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Final Report for the Office of Civil Defense

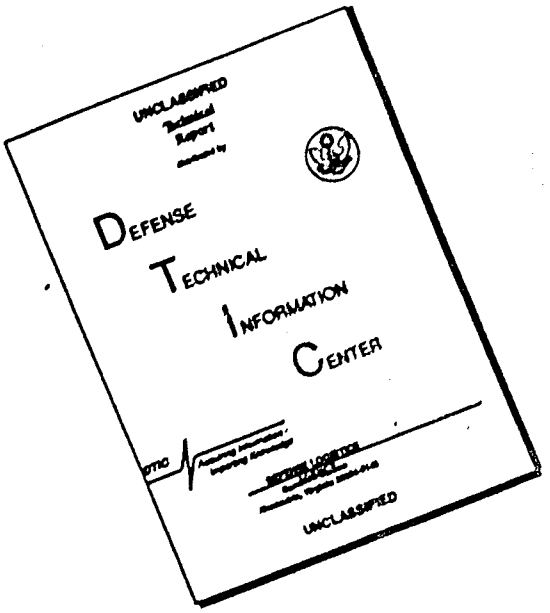
Civil Defense Warning System Research Support

Volume I: Radio Warning System Studies

31 January 1966

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TECHNICAL MEMORANDUM

(TM Series)

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Final Report for the Office of Civil Defense

Civil Defense Warning System Research Support

Volume I: Radio Warning System Studies

Special Research and Development Projects Staff

31 January 1966

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FOREWORD

Volume I, this Volume, and two companion Volumes contain the findings, conclusions, and recommendations resulting from the study of warning system requirements under contract OCD-PS-64-183. The three Volumes are as follows:

TM-L-1960/090/00
Final Report for the Office of Civil Defense
Civil Defense Warning System Research Support
Volume I: Radio Warning System Studies
31 January 1966

TM-L-1960/091/00
Final Report for the Office of Civil Defense
Civil Defense Warning System Research Support
Volume II: Research Studies
31 January 1966

TM-L-1960/092/00
Final Report for the Office of Civil Defense
Civil Defense Warning System Research Support
Volume III: Use of Damage Assessment Information for Warning (u)
31 January 1966

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CHAPTER ONE

INTRODUCTION AND SUMMARY

1.0 INTRODUCTION

In April 1964, the System Development Corporation (SDC) was awarded a contract (OCD-PS-64-183) by the Office of Civil Defense (OCD) to continue activities in the area of civil defense warning system research support.

This volume and two others, TM-L-1960/091/00 and TM-L-1960/092/00, document and summarize the results of that research effort, and comprise the final report required by the contract.

The SDC staff performed the following tasks during the course of the contract:[1]

1. Assisted OCD in evaluating, selecting, and implementing a nationwide radio-based alert and warning system.

2. Selected optimum radio warning system configurations on the basis of operational and performance requirements and designated areas for detailed engineering study.

3. Determined, on the basis of operational and performance requirements, optimum signaling procedures to be used in the transmission and distribution elements of a radio-based alerting and warning system, and studied the need for and degree of security of signaling and other related factors leading to the engineering design of signaling devices.

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1. Several other tasks were originally scheduled, but were not performed. The omitted tasks include a study of the optimum relationship between warning system development and shelter system development; an investigation of civil defense alerting conditions; and an analysis of improved processing of warning information at various civil defense operational levels. These tasks were omitted when other tasks undertaken under the terms of the technical support clause of the contract (item 9 below) were assigned sufficiently high priority by OCD to necessitate reducing the overall scope of work.

4. Studied the civil defense decision-to-warn at all levels of government--federal, state, and local.

5. Evaluated the feasibility and effectiveness of providing strategic warning to industry and determined tradeoffs between shutdown of industry following strategic warning and possible escalation of a crisis versus no shutdown and probable damage to or destruction of plant and surrounding community. The staff also evaluated the impact upon federal warning systems and procedures with regard to providing such strategic warning for shutdown purposes.

6. Developed reliability criteria for evaluating both current and planned warning systems, including expressions for describing the levels of reliability at which a warning system will operate, and a mathematical model for the performance required of the improvements of any warning system if that system is to achieve a predetermined level of reliability.

7. Determined the degree to which federal warning programs have been accepted by Congress; collected and assembled material showing the legislative and fiscal history of these programs; analyzed the development of the programs in terms of the interaction of civil defense agency personnel with Congress; and traced changes in the nature of and the funding requested for programs proposed as well as in the nature of and funding provided for programs accepted.

8. Determined the warning information that could be derived from a nuclear detection or damage assessment system, and reviewed and evaluated the warning potential of current, planned, and proposed nuclear detection and damage assessment systems.

9. Provided technical assistance and liaison on radio-based alerting and warning systems, and in other areas mutually agreed upon by OCD and System Development Corporation.

Volume I contains nine chapters devoted to technical subjects investigated under the general heading of radio-warning system studies (Tasks 1 through 3, and 9, above), a Bibliography and a Glossary. These chapters are devoted to the following subjects:

- Chapter One, Introduction and Summary: Contains an introduction and a series of summaries of the succeeding chapters in this volume.

