and may be returned to normal by depressing the remute button.

The television receivers function in the same manner except that when the loud speaker is muted the picture screen is black. When the receiver is demuted the screen instantly becomes brightened for video information.

The two-tone generator is mounted on a 7-inch Rack Panel and can be operated at the panel or by remote control An operations command switch is protected by a cover to prevent accidental switching. When the command switch is pushed an electric timer is set in motion which switches on the audio output of the generator. After 22 seconds the timer stops and the audio output is shut-off. Individual locked controls are available for setting the output level of each tone (this is discussed elsewhere).

EQUIPMENT ACCEPTANCE TESTS

During an acceptance test of the equipment procured for the Special NIAC Working Group, conducted "on-the-air" in the vicinities of Washington, D. C. and Baltimore, Maryland, from January 2 through January 15, 1968, the responsive circuitry of the test receivers failed to function. As a result of extensive and detailed study of the matter by the FCC Laboratory, the components causing failure of the responsive circuitry of the test receivers were isolated and identified as the frequency sensitive resonant reed relays, two of which are used in each receiver.

After a considerable amount of investigation and redesign, twenty resonant reed filters were shipped to the FCC Laboratory where ten of the three hundred AM/FM test receivers were modified by utilizing the replacement components furnished by the contractor. These ten AM/FM receivers were then subjected to a second equipment acceptance test which was conducted "on-the-air" in the vicinity of Washington, D. C. and Baltimore, Maryland, during the period of October 7, , through October 21, 1968. Some of the modified receivers, as expected, did not respond to all individual test transmissions made during the test period. Further, no false responses occurred during the test. The large percentage of positive responses and the entire absence of false responses justified proceeding with proof-of-performance tests of the system without further delay in equipment tests. Accordingly, the FCC Laboratory recommended modification of the remaining 340 receivers.

THE FIRST PROOF OF PERFORMANCE TESTS

The ten test receivers modified at the FCC Laboratory along with one two-tone signal generator were shipped to station WMT Cedar Rapids, Iowa. Personnel at Station WMT placed the receivers in the hands of observers, one of which was in Decorah, Iowa (approximately 90 miles). Some were placed on farms and others at radio broadcast stations. Six (6) were to be tuned to WMT-FM, four (4) were to be tuned to WMT(AM). During the test period 420 individual observations were possible from the 42 test transmissions made over WMT and WMT-FM. The receivers responded 383 times out of the 420 possible responses. Of the thirty seven (37) non-response reports twenty three (23) were due either to the fact that no observation was made or reported by the observers. Twelve (12) were due to the receiver being improperly tuned to receive the originating station and one was due to a lightning stroke which hit near the receiver at the exact time of the test. Only one (1) was unexplained.

A similar two week test conducted from July 14, through July 27th, 1969 produced similar results, with eight receivers. (One receiver became defective and one observer went on vacation.)

During these two test periods only three (3) non-response reports were submitted which could not be explained. When compared with the 668 positive responses reported, a reliability figure in excess of 99% results. No false responses were reported.

Modification of the remaining AM/FM and the television test receivers was completed by the Zenith Radio Corporation at the FCC Laboratory in June

1969. The initial shipment of two-tone generators and AM/FM receivers to originating stations and observers in a ten-State area began on July 1, 1969.

PREPARATION FOR THE TESTS

The Special NIAC Working Group established the objective of assigning ten test receivers for test observations in the service area of each broadcast station designated to originate the two-tone test transmissions. Invitations (Exhibit J) to participate in the AM/FM tests were sent to stations in the states of Florida, Louisiana, Tennessee, Iowa, California, Indiana, Illinois, New York. Insofar as possible colocated AM/FM broadcast stations were selected to originate the test transmissions. A list of the test origination stations is shown in Exhibit K.

Upon receipt of an agreement from an AM/FM licensee expressing a willingness to assist in conducting tests by transmitting the two-tone test signal three times daily for 14 consecutive days, invitations were extended to other broadcast licensees located in the estimated service area of the station originating the test transmissions. Two hundred thirty four (234) stations participated in the tests (See Exhibit L). All participants were supplied a packet containing procedures, monitoring assignments (AM or FM), a schedule of test transmissions, a supply of daily reporting forms and self addressed, postage paid, return envelopes. Included in the packet, was a set of general instructions and the names and telephone numbers of the responsible person at the station originating test transmissions. (See Exhibit M). AM/FM receivers and tone generators were mailed parcel post from the FCC Laboratory, Laurel, Maryland. (TV receivers were delivered by truck). Daily reporting forms were requested from the originating stations and the observers. In this manner data was available on the exact time of test transmissions, whether or not a test transmission was missed or if any unusual occurrence (such as improper test transmission) occurred during any day. Reports from observers were evaluated daily against the transmission reports. Tests conducted in August and September, 1969, were for the most part between broadcast licensees to meet the requirements of the THIRD METHOD of the Emergency Action Notification System (EANS) Section 73.905(c), FCC Rules). Early in September 1969 letters (Exhibit N) were mailed to all participants in the earlier tests asking them to participate in further tests designed to meet the FOURTH METHOD of the Emergency Action Notification System. Each licensee who had been loaned a test receiver to observe test transmissions from an originating station was asked to place his receiver in the hands of a person not associated with the broadcast industry or otherwise involved with any communications systems such as police, highway patrol, etc. Each licensee was furnished a packet of instructions and reporting forms to be given to the person who would make the observations for the public tests. For this series of tests the originating stations established their own schedules and corresponded directly with either the licensees or the public observer. At the conclusion of these tests involving public observers the test receivers were to be returned to the broadcast licensees for further tests to be specified by the Special NIAC Working Group.

RESULTS OF PROOF-OF-PERFORMANCE TEST

Exhibit O shows the approximate geographical location of twenty-eight two-tone signal generators. One generator (the prototype) is retained at the FCC Laboratory. The one remaining generator has been held as a spare.

With test receivers on location the test transmissions commenced August 11, 1969 with approximately fifty-four (54) observers reporting. Exhibit P displays the number of receiver observers reporting during the months of August, September, October, November and December, 1969. The peak number of observers reporting at any one time was two hundred fifty four (254).

Television tests were conducted through August, September and October, 1969 as shown on Exhibit P.

Referring to Exhibit P, the tests held in June and July involved both radio station personnel and the general public as observers. Test receivers for the August/September, 1969 tests were located, in most cases, either at radio broadcast studios, or transmitters or in the homes of broadcast personnel. Receivers for the September/October/November and December, 1969 tests were loaned to members of the general public who had no connections with the broadcast industry.

During all of the tests a total of 18,129 positive receiver responses were reported. Potentially 23,631 individual observations could have been reported had all observers been able to observe and report every test, and if all broadcast stations could have conducted each test on time and without failure. As it turned out the difference between the actual positive responses reported and the ideally potential number of responses and reports was 5,502. The reasons why the ideal potential was not reached is as follows:

- In 2,670 cases, reports were not made or not submitted by the observers or tests were not observed due to absence of the observer, or in some cases were lost in the mail.

- In 211 cases the receiver was reported as being improperly tuned to the originating station to receive a test.

- In 596 cases the originating station failed to run the tests.

- In 2,025 cases reports were received which indicated that the receivers did not respond to the test signals.

The 2,025 non-response reports were carefully examined and separated into three very definite categories. It was found that in 934 cases the RF signal available to the receivers was either too weak, non-existent or was subject to excessive interference from other stations, from television receivers, or from saturation due to being placed in excessive RF fields, for example only a few feet away from AM and FM broadcast transmitters. 720 of the non-response reports were determined to be due to malfunctions in test receivers. The remaining 371 non-response reports were not explained by reporting observers.

As shown above, 23,631 individual observations potentially could have been made. Had all been reported as positive responses the tests could then be given a score of 100%, representing the most favorable condition. On the other hand the most unfavorable condition would be represented by assuming that all observations not reported as positive responses were in fact failures. This would result in a score of 76.7%. Neither of these percentage figures or scores are realistic hence a more representative figure lies somewhere between them.

2,670 observations were reported as not having been made or no report was received. This number represents 11.3% of the ideal potential total. It cannot be said with certainity that had these observations been made they would have been reported as "positive responses" or as "non-responses", thereby providing no solid grounds for judgement.

In 211 cases the observer stated that the receiver was not properly adjusted for the test. Without question this reduces the number of ideal potential observations.

In 596 cases observations were rendered impossible because the test transmissions were not broadcast by the originating station. There can be little question that this situation also reduces the number of ideal potential observations.

A total of 1654 observations reported as non-responsive can be directly related to insufficient RF signal from the observed station and to defective receivers, neither of which represents a normal condition. Therefore it is the Sub-Group's judgement that the number of ideal potential observations should be reduced by this amount.

The above accounts for all but 371 of the total possible observations that could ideally be made. These 371 observations were reported merely as non-responsive with no explanations, hence they could be judged to represent 371 potentially positive response reports. Adding this number (371) to the total number of positive responses reported (18,129) and assuming the sum to represent the total number of potential responses, it can be said that the tests resulted in a score of 98%.

Reducing the ideal number of observations by those missed through improperly adjusted receivers (211), test transmissions not made (596), insufficient RF signal (934) and defective receivers (720), the number of potential observations then becomes 21, 170. On the premise that the 2,670 cases where no observations were reported or no reports were received (plus the 371 unexplained non-response reports) must, in fact be considered as non-responsive observations, the test score can then be placed at 87.4%. This treatment, however, seems unduly harsh and not realistic.