- Chapter Two, Interim Operational Requirements: Compiles requirements for the proposed Radio Warning System.
- Chapter Three, Alternate System Configurations: Presents the main characteristics of three possible Radio Warning System configurations.
- Chapter Four, Proposed Alert Signal and Warning Messages: Recommends an alert signal and a set of warning messages suitable for dissemination over the Radio Warning System.
- Chapters Five through Ten: Present series of analyses of various problems related to the design of domestic receivers for use with the Radio Warning System.

Chapters Two through Ten reproduce previously published reports. However, they have been updated, where necessary, to reflect the status of the Radio Warning Program as of 31 January 1966. No attempt has been made to provide continuity from chapter to chapter, particularly those devoted to receiver design problems because it is felt that anyone reading them will gain considerable insight into these problems and that what little inconsistency is apparent is normal to a developing program.

Volume Two, TM-L-1960/091/00, contains the findings of all other unclassified warning research studies. These include Tasks 4 through 7, and 9 above.

Volume Three, TM-L-1960/092/00 is classified Secret Restricted. It contains information warning data that could be derived from a nuclear detection or damage assessment system (Task 8, above).

Following are summaries of Chapters Two through Ten of Volume I, respectively.

2.0 SUMMARY OF CHAPTER TWO: INTERIM OPERATIONAL REQUIREMENTS

This chapter presents a compilation of operational requirements for the Radio Warning System derived from meetings and discussions among Office of Civil Defense personnel and associated contractors (Gautney & Jones Communications, Inc., Stanford Research Institute, and System Development Corporation).

2.1 CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the operational requirements presented in this chapter be accepted by OCD as the defining criteria for the Radio Warning System, thus providing a foundation for the development work on the system to which all design effort must conform. Although the operational requirements should

be adhered to by system designers, their application should be flexible enough to allow changes to be made based on later and more complete information.

2.2 UNDERLYING PUBLIC REQUIREMENTS

The needs of the public, as they affect the system, must be examined in two separate time frames: the situation of immediate danger to life and the normal pre-emergency period. To satisfy the former, the warning process should meet the following basic system requirements:

1. Coverage. The warning message must reach as many people as possible when the emergency arises, wherever they may be at any time, day or night.

2. Credibility. The warning message must be credible to them so they will react properly without costly delay. To this end the warning process must be reliable and contain self-authenticating features.

3. Content. The warning process must direct them as to what to do. This implies existence of protective measures and a shelter system. It requires that intelligible voice instructions be transmitted to the public. Strictly local instructions, while not a part of the Radio Warning System, must be integrated into the overall warning process.

Regarding the normal time frame, the system should provide for 1) public financial support, 2) public training, and 3) public conditioning to a certain amount of annoyance, particularly from any equipment located in the home.

2.3 THE ROLE OF OPERATIONAL REQUIREMENTS IN SYSTEM DESIGN

Distinction must be made between the terms operational capability and operational requirement. The former term represents the general statements made during the early stages of system design describing characteristics desired in the system, and the latter term represents the more precise statements of minimum levels of performance in specific areas of system operation which set the standards the system designer must meet.

The Directorate for Plans and Operations of the Office of Civil Defense has drawn up a list of desirable features for the Radio Warning System. (This list is reproduced in the Annex to Chapter Two). For the system operator, these desirable features constitute a set of operational requirements. For the system designer, however, the list requires further refinement, as it does not establish minimum standards to be used in determining whether a system configuration merits implementation. The set of operational requirements

must specify characteristics and levels of performance in every area of operation judged essential to carrying out the mission of the system, and as importantly, only in such areas.

Several examples are presented to illustrate the iterative process necessary to bridge the gap between the system operator's specification of broad operational requirements and the system designer's need of a more precise statement of them. Discussed in this context are the requirements regarding:

1. Population Coverage. The actual percentage of people reached by the system will be determined in large measure by the cost of the receiver and the temper of the population at the time the system is installed. Therefore, the choice of system configuration cannot be affected by the number of people it purports to cover, since no specification of population coverage can be claimed for any given configuration. As a result, there is no requirement included specifying the percentage of the population which the system must reach.

2. Regional Networks and Initiation Points. It was originally believed that the system should provide a public warning capability to the OCD Regions, but it has finally been decided that this feature is not essential. Therefore, a regional warning capability is not a requirement.

3. Reliability. The system operators have specified only that the system be reliable. There are many interrelated factors that affect system reliability, e.g., false alarm versus no alarm failures; redundancy in hardware components and communications channels; noise in the radio frequency environment; and human reliability as it affects the system and methods of system testing. Though it would have been possible to specify a technique such as automatic closed-loop continuity checking to guarantee high reliability, it was felt this would unnecessarily limit the choice of configuration. Thus, a general requirement is presented, specifying a minimum level of reliability, which must be met by any configuration regardless of the techniques used to do so.

4. Cost. Because system cost is only one criterion that will be used to judge which hardware configuration to implement, it cannot be specified that the configuration that meets all the other requirements and can be installed for the least cost, will be chosen. The same argument holds for components, such as the home receiver.

5. Strategic Versus Tactical Warning. In this compilation, there are requirements as well as justifications of requirements included on the basis that the system will be used for strategic as well as tactical warning. None of these significantly change the configuration of the system from what it would be if only tactical warning was being planned.