From the above discussions it can be seen that a precise figure of merit is not mathematically obtainable. The subgroups, however, find the results acceptable. In view of the complete absence of proven false responses there can be no question as to the effectiveness of the system, providing the recommended precautions are taken by manufacturers in the design and fabrication of responsive circuitry in their receivers.

DEFECTIVE TEST EQUIPMENT

Two hundred sixty-three (263) of the three hundred (300) AM/FM test receivers produced reports during the tests. The thirty seven which did not produce reports are all accounted for. Several were defective from the outset, two were stolen, one was burned, one was damaged by Hurricane Camile, four were loaned to the Office of Civil Defense and some were never used to observe tests for other reasons. During the tests forty four AM/FM receivers and seven TV receivers developed defects. There were two major causes for the receivers becoming inoperative for test observations. An electrolytic filter condenser is used in the low voltage power supply for the responsive circuitry in all receivers. In the AM/FM receivers this power supply also provides voltage to the RF and Audio sections of the receivers.

It is estimated that in twenty-five to thirty AM/FM receivers the electrolytic condenser developed an "open" condition causing an excessive hum, garbled sound and erratic operation of the responsive circuitry. Where competent, the observer was authorized to replace the capacitor which was easily identified.

The next most troublesome problem was the contacts of the small relays used in the responsive circuitry. Here again, where possible the observer was instructed and authorized to clean the contacts.

Some few receivers developed normal receiver troubles such as becoming insensitive and ceasing to function all together due to burned out power transformers, bad transistors, etc. Some television receivers experienced loss of synchronization due to weak or burned out tubes.

The two-tone signal generators performed well. One developed faulty relay contacts and in another a transistor became defective. One originating station suggested that the tuning forks (for 853 and 960 cycle-per-second) be shock-mounted since the fork vibrations were mechanically transferred to the rack cabinet which in turn acted as a sounding board to audibly distribute the sound throughout the master control room.

EXTRA SENSITIVE RECEIVERS

Just as there were defective test receivers there were also test receivers which performed over and beyone expectations. Examples of such performances are as follows:

- Receiver #293, from August 18th through August 31, 1969, was located at Station WCKS(FM) Cocoa Beach, on the eastern shore of Florida. Receiver #293 was tuned to WFLA-FM Tamps, Florida on the Gulf of Mexico. The distance was in excess of 100 miles and the estimated signal strength at the receiver (from the F(50, 50) FM Channels Curves, Figure 1, Section 73.333) was in the order of 20 microvolts per meter. 37 out of 40 tests were reported as positive responses.
- Receiver #129, from September 1st through September 15, 1969, was located at Station WTJS, Jackson, Tennessee for the purpose of monitoring WSM-FM, Nashville, Tenn. The distance is approximately 115 miles and the signal strength at the receiver in the order of 30 microvolts per meter (per Figure 1, Section 73.333 of FCC Rules). Forty four test transmissions were made by WSM-FM. On forty-one of the tests the receiver gave positive responses. One test was missed due to the receiver being improperly tuned and two tests were reported as non-responsive.

Receivers with only a short whip antenna tuned to an FM station 100 miles away does not necessarily represent a normal mode of listening, but the exceptional response does indicate that FM networks can be successfully activated through the use of the two-tone attention signal.

SKYWAVE OBSERVATIONS

A few observations were made in Philadelphia, Pennsylvania and Syracuse, New York on the nighttime signals of WSM(AM) Nashville, Tennessee.

On each occasion the receiver responded to the two-tone "Attention Signal." Bearing in mind that WSM operates on 650 Kc/s and that WNBC, New York City operates on 660 Kc and further that the test receivers utilize only a ferrite core antenna for AM reception, there can be little question that, if required, the use of the two-tone signal over great distances via AM sky-wave can be used for activating muted receivers. (Nashville to Syracuse approximately 740 miles - Nashville to Philadelphia approximately 675 miles).

LONG DISTANCE TV OBSERVATION

A similar situation was found during the television tests. TV Test Receiver #027 was located in the vicinity of New York City for the purpose of making reports on the transmissions of WNBC-TV, Channel 4, New York, New York. During the early morning hours of August 29th and 30th, 1969, Station WRC-TV Channel 4, Washington, D. C., made on-air tests of the two-tone attention signal in preparation for a 14 day test period starting September 29, 1969. WNBC-TV New York had completed its broadcast day and was off the air. Television Test Receiver #027 had been left in the muted position during the night, tuned to Channel 4. The WRC-TV test transmissions demuted the receiver on both test transmissions both of which were conducted using the WRC-TV test pattern for station video identification.

FALSE RESPONSE REPORTS

During the period of tests (June through December, 1969) 25 false response report forms were received. 24 reports were found not to have any validity, as can be seen by reference to Exhibit Q. The observer on Receiver #241 submitted five false response reports. Four of the five were found not to be valid apparently due to a misunderstanding by the observer as to what constitutes a false response. One report could not be explained and could be a valid false response. However, in view of the observers pattern of submitting false response reports and his apparent lack of comprehension of what constituted a false response, the working group places no significance upon the report in question. It is therefore concluded that not once during the tests did any test receiver falsely activate itself.

STL's

During committee deliberations some concern was expressed about the effect on the two-tone signal when transmitted by stations using Studio Transmitter Links. Two stations in California, one station in Florida, and one in Louisiana experienced no problems with STL's.

METHOD OF TABULATING REPORTS

The Field Test Ad Hoc Committee endeavored, as nearly as possible, to make the tabulation of the daily test reports a "Go" "No Go" process which would yield that data required to make a judgment on the proposed two-tone signalling system. It was essential that certain basic statistics be determined from the reports, for example, exactly how many tests were conducted by each originating station, were the tests conducted on schedule, did any unusual occurrence take place at the station before, during or after each test, (2) if a positive response to a test was not reported by an observer, what was the cause?

The daily reporting forms for both originating stations and observers (Exhibit R) were used in two equipment acceptance tests and in two test periods in Iowa involving approximately 1700 individual test reports. As a result of this experience one deletion was made from the observers daily report form; namely, a question asking the observer "How long he heard the two tones." In some few instances the form was misunderstood, but in the main the reporting was consistent.

Exhibit S is the form used to tabulate the data from the observer's daily reports. Where necessary, notes were added. Exhibit T was used to total the results.

AUDIO PROCESSING EQUIPMENT

Many stations utilize audio signal processing equipment to obtain various treatments of the program material before it is fed to the transmitter. Only in one instance during the tests did such processing equipment appear to present a problem. Upon examination it was found that the station was endeavoring to bring the modulation level up to 80% with both tones being applied simultaneously to the audio input. As explained before each tone must be applied individually and the modulation level adjusted to 40% $\pm$ 5%. When this is done and both tones are applied simultaneously the modulation monitor will not read 80% $\pm$ 10%, which is what the station was trying to achieve. As a result the audio processing equipment was being run beyond its limits introducing distortion and unstable operation. After the audio levels were properly adjusted for each individual tone the station experienced no further trouble.

FORMS

A wide variety of forms, memoranda and letters were required during the course of the tests. Although some of these items appear in other Exhibits, Exhibit U contains samples of those used during the equipment acceptance tests, the tests between stations, the general public tests and the television tests.

USE OF MAGNETIC TAPE AS A SOURCE OF THE TWO AUDIO TONES

During the course of tests of the two-tone signalling system one station, KALB-FM, Alexandria, Louisiana, conducted tests for one week (September 22nd thru September 28, 1969) using a tape cartridge. The tones were recorded on the tape from the two-tone signal generator (Serial #14) provided to KALB for the tests.

This particular test took place during the period that the test receivers were in the hands of the general public. Only five receivers were assigned to make observations on KALB-FM (#'s 055, 011, 077, 149 and 237). Receiver 011, and 055 became defective during early tests. #055, located in Alexandria did produce 12 positive activations out of a possible 21. Receiver #077 was located at Jennings, Louisiana about 75 miles South of Alexandria. The public observers reported that the signal was weak and was accompanied with background hiss. Four positive responses were reported during the time the tape cartridge was used by KALB. During the second week of tests when the tone generator was used by KALB-FM, all tests were reported as positive.

Receiver #149 was located at Natchitoches, Louisiana, about 50 miles northwest of Alexandria. Only the nighttime (3rd) test of each day was to be observed on KALB-FM. Out of 7 possible tests 4 were reported as positive.

Receiver #237 was located in Shreveport, Louisiana, which is approximately 140 miles from Alexandria, Louisiana. Not one positive report was received from the observer during the two week test. This receiver was placed at KWKH, Shreveport, Louisiana, to provide a test of off-air network possibility between Alexandria and Shreveport. KWKH had used a yagi antenna in earlier tests with very good results for a 140 mile path. The public observer (a lady) had no such antenna.

At a meeting held in Washington, D. C. March 25, 1970 of the Transmission Standards Sub-Group, the Interconnecting Facilities Sub-Group and the Field Test Sub-Group, it was concluded that findings as to how the attention signal should be electrically generated was not required of the NIAC since such specifications would fall more reasonably in the area of development. For example, when the NAB Recording Committee established standards for magnetic tape speeds of 7.5, 15, and 30 inches per second, the committee did not specify the mechanics of obtaining those tape speeds.