2.4 GROUND RULES AND ASSUMPTIONS

1. Current System. The outdoor/indoor alerting and warning system based upon sirens and the Emergency Broadcast System (EBS) has been judged inadequate for future needs by OCD.

2. Radio-Based System. The present program is directed toward the development of a radio-based alerting and warning system.

3. Start Date. Installation of the Radio Warning System is planned to start as early as 1968 if deployment of such a system is approved.

4. Protective Measures. It is assumed that adequate shelter will be available by the time the Radio Warning System is installed.

5. Nonhomogeneity. Although present outdoor alerting techniques have been judged inadequate, they will still have a role in the overall warning process even after the Radio Warning System has been implemented.

6. Emergency Broadcast System. The EBS is not a constraint on the Radio Warning System Operation. The services provided by EBS will still be needed, but it may not necessarily exist in its present form.

2.5 INTERIM OPERATIONAL REQUIREMENTS: FUNCTION

2.5.1 National Alert and/or National Warning

The Radio Warning System shall provide the public, through radio receivers located in dwellings, places of business, and institutions, a timely national alert and/or national warning of an enemy attack and/or the effects of such an attack.

2.5.2 Activate Other Systems

The Radio Warning System shall be capable of activating other public alerting and warning systems. Where several different selective alerting and warning functions exist in these systems, the Radio Warning System shall be capable of activating these systems in the appropriate functional mode.

2.5.3 Hard Copy

The Radio Warning System shall be capable of transmitting information as hard copy where such information is needed to provide program material for voice messages to be delivered to the public. Hard copy will also be transmitted to provide immediate authentication of the automatic assumption of control of a facility's transmitter.

2.6 INTERIM OPERATIONAL REQUIREMENTS: COVERAGE

2.6.1 Continuous Activation Capability

The Radio Warning System shall be capable of being activated any time of day, any day of the year.

2.6.2 Geographic Coverage

The Radio Warning System shall provide adequate signal strength to activate public receivers located anywhere within the 48 contiguous states. The system shall be capable of interfacing with the warning systems in the noncontiguous states, territories, and possessions.

2.7 INTERIM OPERATIONAL REQUIREMENTS: STRUCTURE AND OPERATION

2.7.1 Automatic and Semiautomatic Operation

The Radio Warning System shall be capable of operating both automatically and semiautomatically from the time of activation through the delivery of the alert signal and/or warning message to the public. Semiautomatic operation will consist of the transmission of live-voice messages to some segments of the public and the manual transmission of hard-copy messages within certain portions of the system's control network.

2.7.2 National Initiation Points

The Radio Warning System shall have a primary national initiation point and one or more backup initiation points. The primary point will be located at the NORAD Combat Operations Center.

2.7.3 Access to the System

Tactical warning points must be provided the capability to preempt the system in order to override a strategic warning already in progress. Except for this restriction, the national initiation points of the Radio Warning System shall have independent access to the system through the system's control network transmitter(s); that is, communications channels from each of the points shall be provided directly to the control transmitters and no control over access to the system other than procedural shall normally be exercised over any initiation point by any other initiation point.

2.7.4 Selective Functions

The ability to perform the following six functions shall be provided as minimum to the operator of the Radio Warning System at each of the national initiation points: alert and warn, warn only, cancel test, preempt, and transmit hard copy.

2.7.5 Operational Status and Verification of Activation

The operational status of components at each level of the system shall be made available at the national initiation points. An indication of successful operation or failure of the system at any and all levels above the home receiver shall be provided to the operators at one or more of the national initiation points at the time of system activation.

2.7.6 Nonhomogeneity

The Radio Warning System may be a nonhomogeneous system, that is, different types of equipment may be used within different portions of the system to accomplish the same function.

2.7.7 Muted Receivers

The public receiver component of the Radio Warning System shall normally remain in a muted condition, that is, the audio portion of the receiver will not operate until it is necessary to transmit a signal or message through the receiver to the public.

2.7.8 Positive Control of Public Receiver

The public receiver component of the Radio Warning System shall be designed to operate under the positive control of the system operator, that is, the demuting and remuting of the receiver shall both be controlled by signals from the alert and warning transmitter.

2.7.9 Location of Alert Signal Generator

The equipment used to generate the public alert signal for the Radio Warning System shall be located at the transmitter or control facility of the radio station that distributes the signal to other radio stations, or that delivers the signal to the public, but not in the home receiver itself.

2.7.10 Alert Signal

The Radio Warning System shall be capable of transmitting messages to the public with or without the accompanying alert signal. (Preliminary studies indicate that an alert signal intensity on the order of 90 decibels at 10 feet will be required.)

2.7.11 Warning Message

The Radio Warning System shall transmit pretaped warning messages to the public whenever possible, but the capability to transmit live messages to the public must also be provided to cover unusual situations for which standardized messages are inappropriate. The warning message shall be delivered by the public receiver with sufficient audibility and intelligibility to insure its being readily understood by a person located in the same room as the receiver. (Preliminary studies indicate a warning message intensity of the order of 75 decibels at 10 feet will be required.)