The Sub-Groups in joint meeting adopted theposition that any broadcast licensee may apply to the FCC for authority to conduct on-air tests of the two-tone signalling system using magnetic tape (or other methods) to produce the two-tone Attention Signal, as a developmental project. The Committee further supported the proposal that any broadcast licensee who wished to conduct such a developmental program should be given authority to use the NIAC two-tone receivers (and a tone generator) for a period as long as a year. The Sub-Group, in joint meeting (March 25, 1970) made it abundantly clear that such developmental projects would be carried out by broadcast licensees for the benefit of the broadcast industry and that such projects, even though supported by NIAC, would not constitute a NIAC activity.

ECONOMICS

Acceptance of the two tone signalling system, or for that matter any system, by receiver manufacturers and the general public will depend on the amount of added cost which the consumer is willing to pay for the added feature. Any consideration of the cost encountered to add responsive circuitry to the receivers chosen for the tests would be totally inappropriate. However, even during the time of development of the circuitry for the test receivers, frequency sensitive devices became available on the market at a price which was from one-third to one-half the cost of the frequency sensitive devices actually used in receivers for the tests.

It is the Sub-Group's strong conviction that once the FCC announces adoption of the two-tone signalling system, receiver manufacturers will commence their development of receivers designed to be responsive to the two-tones and that through application of the latest technology will bring the added cost to an acceptable figure.

The cost of equipment to generate the two-tones for Attention Signal transmissions by radio and television broadcast stations will also be brought to a minimum by the manufacturers of broadcast type equipment.

LATCHING VS. NON-LATCHING RECEIVERS

Test receivers specified by the Sub-Group for the proof-of-performance tests are of the latching variety. That is, when the responsive circuitry is activated, a relay with a pair of holding contacts is closed. This relay demutes the receiver, if it is muted, and by-passes the volume control for full volume. To remute the receiver or reduce the volume level, a small button on front of the receiver must be momentarily pushed to release the holding relay.

A survey was made by the Defense Commissioner in April, 1965 among the twenty members of the Executive Committee of the Special NIAC Working Group to determine their preference for either the latching or non-latching system for both the Third and Fourth Methods of the EANS. Eighteen replies were received. Twelve preferred the latching system whereas only three felt the non-latching system to be more appropriate.

Receivers need not be designed to latch at full volume until the volume is manually reduced. If full volume is desired for alerting purposes the circuitry can be designed to return the volume to normal after any desired time interval. In fact the circuitry can be designed to remute the receiver after a time interval.

A non-latching system is sometimes referred to as a driven system. As with the latching receiver the non-latching receiver is activated by the transmitter signals. In the non-latching system a holding tone is transmitted continuously to keep the receiver turned on. When the holding tone is no longer transmitted, the receiver returns to its muted or normal listening condition.

The driven system possesses an advantage in that theoretically it can be tested without undue annoyance to a listener. However, if receivers for the two tone system are constructed with a "timed-latch," to attract attention, the annoyance of testing to the listener would be no more or less than with the driven system.

OTHER SIGNALLING SYSTEMS

On February 13, 1969 the FCC issued a Public Notice wherein it was recognized that the work of the Special NIAC Working Group looking toward an improved EBS Signalling and Public Alerting System had been in progress for more than five years and that during that period the rapid pace of communications technology presented the possibility that there may be systems other than the proposed two-tone system that warranted consideration. Accordingly, the Commission extended the deadline for submission of new system proposals to May 1, 1969. The Public Notice (Exhibit V) stated that, "...... in view of the considerable effort already expended toward perfecting the proposed NIAC two-tone alerting system, any competing proposal must, on its face, demonstrate a marked overall superiority to the proposed NIAC two-tone system in order to qualify for consideration." The Public Notice went on to say, "Any proposals received will be referred to the Special NIAC Working Group for evaluation, with recommendations to be submitted to the Commission."

One new system proposal was submitted in accordance with the Public Notice by the International Electric Corporation (IEC), Minneapolis, Minnesota. The system proposed by IEC referred to as the Cue Signal System, was developed by engineers of the Kokusai Electric Co., Ltd., Tokyo, Japan. Proponents of the Cue Signal System were invited to demonstrate their system to the Special NIAC Working Group - Emergency Alerting of the General Public - Transmission Standards Sub-Group. The demonstration was presented in Room 752, offices of the FCC, the morning of June 11, 1969. Following the morning demonstration a joint meeting of the Transmission Standards Sub-Group and the Field Test Sub-Group was held in the afternoon of June 11, 1969, where in accordance with the Public Notice (Exhibit V) an Ad Hoc Group was appointed to prepare a formal evaluation of the IEC proposed Cue Signal System for consideration by the Transmission Standards Sub-Group and transmittal to the FCC. The Evaluation Report was completed and transmitted to the Chairman of the Special NIAC Working Group for approval of the Executive Committee. The Executive Committee approved the Evaluation Report and transmitted it to the Defense Commissioner. The chairman's letter of trans mittal and the-Evaluation Report are attached as Exhibit W. It will be noted that the Evaluation Report concludes that the Cue Signal System proposed by the IEC does not demonstrate marked superiority compared to the NIAC two tone system, and that it does not appear that a comparative field test is warranted. The Defense Commissioner transmitted these findings to the IEC in March 1970, advising the IEC that the NIAC intended to proceed with the two-tone system and they did not intend to give further consideration to the Cue Signal System.

GENERAL OBSERVATIONS

Proof-of-performance tests of the two-tone signalling system have been conducted in a manner which would hopefully yield data representative of day-to-day situations as compared to a sterile and highly controlled laboratory type of test which would not be matched in reality. In many instances test receivers were placed at locations where it was known in advance that the signal from the station originating the test transmissions would be marginal in strength or would be interfered with either by co-channel or adjacent channel stations. This was not a normal listening condition, yet the evidence is clear that the system under such conditions possessed a high degree of responsiveness.

It is equally evident that those test receivers placed in locations where normal listening reception is expected, were responsive and, unless defective, functioned without problems. On the contrary reports were submitted showing in some cases that test receivers responded where the atmospheric and electrical noise was of such level as to render the modulation unintelligible by the listener.

The Sub-Group is of the opinion that many non-response reports would have been eliminated had the originating station and the observers been given a few trial run test-transmissions before the actual reporting began. As it was, reports were expected from the very first test transmission where the observer in practically all cases had not previously experienced a test or knew what to expect from his receiver.

CONCLUSIONS

Proof-of-performance tests of the proposed two-tone signalling system were conducted in the course of every day events by persons associated with broadcast stations and by persons representative of the general public. A count has not been made but it is conservatively estimated that more than 1500 different individuals participated in some manner, giving their time voluntarily and without cost to the Government.

A deliberate effort was made not only to keep the equipment simple but to keep the test procedures and activities as simple as possible yet productive of useful data.

No special precautions were taken in the selections of stations to be used for origination of the test transmissions, except to endeavor to obtain collocated AM and FM stations to enable the use of a single tone generator for both services. The selection of broadcast licensees to participate as reporting observers was carried out so that test receivers would be located and operated under many different environments, for example, high intensity signal areas, low intensity signal areas, areas subject to high level atmospherics or industrial noise, areas where signals would fade or be subjected to co-channel or adjacent channel interference. Some few test receivers were located to check a portion of an FM State Network.

AM/FM test receivers and all tone generators were delivered via parcel post. TV receivers were delivered to licensees by truck. Test observers were mailed instructions, procedures and schedules. There was no attempt to conduct training classes for observers, nor were receivers placed in carefully selected areas where, if measured, the field intensity of the originating station would be most favorable. (Field intensity measurements were not required).

Test receivers that were functioning properly and which were located in a reasonable RF field from the originating station did not fail to function or respond to the two-tone test transmissions. No attempt has been made to go back to test observers to determine the cause of those non-response reports which could not be explained. It is reasonable to assume that if a detailed search were to be made a larger number of the non-response reports could be explained satisfactorily. However, in view of the very low number of such unexplained reports and the very large number of positive responses, reports in the Sub-Group's possession indicate that further search is not necessary, since it has been proven that the two-tone attention signal can be relied upon to cause responsive circuitry in a receiver to react to the incoming signal on command and to reliably perform whatever switching function is desired of it.

During the long periods between test transmissions the test receivers were in effect being tested to determine whether they could be activated by the program content of the station to which they were tuned or by received electrical noise or interference. Exhibit Q outlines the false response reports submitted by observers. In only one instance is there a possibility that a false response did occur, but even that one is doubtful because of the circumstances under which it was submitted.

The Sub-Group specified that the responsive circuitry in the receiver must not respond until 8 seconds of tone transmission had been observed. The test receivers were equipped with circuitry designed to function after receiving the two tones for 12 seconds. In view of the complete lack of provable false responses in both Laboratory and field tests using a time delay of 12 seconds, it is the Sub-Group position that essentially the same conditions would have been experienced had the time delay in the receiver been set at 8 seconds.

The Transmission Standards Sub-Group then concludes that (1) the Attention Signal and transmission standards used during the proof-of-performance tests should be recommended for adoption and implementation by the FCC, and that (2) the FCC recommend that radio receiver manufacturers who plan to offer receivers for sale containing circuitry responsive to the two-tone attention signal, so design their receivers to require at least 8 seconds of the two-tone transmissions before any reaction or switching takes place.