2.7.12 Interaction with Other Systems

Provision shall be made in the Radio Warning System for the exchange of information, either automatically or manually, with those systems that are involved in the warning process either as sources for warning intelligence or as complementary means for transmitting warning and/or warning information.

2.8 INTERIM OPERATIONAL REQUIREMENT: MAXIMUM RESPONSE TIME

The response time of the Radio Warning System shall be such as to insure that an alert and warning can be provided to target areas within a time period approaching one minute as a maximum and to nontarget areas within a time period approaching three minutes. Variation in response time between target and nontarget areas shall be allowed only if radio frequencies must be shared by several facilities within the system on a time-division basis, or if some similar technical sacrifice must be made.

2.9 INTERIM OPERATIONAL SPECIFICATIONS: RELIABILITY

2.9.1 Minimum Performance Level

The reliability of the Radio Warning System shall be such that the expected number of people put at risk by failures in the system shall not exceed 0.1 percent of the entire population. The figure of merit to be used in calculating the expected number of people put at risk shall be the instantaneous availability of the system, i.e., the probability that the system will function in a completely satisfactory manner upon activation.

2.9.2 Redundant Equipment

Redundant equipment shall be installed in the Radio Warning System above the public receiver level when indicated as necessary by an engineering evaluation of system reliability. Where such redundancy exists, automatic switchover to standby equipment shall be provided in the event of a failure in the active equipment.

2.9.3 Fail Safe Equipment

All equipment used in the Radio Warning System shall be designed to maximize the probability that components will fail in a silent or safe condition, not in a condition which simulates system operation.

2.9.4 Receiver Protection

The public receiver component of the Radio Warning System shall be designed to withstand the wear and tear that can be expected in an exposed location in an average household which may be situated anywhere within the wide range of environments found in the various climatic areas of the United States. Further, it shall be assembled in such a way as to discourage or prevent a person from tampering with it.

2.9.5 Testing Program

The Radio Warning System shall be tested down to and including the public receivers on a frequent basis. The frequency of these tests shall be determined so that the expected number of public receivers that are allowed to become inoperative between tests shall not exceed a fixed percentage of the total number of receivers. (The allowable percentage of inoperative receivers remains to be determined.)

2.9.6 Maintenance

The failure of equipment used in the Radio Warning System at levels above the public receiver shall automatically be indicated to maintenance personnel.

2.9.7 Dual Operator Positions

Provision shall be made in the Radio Warning System to require the actions of two individuals to activate the system from any national initiation point. (The exact method that will be used to carry out this requirement remains to be determined.)

2.10 INTERIM OPERATIONAL REQUIREMENTS: SURVIVABILITY, SECURITY AND SABOTAGE

2.10.1 Survivability

The Radio Warning System shall be survivable in the following sense: in the event of an overt attack on the United States (except for an undetected attack directed against the Radio Warning System itself), shall be capable of surviving in operating condition for a period sufficient to enable the delivery of a national alert and warning. Following the attack, the planned reconstitution capabilities of the system shall be sufficient to insure a continued public warning capability with minimum interruption due to attack effects. Reconstitution planning shall determine the means of increasing the likelihood of the continued operation of facilities originally included as system components, as well as the means by which other communications facilities which might survive an attack might be utilized to provide warning to the public.

2.10.2 Jamming

The control portion of the Radio Warning System shall be provided with anti-jamming capability. The RF sensitivity of the public receiver component of the system shall be made adjustable and shall be maintained at a level no greater than that which is necessary to receive legitimate signals from system transmitters.

2.10.3 Spoofing

The control portion of the Radio Warning System shall be made sufficiently secure to prevent its being spoofed. The system shall be designed to enable the rapid detection by system operators of any attempt, whether belligerent or mischievous, to spoof the system. The system operators shall be provided with the ability to inform the public of the situation as soon as possible, using the Radio Warning System itself as well as other means of communicating with the public.

3.0 SUMMARY OF CHAPTER THREE: ALTERNATE SYSTEM CONFIGURATIONS

This chapter presents the main characteristics of three possible Radio Warning System configurations: Radio-Based; AUTODIN; and Landline-Radio. Each is based on a somewhat different interpretation of the Radio Warning System mission, and on differences in the relative weighting of such parameters as reliability, survivability, and security. In addition, a redefinition of some of the operational requirements that have been specified in earlier documentation is proposed. In the process of redefining some of the requirements, a few of the problem areas have been investigated and discussed. Solutions offered to some of the problems are based on the assumptions and arguments developed in this chapter.

3.1 MISSION OF THE SYSTEM

The mission of the Radio Warning System is to provide the public, through radio receivers located in dwellings, places of business, and institutions, a timely national alert and voice warning of an impending enemy nuclear attack. The purpose of this alert and warning is to enable the public to take protective measures to increase the probability of their survival. The Radio Warning System is different from previous warning systems in that it has in one system:

1. The capability of a quick reaction time.
2. The capability to alert the public by generating a distinctive, attention-getting sound.
3. The capability of delivering a voice message to the public.
4. The capability to cover a broad population.

The Radio Warning System will not replace the existing warning systems, which have their own unique contributions to make in the overall warning situation. Other systems, however, will be affected by the Radio Warning System, and all systems will be made to complement each other and contribute toward providing a complete warning capability.