APPENDIX B

NATIONAL WEATHER SERVICE CRITERIA FOR VHF-FM TONE ALERT ACTIVATION

NATIONAL WEATHER SERVICE SILVER SPRING, MARYLAND 20910	Operations Manual Letter 71-8

Date of Issue: April 1, 1971	Effective Date: April 1, 1971
In Reply Refer To: W112x1	File With: C-64

Subject: Criteria for VHF-FM Tone Alert Activation

Activation of the VHF-FM tone alert signal is required by, and restricted to, the following conditions:

1. Upon the issuances of all watches or warnings for meteorological and/or hydrological phenomena affecting any area within the broadcast range;

2. Whenever a severe weather and/or hydrological statement or report is issued which contributes significantly to the awareness and preparedness of the public;

3. When, in the judgment of the OIC/MIC or duty officer, there is an urgent need to inform all concerned of existing or expected hazardous meteorological and/or hydrological conditions; or

4. For drill purposes or the testing of the tone alert equipment. Activation for drills and routine testing shall be limited to Wednesdays between 1000 and 1300 LST, and when no inclement weather is forecast for the general area. Tone alert signal activation for all drills and tests shall be accompanied by a statement emphasizing the fact that it was for a drill or test.

George P. Cressman

George P. Cressman
Director, National Weather Service

APPENDIX C

RECEIVER COST DATA

This appendix presents a compilation of receiver, transceiver and special-purpose monitor equipment by type. The data contained herein forms the basis for and is summarized in Figure 2-1, Section 2 of this report.

The information was collated from electronic equipment retail catalogs, manufacturer's brochures and from a compilation made by the National Weather Service. Prices shown are current where available, but are subject to change. The list of equipments is not intended to be exhaustive but a representative cross-section of the devices available in each category.

C.1 AM BROADCAST BAND PORTABLE RECEIVERS

The number of models priced in this category is too large to permit inclusion. Many devices are unidentifiable as to manufacturer or model, being listed only as "portable AM radio," "7-Transistor Mini-Radio," etc. The devices ranged in price from $4.95 to $16.95.

C.2 AM/FM BROADCAST BAND PORTABLE RECEIVERS

Manufacturer or Distributor	Model or Catalog Number	Price $
Allied	10A 4225 S	11.88
Lafayette	Deluxe AM/FM	14.95
Lloyd's	10C 4030	16.95
Panasonic	10C 4026 S	19.95
Sony	3F-85	24.95
Allied	2680	29.95

C.3 AM BROADCAST BAND/147-174 MHz VHF BAND*

Manufacturer or Distributor	Model or Catalog Number	Price $
Lafayette	Guardian II	21.95
Juliette	AM/PB	24.95
Lafayette	AM-PFB	29.95
York	AM/PSB	29.95
Sonar	FR103 XTAL	39.95
Sonar	FR103-SA	49.95

*These devices are tunable across or have single-channel capability in this band.

C.4 MULTI-BAND PORTABLES WITH 147-174 MHz BAND

Manufacturer or Distributor	Model or Catalog Number	Price $
Allied	10A 4347 S	32.95
Craig	Police Band Portable	39.95
Lafayette	Air Master 400	44.95
Soundesign	Five Band	59.95
Lafayette	Guardian 5000	59.95

C.5 PUBLIC SERVICE BAND MONITORS

Manufacturer or Distributor	Model or Catalog Number	Price $
Lafayette	VHF Monitor	17.95
Allied	VHF Monitor	17.95
ERI	Multivox 140	19.95
Juliette	APB-11	22.95
Radio Communications	Weathercaster	24.00
Halicrafter	CRX-102	39.95
Tonemaster	36A 5003	49.95
Lafayette	PB-150	69.95
Lafayette	PF-200	99.95
Electrocorp	Bearcat	139.95
Standard Radio	SR-C804Z (6 channel marine)	139.95
Regency	DR-200	200.00

C.6 PUBLIC SERVICE BAND MONITORS WITH TONE-ALERT FEATURE

Manufacturer or Distributor	Model or Catalog Number	Price $
Federal Sign and Signal Corp.	10-10 AP	156.00
Regency	TMH 1-T	186.00
Cobra	10-6	189.00
Motorola	-	200.00

C.7 VHF MARINE TRANSCEIVERS

Manufacturer	Model	Channels	Power	Price
Standard Radio	SR-C811 S	6	3	199.95
Pierce-Simpson	Binini	6	25	249.95
	Capri	12	25	299.95
Standard Radio	SR-C801 SA	12	10	329.95
Simpson	-	-	3	330.00
Sonar	M2308	5	25	395.00
Standard Radio	SR-C851 S	12	25	449.95
Konel	-	12	25	499.00
Unimetric	-	12	-	499.50
Heathkit	VHF-FM	6	25	499.95
RF Communications	-	12	25	555.00
	-	12	25	683.00
ITT-Decca	STR-15	-	25	750.00
Collins	-	All*	25	2400.00
Motorola	-	All*	25	2400.00

*Employs frequency synthesizer

APPENDIX D

CHARACTERIZATION OF RECEIVER TYPES

D.1 INTRODUCTION

This appendix presents a detailed report of the test procedures used to characterize the performance of portable AM, FM, and VHF receivers. The resultant performance characterization, in the form of input/output curves, are also included.

The potential utility of a given weather dissemination system depends primarily on the parameters of the receivers being used since the parameters of the transmitters are more or less fixed. This is particularly true for commercial AM and FM broadcasts, where the types and qualities of receivers can greatly vary. The variability of receiver parameters is not nearly so great for Public Coast radiotelephone and Coast Guard VHF broadcasting systems, since these receivers are of the "installed" rather than "portable" variety.

D.2 SCOPE

Considerable effort was expended in gathering specifications on various kinds and types of receivers and on determining the precise meaning and definition of the performance parameters quoted by various manufacturers and suppliers. It soon became apparent that while much of the specification information was useful in comparing one receiver against another, it was virtually impossible in most cases to determine absolute receiver performance from it. The performance parameters of major interest are "sensitivity," which is a measure of the signal power required for a given level of performance; and "selectivity," which is a measure of a receiver's ability to reject out of band interfering signals.

In the case of "installed" receivers, such as VHF/FM and MF/AM radiotelephone equipment, the available specifications were consistent and sufficient to characterize an "average" receiver. For VHF/FM equipment, the average sensitivity was determined to be approximately 4 μV for Grade 3 service. This figure was corroborated in a survey reported in Reference 5. In the areas being studied for MF/AM receivers, the noise floor of the receivers will be determined by the atmospheric, or external, noise level (Appendix E). Hence, the absolute sensitivity of these receivers is not of major importance.

Unfortunately, specification data available and obtainable was inconsistent and not sufficient to characterize the performance range of portable receivers likely to be used by recreational boatmen to monitor commercial broadcasts or the NWS VHF/FM broadcasts. To this end, a series of tests was designed to allow performance predictions to be made, in terms of useful range, for these portable receivers. These tests were carried out with the cooperation of the U.S. Coast Guard, which provided marine transportation and equipment required, and the National Weather Service, which provided most of the receivers to be evaluated.

D.3 TEST PROCEDURE

In the design and planning of the tests, every effort was made to conform to EIA and/or IEEE standards and definitions wherever possible (References 5, 6, 7, 8, 9, 10, 11, 12 and 13). Specifically, the tests were performed using a 1-kHz tone, 60 percent modulation for AM, and 3.3-kHz peak deviation for FM. The measured sensitivity should be termed "radiation sensitivity," since the performance was plotted as a function of the signal strength at the antenna rather than at the input to the receiver (chassis sensitivity).

The outputs of the receivers were measured at the speaker terminations. The "signal + noise" measurement was made with a modulated sinusoidal 1-kHz tone applied to the receiver; the "noise" measurement was made with the modulation removed, but with carrier present. Audio output measurements were made as the input signal power was varied.

This type of testing was necessary since the available specifications were:

a. "Chassis sensitivity" numbers, which were referenced to a 50-ohm input impedance (determination of actual effective input impedances for the variety of available receivers was beyond the scope of the study).

b. In no way related to the wide range of variability in required signal power imposed by the different sizes, types, and qualities of antennas presently in use on commercially available receivers.

The purpose of these tests was to characterize the effect of receiver performance variations on the potential useful range of given weather dissemination broadcast systems. The tests were not designed to provide an absolute characterization of the performance of any one receiver or receiver type, and the results should not be interpreted in such a manner. Essentially, the tests provided a framework of control conditions within which it was possible to make a subjective evaluation of range limitations imposed by representative receivers with known relative performance parameters.

D.4 PERFORMANCE OF THE TESTS

Three types of tests were performed:

a. Open field tests under controlled conditions.

b. Laboratory tests under controlled conditions.

c. Subjective open field evaluation of actual broadcasts.

The receivers tested were of three types:

a. Portable AM broadcast receivers employing ferrite loop antennas.

b. Portable FM broadcast receivers employing extendible whip antennas.

c. Portable VHF-FM receivers employing extendible whip antennas; both fixed crystal tuned and variable tuned types.