3.1.1 Constraints

No attempt to define a command and control capability as part of the Radio Warning System has been made in this chapter. Also, the level of detail of the system configurations presented is not sufficient to allow adequate cost analyses to be made at this time. Only variations in the control network subsystem will be discussed. The radio facilities for broadcasting to the public will be considered to be the same for all three configurations. All of the control network subsystems presented are considered to interface with a broadcast subsystem consisting of eight low-frequency, subnational transmitters plus approximately 60 commercial broadcast stations.

3.1.2 Conclusions and Recommendations

All three different system configurations that have been examined in some detail appear to be technically feasible. However, a number of problems remain to be solved before an operational system can be implemented. More precise definition of the system requirements, and a rationale for weighing their relative importance should be developed as soon as possible to allow meaningful cost-effectiveness comparisons to be made of the different configurations. It is recommended that the principles of Value Engineering, as developed by the Department of Defense, be applied to the development of the Radio Warning System.

3.2 RADIO-BASED CONFIGURATION

This configuration is based upon use by OCD of the low-frequency (60 kHz) time-standard station, WWVB, at Fort Collins, Colorado, for disseminating the control signals from the national initiation points to the transmitters that broadcast the alert and warning message to the public. NBS* is the normal everyday user of the station, broadcasting at 60 kHz to the public with time signals derived from the NBS cesium atomic frequency standard.

During an alert situation, OCD will assume control of WWVB and will transmit frequency shift-keyed teletype signals to control subnational low-frequency (LF) and commercial broadcast stations. A switch closure from the operator's console starts the transmission of a coded message over the first link of the control network. This first link, from the National Warning Center at NORAD COC to the NBS transmitter at Fort Collins, will be a full-period, microwave channel. The purpose of the first control message is to activate the primary transmitters at Fort Collins by putting them on the air in the OCD mode of operation.

---

*National Bureau of Standards

A programmer puts in a timed delay to allow for completion of the hardware switching, and for WWVB to be ready to start transmitting on 61.15 kHz in the OCD mode. The programmer then initiates the sending of the second message, which causes a stunt box to provide a switch closure to a transmit KW7 cryptographic device at WWVB. This switch closure causes the KW7 to send synchronizing signals via the 61.15 kHz transmitter to synchronize all of the KW7s at the lower echelon stations.

When a communication channel has been established to the subnational and commercial broadcast transmitters, a transmitted code group causes stunt boxes to activate controllers at each of these lower echelon transmitters. At the subnational transmitters, which are OCD dedicated and have no other mode of operation, the controllers have only to switch on the plate power supply and the transmitters are ready to broadcast to the public. At the commercial broadcast stations the controller has to switch program lines, modulators, plate power and possibly other equipment, depending on the configuration of each station. In this manner, all stations will be put in a condition to broadcast the OCD alert and warning message. The next code group will be interpreted by the stunt boxes at all stations to be the selection of the correct alert and warning tape drive unit from the voice tape deck. The selection of the tape unit will be followed by immediate read out of the taped alert and warning message to the modulators of the transmitters for broadcast to the public. Once the alert and warning broadcasts have been started at all of the subnational transmitters and commercial broadcast stations, a teletype authentication message is sent down from the NWC to all commercial broadcast stations and printed out on the local page printers.

3.3 AUTODIN CONFIGURATION

This configuration is based on the use of AUTODIN to provide the necessary communication network for activating the Radio Warning System. AUTODIN is an automatic switching network operated by the Defense Communications Agency consisting of nine switching centers and interconnecting trunk lines. The network is designed to provide high speed, flexible communications for the Department of Defense and related users. It can be used for Radio Warning System control if tributary lines are added from the switching centers to the National Warning Centers, subnational warning transmitters, and possibly the local broadcast facilities.

In this configuration, each National Warning Center and subnational warning transmitter would be equipped with Compound Terminals. The Compound Terminal (CT) transmits and receives teletype messages via modified Automatic Send and Receive Sets. Transmission is synchronous and in 8-bit common-language Fieldata code, of which 7 levels are used for information and the 8th level for a parity check. The data rate is 150 bits per second requiring twice the bandwidth of a standard teletype channel.

The local broadcast facilities will be equipped with both their own LF receiver, and/or an AUTODIN Teletype Terminal, looped with other facilities for authentication purposes, and as a back-up for manual initiation of warning transmissions if, for some reason, the LF link from the subnational transmitter is inoperative. The Teletype Terminal transmits and receives messages in the 5 level Baudot code. Transmission is by standard telegraph means. Characters are sent asynchronously in bit serial form.

The low-frequency (LF) subnational and broadcast transmitters will retain their present function of providing the radio link to the public, but may or may not be used to transmit control signals to commercial broadcast stations. The three national initiation points at Colorado Springs, Colorado; Denton, Texas; and Washington, D.C., are each connected to AUTODIN by landline links to at least two alternate switching centers. Alternate links are provided to add redundancy and increase the reliability and survivability of the system. All traffic on these lines is encrypted to insure the same level of security as that afforded by the AUTODIN circuits. Drops from AUTODIN will be furnished to the subnational warning transmitters in their proposed locations. The local broadcast facilities may be provided with an AUTODIN drop, or they may depend on the subnationals for activation, or both.

When the system is activated for any reason, two flash priority messages will be initiated at the National Warning Center. One will be to the local broadcast facilities indicating that OCD has assumed control of their facility and the reason therefor. The second message must contain the time the message was initiated from the National Warning Center in order that the LF transmitters can synchronize their transmissions in case of conflicting frequency allocations causing zones of interference.

AUTODIN's speed fits well within the time constraints of adequate warning. It is designed to deliver high priority messages to any recipient within six seconds.

Another requirement of any warning system is that it should not be subject to seizure, either for overt or covert purposes. The AUTODIN switching centers are secure facilities and, therefore, are not accessible to unauthorized personnel. Also, traffic between the centers is encrypted, thereby making it virtually impossible to seize lines between centers.

AUTODIN is an extremely reliable system. Its lines are common carrier lines, which are maintained on a continuous basis, and it is able to seize lines from the AUTOmatic VOice Network (AUTOVON) in case of overload. AUTODIN is a distributed network, i.e., every switching center is connected directly to every other switching center, making alternate routing possible in case of line outage or switching center failure. Messages sent between switching centers are confirmed and acknowledged, thus guaranteeing the receipt of messages sent over the system.

3.4 LANDLINE-RADIO CONFIGURATION

This configuration is based upon use of the NBS transmitting station WWVB and a low-quality leased wire line to disseminate the control signals from the national initiation points to the transmitters that broadcast the alert and warning message to the public.

High system reliability is achieved in this configuration by the use of two reliable, dissimilar communication channels, i.e., radio and leased wire, to provide redundancy against system failure. This diversification of facilities also allows a high level of security to be obtained without sacrificing reliability. The fact that the two communication channels are completely different makes it difficult for an enemy to spoof the system. It also reduces the probability that any natural or inadvertant man-made phenomena that could generate a false control signal on one channel would also induce one on the other channel. A third benefit gained from this diversity of facilities is an increased probability of surviving the initial phases of an enemy nuclear attack. Though both of the channels must be highly reliable, requiring considerable redundancy, they are not necessarily high cost facilites. The low data rate requirements of the system can be satisfied by a 15-Hz wire facility. The low data rate will also allow the WWVB transmissions to be coded to take maximum advantage of the available power and bandwidth of the system. This should provide a high signal-to-noise ratio, resulting in very reliable coverage of the United States with the single transmitting station at Fort Collins.

When the decision-to-warn is implemented by the system operator, parallel switch closures are sent from the operator's console to a programmer that interfaces with the radio channel, and to a wire encoder that interfaces with the wire channel. Upon receipt of the switch closure, the programmer sends a start code group to the controller at Fort Collins, which initiates the changeover of the NBS transmitter from operation in the NBS mode to operation in the OCD mode. When this changeover is completed, the transmitter begins radiating carrier power only at a frequency of 61.15 kHz. At the National Warning Center, the monitor receiver that is tuned to this frequency provides an input signal to the programmer that initiates the second output, i.e., the tactical alert control message. This message is transmitted by the NBS transmitter and received at each of the transmitter sites that broadcast to the public, where it is decoded and fed into a logic circuit. When the operator's console furnishes the switch closure to the wire encoder, the code group designated by the switch closure is generated and sent down the wire line to the public broadcast transmitter.

At the heart of the control network are the logic circuits at each of the public broadcast transmitter sites. The logic circuit is the device that receives the control signal from two different channels, checks their authenticity, and decides whether to initiate the warning broadcast or sound an alarm calling for human intervention in cases where the probability is

high that the received alert control message is false. The logic circuit constantly monitors both incoming channels. The 60-kHz-monitor receiver is tuned to WWVB at all times and furnishes an audio input to a WWVB recognition circuit, which determines whether WWVB is operating. This information is supplied to the logic circuit. The logic circuit also continuously monitors the wire line inputs. It has recognition circuitry that accepts the codes generated by a line check code generator, and from the presence or absence of these codes determines whether the wire line is operable.

With this basic information on the conditions of the input channels being maintained continuously, the logic device is in a position to make logical decisions about the authenticity of the incoming control messages, and to implement these decisions by either automatically initiating the warning broadcast to the public, or asking for a human decision to be made whether to proceed with the alert. The logic being instrumented is that, with both channels known to be working properly immediately prior to reception of the commands, the probability that both channels could be simultaneously seized by unauthorized persons is extremely low.

3.5 PROBLEM AREAS

Four problem areas have been identified and singled out for special consideration since they are of a fundamental nature and should be discussed and resolved as soon as possible. These are: 1) Functions performed by teletype and live voice; 2) Data rate considerations; 3) Security and authentication; and 4) Overlapping coverage.

1. Functions performed by teletype and live voice.

A need for hard copy has, in the past, been based on three arguments: a) to provide text for a live-voice warning input at a lower echelon; b) to provide authentication to the owner of a commercial broadcas station when his facility is seized by automatic circuitry for the broadcast of a radio warning; and c) to be used as a tool for trouble-shooting system malfunctions.