The specific receivers tested were:

VHF - Sentry - Sonar FR103 - Ser. 1487743 (VHF & AM)

VHF Monitor - Lafayette - Stock No. 99-3531L

VHF Monitor - Hallicrafter - Model CRX-102

VHF Monitor - E.R.I. Multivox, Model 140 (VHF & AM)

VHF Monitor - Federal Sign and Signal - Model 1010 - Ser. 21222

VHF Monitor - Lafayette - PB-150 - Ser. 18310

Broadcast - Lafayette - Model 17-0167L (AM & FM)

Broadcast - Zenith - Royal - Model 51 (AM & FM)

The configuration of the test equipment is shown in Figures D-1 and D-2. The following equipment was used:

Stoddart Power Supply - Model 91923-2 - S.N. 66B156

Stoddart RI-FI Meter - NM-30A - S.N. 66AD81

Stoddart RI-FI Meter Assy. - NM-20B - S.N. 414-20

Stoddart Power Supply - Model 90780-2 - S.N. 414-20

High Frequency Antenna Kit - Model 91870-2

Loop Antenna Model 90298-2

Tripod - Model 91933-2

Cable Package

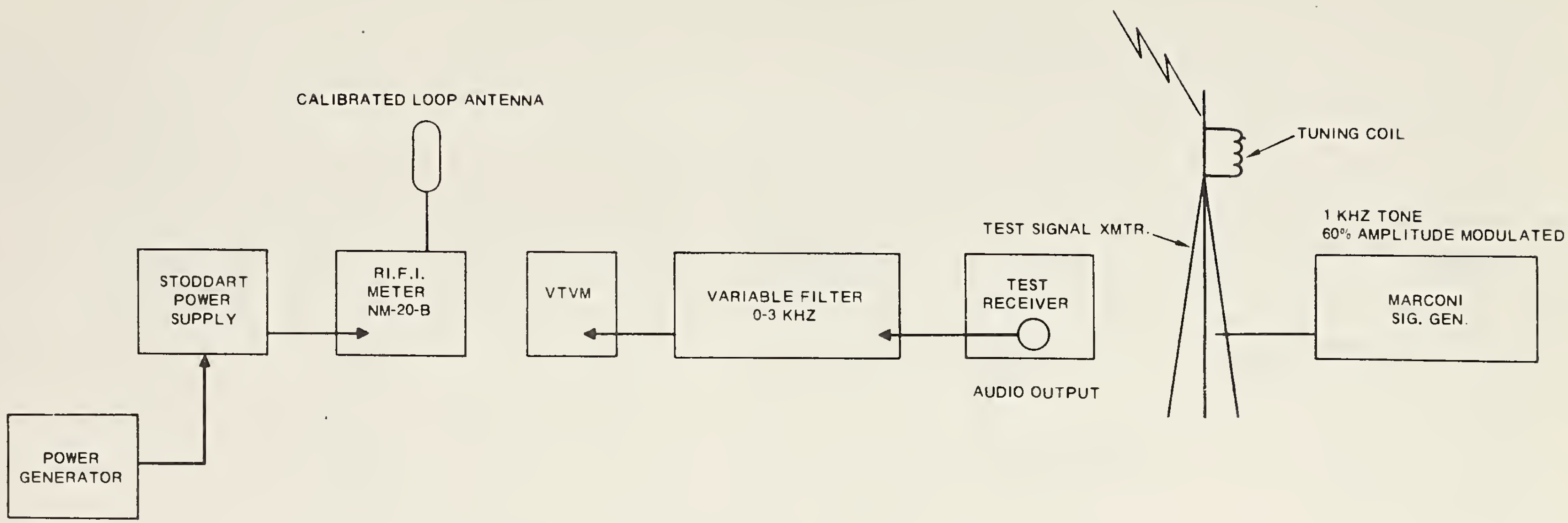

Figure D-1. Field Test Configuration - AM Portable Receivers

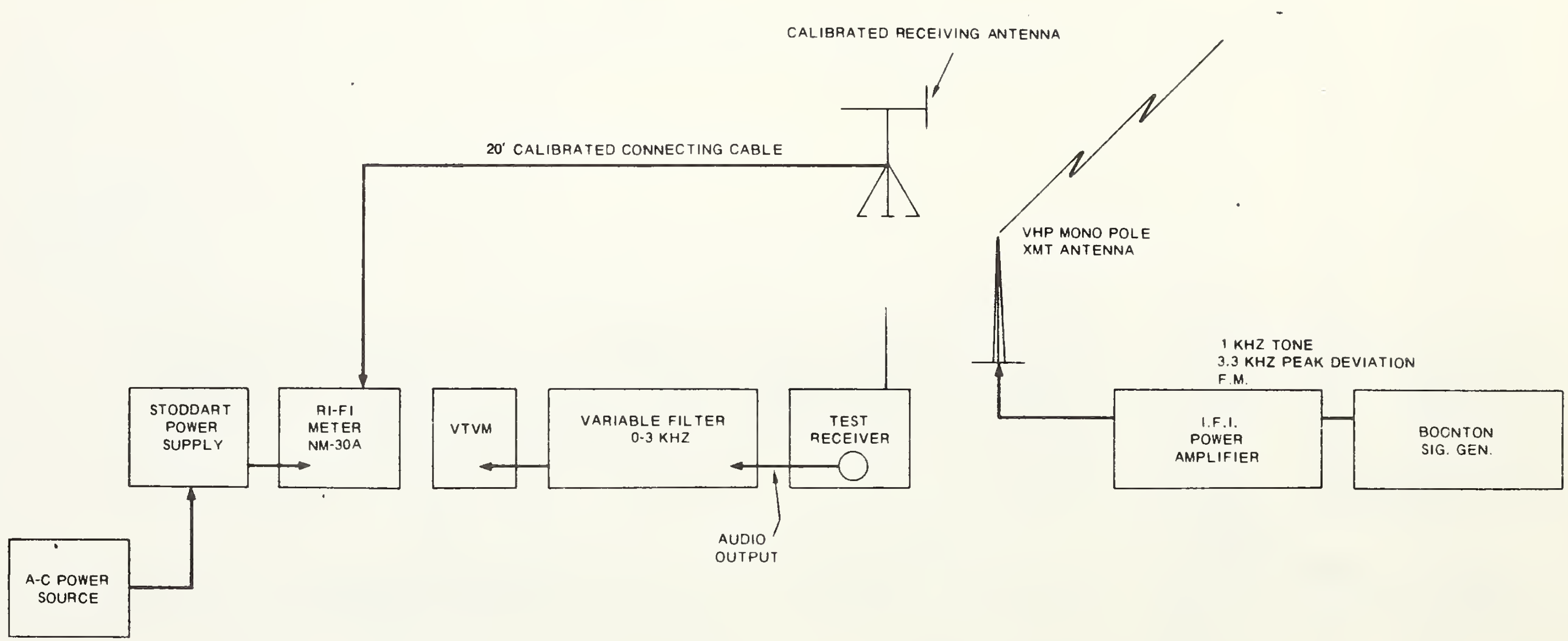

Figure D-2. Field Test Configuration for FM Portable Receivers

Marconi Signal Generator - Model TF144/H4 - S.N. 662500895

Ballentine RVTVM - Model 320A - S.N. 6538

R.I.I. Variable Filter - R-5000 Series

Tuning Coil - 92 μ Henry

100' ft. Power Extension Cord

Portable Power Generator

I.F.I. Power Amplifier - S.N. 01017

Boonton Signal Generator FM/AM - Type 202H - S.N. 662506893

The open field tests were performed at a site in Alexandria, Virginia. For the AM receiver tests, the receivers and field strength measuring equipment were located a little more than one-quarter mile from the transmitting antenna to ensure that the receivers would be located in the "farfield" of the transmitting antenna. Due to this requirement, it was not possible to perform additional testing of AM receivers within the confines of the laboratory.

The open field tests on FM receivers were performed in the same general location, but the distance between the test signal transmitter and the receivers was less than 200 feet. These tests were repeated within the laboratory using the same configuration depicted in Figure D-2 but different transmitting antenna.

For the AM receiver open field tests, the transmitted signal power was varied over a range that produced measured field strength at the receivers of from 400 μV/m to 5600 μV/m. For the FM receiver open field tests, received field strength was varied between 200 μV/m and 20,000 μV/m. These ranges of received field strength were adequate to ensure measurements from below receiver noise to saturation.

Laboratory tests were performed on the portable FM receivers over a range of signal strengths varying from 5 μV/m to 32,000 μV/m, as measured at the receiver. These tests were performed on two successive days under conditions of high and low external noise levels.

On 24 November, CSC personnel were taken aboard a 40-ft. Coast Guard boat from the Annapolis, Md., station. The test receivers were taken aboard and stops were scheduled at approximately 5-mile intervals so that receiver performance could be evaluated while actually monitoring commercial broadcasts and NWS station KHB-36. These evaluations were performed on the Chesapeake Bay between Annapolis and Cove Point. Commercial AM broadcasts were monitored from stations WBAL, WCAO, WPIK, and WNAV. Commercial FM broadcasts were monitored from stations WCAO and WNAV. The locations of each stop were determined by Coast Guard personnel so that each set of evaluations could be related to the distance from each of the transmitting sites. The expected field strength at each of the monitoring points was then determined by interpolating from these stations published field strength contours, using standard transmission curves of References 3 and 4.

D.5 RESULTS

The results of the above tests and evaluations were combined and are presented in the form of input/output characteristics in Figures D-3 through D-6. These curves are the result of averaging the measured data. They compared favorably with the subjective evaluation performed on the Chesapeake Bay. The curves represent the characteristics to be expected of commercially available portable receivers, and should not be interpreted as the "specified" or performance characteristics of any given receiver. Their main purpose is to provide a data base from which the expected effective range of various potential

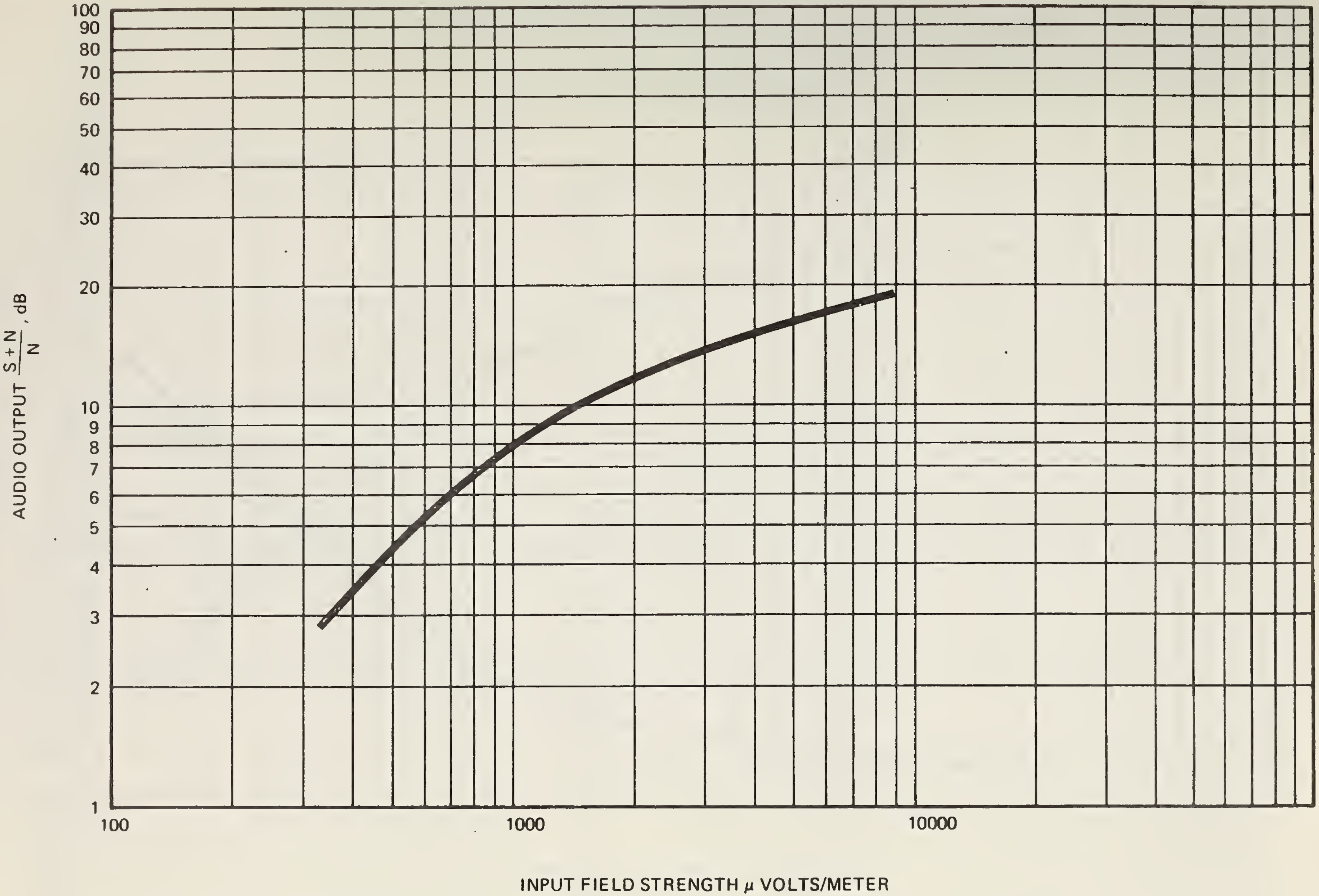

Figure D-3. Average Characteristics for Portables AM-Broadcast Receivers - Ferrite Loop Antenna

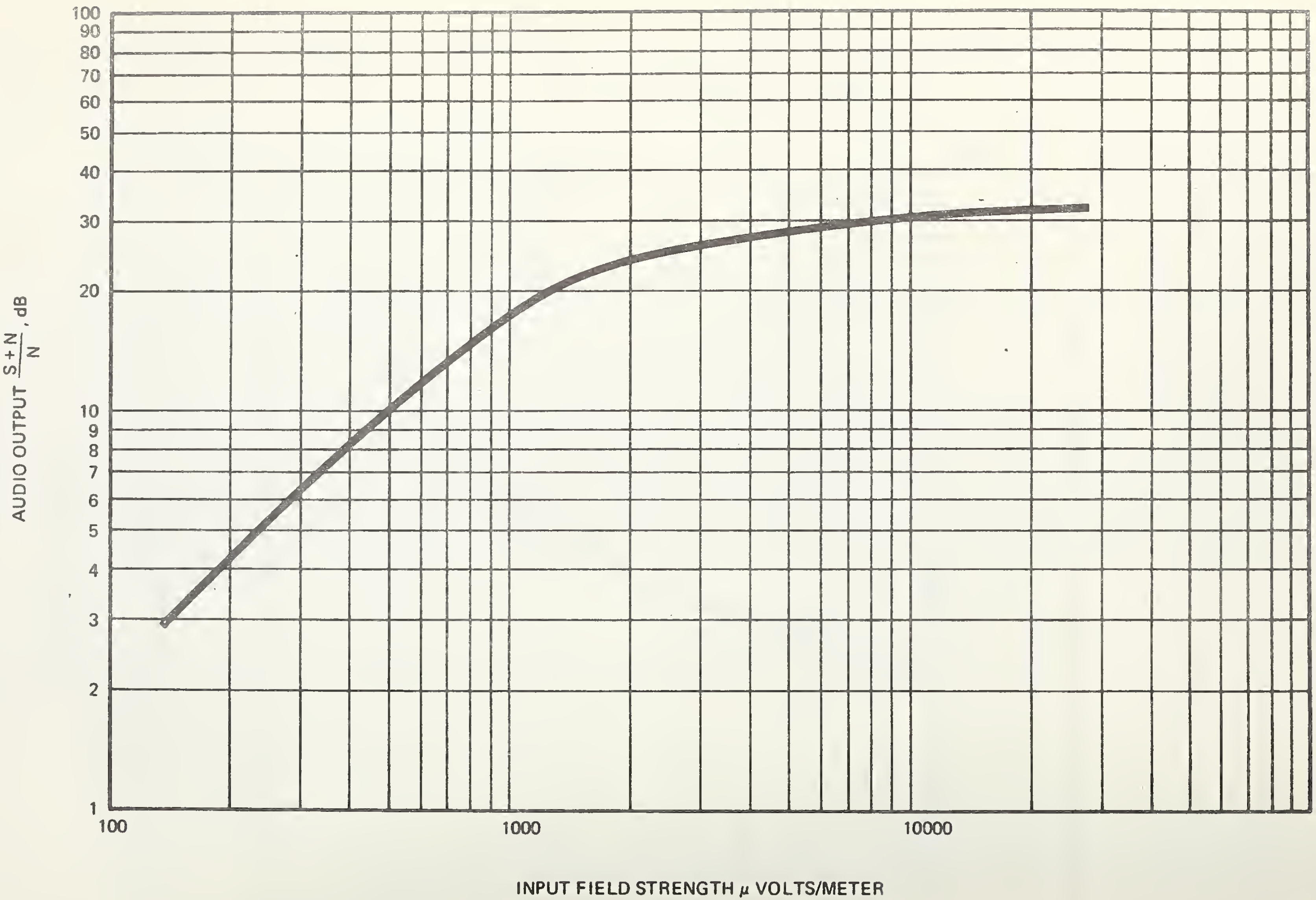

Figure D-4. Average Characteristics For Portable FM Broadcast Receivers Using "Whip" Antenna