These arguments are shown to be invalid by showing there is insufficient time in a tactical alert to compose ad lib messages and that other, slower means exist for transmission of non-time-critical strategic messages.

2. Data Rate Considerations.

It is shown that without the need for transmitting ad lib teletype messages, the actual amount of data that need be transmitted through the communication links of the system is very small. This means a low data rate for transmission

of the control messages may be used without introducing unacceptable delays in the message transmission. This allows the use of much narrower bandwidths with significant increases in signal-to-noise ratio. These improvements ease many of the design problems of the system and increase the system reliability.

3. Security and Authentication.

Different methods of achieving signal security and message authentication are discussed. These are: a) Use of cryptographic devices on a simplex, intermittent channel; b) Two-mode simplex operation on a full-period channel; and c) Two different types of full-period, simplex channels, each operated in a two-mode manner. The latter method is shown to offer high security, high reliability and reliable authentication. Costs are moderate since the second channel would be required by the system as backup to insure high reliability, regardless of whether this type of operation is used.

4. Overlapping Coverage.

The problems of trying to cover the Continental United States with adequate radio signals from multiple transmitters is discussed. When insufficient frequencies are available to insure that adjacent transmitters operate on different frequencies to avoid interference with each other's signals, some form of time-sharing method of operation must be evoked. This creates two undesirable conditions which are discussed: a) The time-sharing results in interrupted warning to the public. This is shown to degrade the effectiveness of the warning by making it less likely to wake people at night, and by causing less than optimum coverage due to short-term population mobility. It also creates annoying problems in establishing a periodic system testing program; b) Time-sharing creates difficult technical problems. Precise timing synchronization is required among all transmitters to make the system operate satisfactorily. This requires additional logic circuitry and precise time standards. The effects of intermittent operation on the system hardware, i.e., the transmitters and the home receivers, due to time-sharing can be detrimental to their performance in a critical period.

4.0 SUMMARY OF CHAPTER FOUR: PROPOSED ALERT SIGNAL AND WARNING MESSAGES

This chapter presents recommendations for the prerecorded alert signal and warning messages that are to be presented to the public on a nationwide basis via the Radio Warning System. The alert signal and warning messages are to be received through special-purpose radio receivers. The prerecorded tapes containing the alert signal and warning messages are mounted in playback equipment at selected radio stations throughout the country. Some stations are special low-frequency stations; others are specially equipped AM, FM, and TV broadcast stations. Because relatively few stations are to be used, the prerecorded alert signal and warning messages must provide intelligence suitable for dissemination to the entire country.

4.1 CONCLUSIONS AND RECOMMENDATIONS

The alert signal recommended is Car Horns R1 and R2--Speeded, generated by sounding two horns from an unspecified foreign automobile. The lower-pitched of the two is sounded continuously, while the higher-pitched is pulsed at the rate of two pulses per second. The minimum duration of the alert signal should be approximately 40 seconds, and the loudness-level 90 db at 10 feet. Five specific messages are recommended:

1. Alert signal and warning message (recommended for tactical warning only).

2. Warning message without an alert signal (recommended for strategic warning).

3. Cancel message (to countermand a false alarm disseminated to the public).

4. Test message without alert signal (for testing the Radio Warning System through to the home receiver).

5. Test message with modified alert signal (for testing the Radio Warning System through to the home receiver and conditioning the public to the alert signal).

Tables 1-2 through 1-7 present suggested warning messages, whose sound pressure levels should be approximately 65-75 db at 10 feet.

4.2 WARNING PROCESS

The task of selecting the alert signal and of designing the various messages transmitted over the Radio Warning System is tantamount to designing the interface of that system with the total civil defense program. Signals and messages can be devised, but they are effective only under the following conditions:

1. If they are coordinated with the shelter program; the messages must be directed to the level of protection available.

2. If they are presented effectively to the public through training, education, and advertising; neither shelters nor the Radio Warning System can be effective unless the public is conditioned to the effective use of both.

3. If they are supported by effective civil defense at the local level. The best national programs in warning and shelters are likely to be inadequate without close support from local civil authorities, including the making available of local broadcasting facilities for communications with the public in the preattack and trans attack periods.

4.3 RECOMMENDED ALERT SIGNAL

4.3.1 Selection of a Signal

Only limited information is available on alert signals suitable for dissemination via the Radio Warning System. Much of this information is contained in a study performed for the Office of Civil Defense (OCD) by researchers at Michigan State University (MSU).[1] It identified certain sounds and signals as having a high potential for alerting the public.

Starting with recordings of 400 sounds--including currently used warning signals, environmental sounds, and electronically produced sounds--MSU researchers collected over 1200 individual subjective ratings of these sounds (in both laboratory and field environments). The six with the highest overall ratings are:

Rank	Signal
1	Missile Alarm
2	Yelper Siren

[1] Herbert J. Oyer and Edward J. Hardick, Response of Population to Optimum Warning Signal, Michigan State University, SRR 163, September 1963. This report was completed under contract OCD-08-62-162.

3	British Air Raid Siren--Speeded
4	Falcon Horn #1
5	Car Horns R1 and R2--Speeded
6	Yelper Siren--Speeded

(The term "speeded" appended to 3, 5, and 6 above, indicates that these signals were played back at twice the level at which they were recorded.)