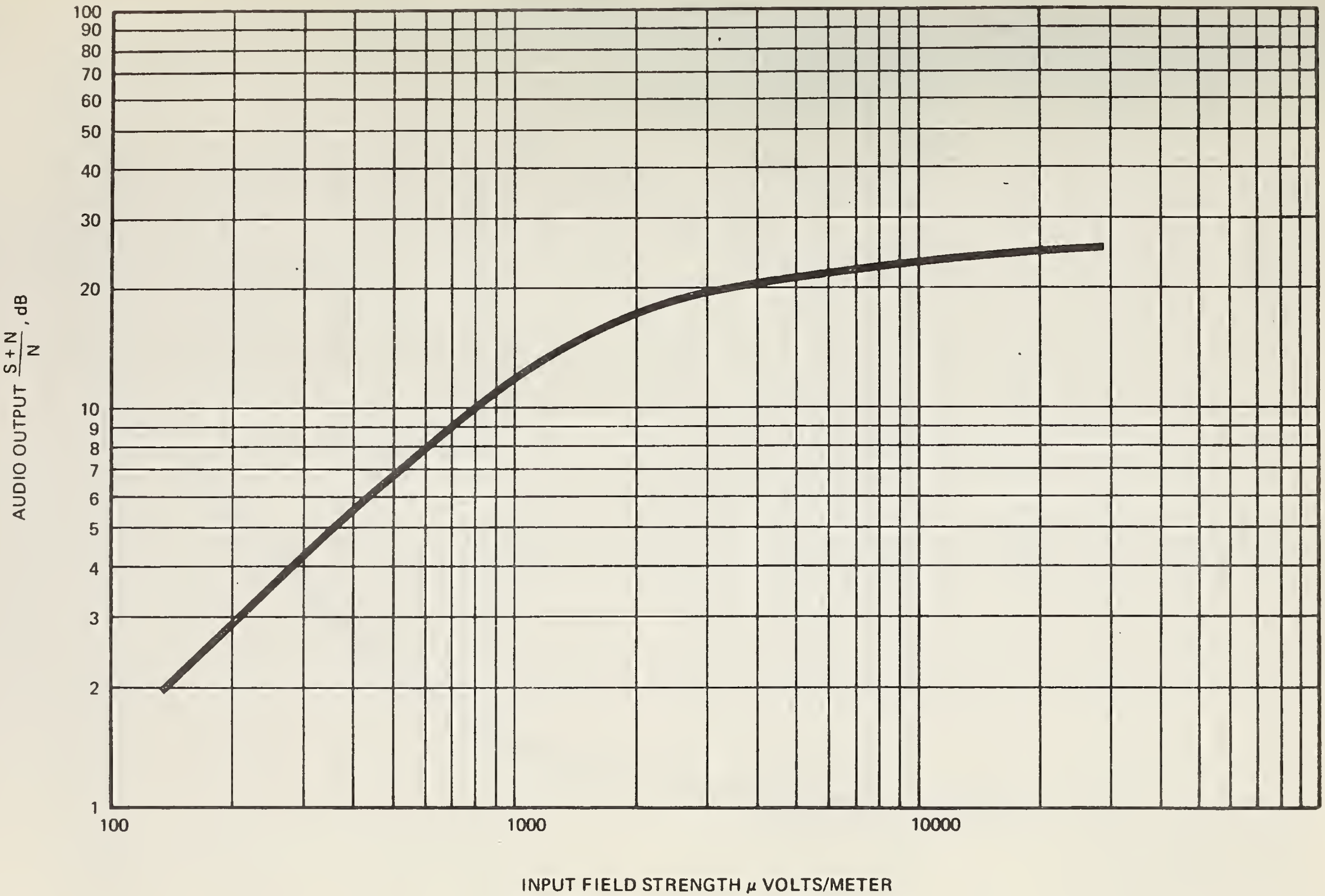

Figure D-5. Composite Characteristics of "Average" VHF Portable Receivers - Using "Whip" Antenna

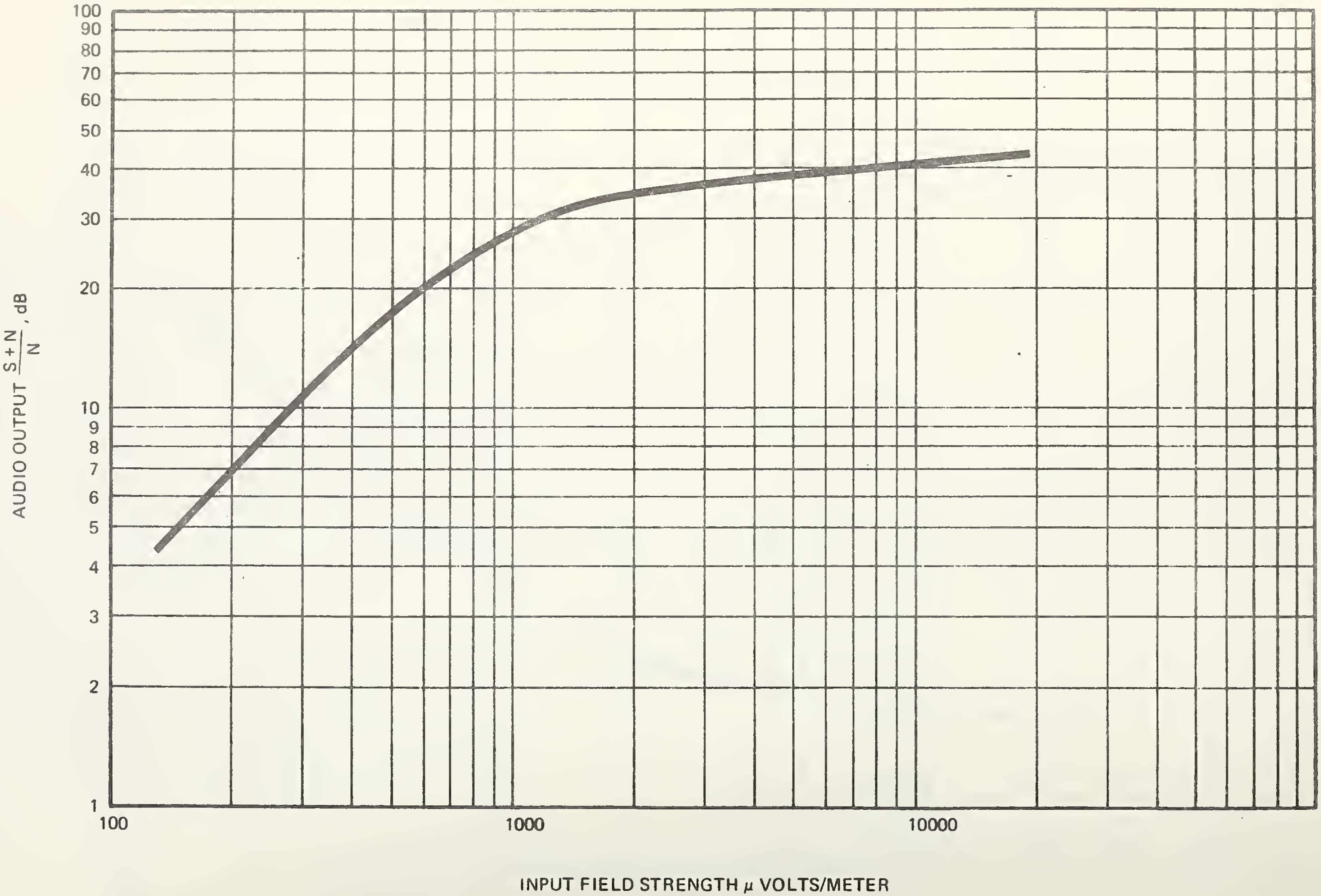

Figure D-6. Composite Characteristics of "Excellent" VHF Receivers Using "Whip" Antenna weather dissemination systems may be calculated. Evaluation and averaging procedures used in developing these curves represent conservative estimates. For this reason, it is felt that the "type" receivers characterized will for a great percentage of the time actually exhibit performance that will at least equal that represented in Figures D-3 through D-6.

Figures D-3 and D-4 represent the average characteristics to be expected from small, inexpensive portable receivers available for the AM and FM broadcast bands, respectively. Figure D-5 represents the average characteristics to be expected from small low to medium priced (under $80) receivers available for receiving in the VHF band, particularly those designed to include the NWS broadcasts at 162.55 MHz. Figure D-6 is representative of the performance to be expected from higher quality - more expensive - VHF receivers. The performance characteristics of this figure are considered "excellent."

D.6 CONCLUSIONS

As a result of this testing and evaluation a baseline has been developed for receiver performance. Due to the variety of receiver types examined and the variability of performance among individual receiver types, it was decided that an average characteristic, defined in Figures D-3, D-4, and D-5, would be most useful for determining system range limitation. It is also believed the development of an average curve minimizes differences of selectivity exhibited by the receivers tested, especially since tests performed under both high and low external noise conditions were included in the averaging. A major factor to be considered is the choice of an audio signal-to-noise ratio that is to be used in setting a minimum acceptable performance level. This choice is made difficult by a number of unknown factors. Specifically, the ambient noise level due to conversations, the noise of engines, or other disturbances due to the primary activity taking place aboard a boat is difficult to determine, nor is it possible to determine the distance of the boat operator from a radio receiver, especially when portable equipment is being used. Those two uncertainties compound the difficulty of determining which audio output signal-to-noise ratio would be minimally adequate to ensure that warnings or important factors in a given broadcast would not be missed or misunderstood. Consequently, it was decided that the criteria presently used for public mobile telephone service would be at least as valid as any that could be developed within the scope of this effort. Therefore, the adoption of circuit merit 3 as the minimum acceptable performance level was agreed upon. The grading of circuit merit levels is related to empirical testing involving measures of speech intelligibility as a function of a speech-to-noise ratio. Specifics of the development of this rating scheme may be found in the references. Receiver performance quality of circuit merit 3 implies a signal plus noise-to-noise ratio ranging between 9 and 16 dB. The range limitations imposed by the various receivers were determined by relating the input field strength requirements associated with a 9-dB S+N/N on the curves of Figures D-3, D-4 and D-5. Hence, for purposes of calculating coverage contours for commercial AM, FM, and VHF systems, the required signal field strengths were determined to be:

a. AM - 1200 μV/m

b. FM - 450 μV/m

c. VHF - 700 μV/m

APPENDIX E

EXTERNAL AND MANMADE RADIO NOISE

E.1 INTRODUCTION

To evaluate the limiting performance factors of the types of receivers being considered in the course of this study, the maximum noise levels to be expected in different portions of the radio band were determined.

For medium frequency AM radiotelephones, the maximum expected noise level was calculated at 2670 kHz. For commercial AM broadcasts, the noise level was determined at a frequency of 1000 kHz, which is approximately in the middle of the broadcast band. For receivers operating in the VHF/FM region, the noise levels were calculated at a frequency of 160 MHz.

In the AM broadcast and medium frequency radiotelephone bands, the maximum noise levels to be expected in each of the scenario areas were determined, as well as the season and local time block during which these maxima are expected to occur. The results are presented in Tables E-1 through E-5. It should be noted that the noise levels given are levels that will not be exceeded 90 percent of the time (90 percent service probability) and that they represent atmospheric noise. Fa is the "noise factor" expressed in decibels (Reference 14) and En is the rms noisefield strength for a 1-kHz bandwidth, expressed in decibels above 1 μV/m. E is the corresponding value of En, expressed in μV/m.

In the VHF/FM band used by the Coast Guard, Weather Service Continuous Broadcasts, and Public Coast Class III B radiotelephone receivers, the levels of galactic and manmade noise are calculated. Manmade noise levels are determined for urban, suburban, and rural environments (References 15 and 16). The results of these calculations are listed in Tables E-6 and E-7.

TABLE E-1. NOISE LEVEL, AREAS 1 AND 2

Chesapeake Bay New Jersey Coast	Summer 2000 to 2400 hrs
Frequency = 1 MHz	Fa = Fm + Du Fa = 90 + 9.8 = 99.8 dB
BW = 200 Hz	$En = Fa + 20 \log \frac{f(mc)}{sec} - 65.5$ = 34.3 dB above 1 μV/m E = 51.9 μV/m
Frequency = 2.67 MHz BW = 200 Hz	Fa = 76 + 8 = 84 dB En = 27.5 dB above 1 μV/m E = 23.9 μV/m

TABLE E-2. NOISE LEVEL, AREA 5

Oregon, Washington States	Fall, 1700 to 2100 hrs (Pacific)
1 MHz	Fa = Fm + Du Fa = 70 + 9.9 = 79.9 dB
BW = 200 Hz	En = 24.4 dB above 1 μV/m E = 16.6 μV/m
2.67 MHz	En = 11 dB above 1 μV/m E = 3.55 μV/m

TABLE E-3. NOISE LEVEL, AREA 4

Texas Gulf	Summer, 1900 to 2300 hrs
1 MHz BW = 200 Hz	Fa = Fm + Du Fa = 85 + 9.8 = 94.8 dB En = 29.3 dB above 1 μV/m E = 29.2 μV/m
2.67 MHz	Fa = 72.5 + 8.0 = 80.5 dB En = 24 dB above 1 μV/m E = 18.8 μV/m

TABLE E-4. NOISE LEVEL, AREA 3

South Florida	Summer, 2000 to 2400 hrs
1 MHz BW = 200 Hz	Fa = Fm + Du Fa = 90 + 9.8 = 99.8 dB En = 34.3 dB above 1 μV/m = 51.9 μV/m
2.67 MHz	Fa = 76 + 8 = 84 En = 27.5 dB above 1 μV/m

TABLE E-5. NOISE LEVEL, AREA 6

Great Lake Area	Summer, 1900 to 2300 hrs
Frequency = 1 MHz BW = 200 Hz	$Fa = Fm + Du$ $Fa = 90 + 9.8 = 99.8$ dB $En = 34.3$ dB above 1 $\mu V/m$ $E = 51.9\ \mu V/m$
Frequency = 2.67 MHz	$Fa = 76 + 8 = 84$ dB $En = 27.5$ dB above 1 $\mu V/m$ $E = 23.9\ \mu V/m$

TABLE E-6. GALACTIC NOISE AT 160 MHz

$Ng = -\left(165 + 9.555 \ln\left(\frac{f}{3}\right)\right)$ (Reference 25)

f: frequency in MHz

$Ng = -203$ dBW (Reference 25, BW = 1 Hz)

$Eg = 0.3\ \mu V/m$ (Reference 26, BW = 10 kHz)

TABLE E-7. MANMADE NOISE

Manmade Noise BW = 1 Hz

$$Nm = No + b \log \left(\frac{f}{3}\right) \text{ dBW}$$

1. Urban — No = -132.5 b = -22.5 Du = D_e = 7.4

$$Nm = -132.5 - 22.5 \log \frac{160}{3}$$

$$= -161.3 \text{ dBW (Reference 25, BW = 1 Hz)}$$

Em = 15 μV/m (Reference 26, BW = 10 kHz)

2. Suburban — No = -142.2 b = -24

$$Nm = -142.2 - 24 \log \frac{160}{3}$$

$$= -183.7 \text{ dBW (Reference 25, BW = 1 Hz)}$$

Em = 9.5 μV/m (Reference 26, BN = 10 kHz)

3. Rural — No = -155.4 b = -25

$$Nm = -155.4 - 25 \log \frac{160}{3}$$

$$= -198.6 \text{ dBW (Reference 25, BW = 1 Hz)}$$

In Table E-6, Ng is the expected median value of the galactic noise power in dB relative to 1-W per 1-Hz bandwidth, and Eg is the galactic noise level expressed in μV/m in 10-kHz bandwidth.

In Table E-7, Nm is the manmade noise power in dB below 1 W per Hz. N and b are constants derived from measurements reported in Reference 25, and Em is the manmade noise level expressed in μV/m for a 10-kHz bandwidth.

E.2 PORTABLE RECEIVERS

For AM portable receivers with small ferrite loop antennas, a 1200-μV/m signal field strength is required at the input to the antenna to attain a 9-dB S+N/N ratio at the output. Modifying the atmospheric noise of Table E-1, noise in the 2-kHz signal bandwidth is

$$51.9\ \mu\text{V/m}\left(\sqrt{\frac{2\ \text{kHz}}{200\ \text{Hz}}}\right) = 164\ \mu\text{V/m} = \text{Ne (external noise)}$$

Therefore,

$$\text{input S+Ne} = 1200\ \mu\text{V/m}$$

$$\text{input Ne} = 164\ \mu\text{V/m}$$

$$\text{input}\ \frac{\text{S+Ne}}{\text{Ne}} = 20\ \log\ \frac{1200}{164} = 17.5\ \text{dB}$$

Since this input signal level only results in a 9-dB output S+N/N, it would appear that the inefficiencies of the small antenna, combined with relatively poor receiver chassis sensitivity of the small portable radios modeled, limit performance to less than the expected from external noise limitations.

The external noise level is not very different for standard broadcast band FM portable receivers and VHF/FM receivers. Using the Urban noise level of Table E-7 of 15 μV/m in a 10-kHz bandwidth, an example similar to that for the AM case can be developed.

For FM broadcast band receivers a 450-μV/m input signal level is required to obtain a 9-dB $\frac{\text{S+N}}{\text{N}}$ at the receiver output.

As before: input S+Ne = 450 μV/m

input Ne = 15 μV/m

$$\text{input } \frac{S+Ne}{Ne} = 20 \log \frac{450}{15} = 29.4 \text{ dB}$$

Again it can be seen that the performance of these inexpensive portable receivers is limited by a combination of inefficient antenna and poor chassis sensitivity.

For the small portable NWS receivers, a 700-μV/m input is required to attain a 9-dB output $\frac{S+N}{N}$. Using calculations similar to the above, it can be seen that the same limitations apply.

E.3 INSTALLED RECEIVERS

When considering VHF/FM marine telephone receiver installations, calculations are made based on the assumption of a half-wave dipole receiving antenna and a chassis sensitivity of 4 μV. From the relationship expressing available power from a matched half-wave dipole, it can be shown that a received signal field strength of 11 μV/m is required at the antenna for 4 μV of signal be delivered to the receiver front end. Calculations based on receiver chassis sensitivity, then, inherently assume that signal-to-noise performance of the receiver is determined by the receiver sensitivity. Since a signal level of 11 μV/m will meet this requirement, it can be seen that for this assumption to be valid

$$\text{Input } \frac{S+Ne}{Ne} \geqslant \frac{S+N \text{ internal}}{N \text{ internal}}$$

since $\frac{S+N \text{ internal}}{N \text{ internal}}$ is taken to be at least 9 dB for minimally acceptable performance, then

$$\frac{S+Ne}{Ne} \geq 9 \text{ dB}$$

and since S must be at least 11 μV/m, the maximum allowable external noise level can be calculated as

$$20 \log \frac{11}{X} = 9 \text{ dB}$$

$$\frac{11}{X} = \text{alog } 0.45 = 2.8 \therefore x = 3.9 \ \mu V/m$$

It can be seen from Table B-7 that this will be true only in a rural noise environment and, hence, the performance of receivers operating in higher noise environments would be limited by external noise levels rather than chassis sensitivities.

Marine radiotelephone receivers operating in the 2670 (MF) band are of relatively high quality and operate with antennas whose effective length is significantly greater than the ferrite loop antennas used in portable receivers. The chassis sensitivity of these receivers is also known to be considerably better. Hence, the performance of these receivers will be determined primarily by the signal-to-external noise ratios of the available signal and noise field strengths.

E.4 CONCLUSIONS

From the noise levels predicted in the foregoing tables and the receiver characteristics of Appendix D, it can be seen that:

a. The performance/range limitation of the VHF/FM portable NWS receivers, as well as AM and FM commercial broadcast portable receivers, is essentially imposed by a combination of antenna system losses and poor sensitivity, rather than external noise levels.

b. VHF marine radiotelephones with receiver sensitivities of less than approximately 4 μV would be limited in range/performance in suburban and urban noise environments by the level of external noise. For receivers with values of sensitivity greater than 4 μV, performance limitations would tend to be imposed by their sensitivity rather than external noise levels.

c. AM marine radiotelephones operating in the MF band will, in most cases, have their range/performance limited by external noise levels rather than receiver sensitivity.

APPENDIX F

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