On the basis of the MSU study, the only alert signal that can be recommended for the Radio Warning System is Car Horns R1 and R2--Speeded. This recommendation is based upon the following considerations:

1. It was among the best five as subjectively rated in a series of tests involving over 1,200 people.

2. It was among the top three signals; is subjectively rated by a group of laborers; this rating was of the sound in a field of factory noise.

3. It is highly detectable in ambient noise; it ranks highest of all six alert signals in fields of factory noise, street noise, and speech babble.

4. It is the most effective awakening agent of those tested.

5. It is a unique sound, having no analogue in everyday experience.

Car Horns R1 and R2--Speeded is generated by sounding two horns from an unspecified foreign automobile. The lower-pitched of the two horns is sounded continuously, while the higher-pitched horn is pulsed at the rate of two pulses per second. The resulting sounds are rendered unspecific by tape recording them and then rerecording them at twice the speed of the initial recording. This process tends to double the apparent pitch of the signal and probably accounts for the high alerting potential that was assigned to the signal by a large number of listeners of various ages, sexes, and occupations. It probably also accounts for the excellent power this signal has to penetrate high levels of ambient noise.

The alert signal recommended, therefore, is essentially neutral; that is, it has no specific meaning. Thus, an effective program of training and education can condition the public to respond to it as the immediate signal of a specific danger--nuclear attack. Ineffective use of the signal, however,

especially through poorly designed testing programs, can deprive the signal of any effective meaning, or, even worse, can cause the alert signal to connote a meaningless alarm. The signal, itself, is excellent; the meaning given to it depends not only upon the Radio Warning System, but is also a function of the entire civil defense program. Furthermore, in the interval between initial field tests of the Radio Warning System and availability of receivers to the public, considerable opportunities will be available for reassessing the choice of an alert signal.

4.3.2 Duration and Loudness of Alert Signal

The approach of this discussion is to determine the duration and loudness-level of the alert signal that appears suitable for alerting a sleeping population and to use this time interval and loudness-level for alerting both an awake and a sleeping population. Because of the unavailability of any data that make feasible the selection of a time interval for daytime alerting, the interval selected for nighttime seems intuitively adequate--given an adequate signal-to-noise ratio--to alert the population during its daytime and evening activities.

In two separate sets of experiments, volunteers used the telephone ring to awaken members of a sleeping population.[1] Data from these experiments have been merged, and statistics have been developed for the cumulative percentage of a sleeping population that can be expected to respond to a telephone ring in given periods of time. Table 1-1 summarizes this information.

Table 1-1. Time Response of a Sleeping Population to a Telephone Ring

Awakened (Percent)	Time (Seconds)
50	21
66	30
90	42
95	53
99	75

[1] Theodore Wang, et. al., Air Raid Warning in the Missile Era, Operations Research Office, the Johns Hopkin University, ORO-TR-1, July 1960, pp. 29-33; W. A. Hamberg, et. al., Study of Tactical Movement Concepts and Procedures For Civil Defense Planning, Operations Research, Incorporated, Technical Report 210, pp. 143-161, 173.

If it is assumed that the population is conditioned to the recommended alert signal to some approximation of the degree it is conditioned to the ring of a telephone, then it appears that the optimum duration of the alert signal for awakening the population from sleep should range from approximately 20 seconds to 75 seconds. It appears desirable, furthermore, to achieve as high a level of alert effectiveness as possible on the first alert cycle. This has the following advantages:

1. It potentially starts the greatest number of people moving to shelter at the earliest possible time.

2. It provides the confirmation of as much repetition as possible to those who are still groggy or skeptical.

3. It provides the greatest insurance against premature system failure or destruction.

For the reasons given above, and particularly to minimize the impact of early system failure or damage, it is recommended that the objective of the system be to alert 90 percent or more of the population on the first presentation of the alert. The minimum time for the alert is, therefore, approximately 40 seconds.

It is impossible to determine the extent to which the warning message that follows the alert signal will augment the alert signal itself. If it is assumed that the cycle of alert signal followed by warning message is continuously effective as an awakening agent, then a one-minute alert-warning cycle (of which 40 seconds is an alert signal) could be expected to awaken as much as 95 percent of the population. If, however, the warning message is not as effective an awakening agent as the alert signal, then a 40-second alert could be expected to awaken as much as 90 percent of the population.

The average noise level in a home that has a radio, television set, or phonograph operating is approximately 50 db. (The figure is quoted with a radio, television set, or phonograph operating, since this appears to be more typical of current noise levels in the home.) Noise in small businesses runs, on the average, from 53.5 to 68.5 db. These figures of approximately 50 to 65 db, therefore, set the minimal level of presentation for an alert signal. The limit upon the upper range of alert signal level is approximately 130 db, the point at which damage may possibly be done to a listener's hearing. The alert signal, therefore, should be presented at a level somewhere between 50 and 130 db.

On the basis of overall research studies, MSU researchers conclude that the alert signal should be presented so as to provide a sound pressure level of 80 to 100 db at the listener's ear. Limited experimentation at System Development Corporation indicates that the recommended alert signal should be presented at a sound pressure level of 90 db at 10 feet. Though the effort expended in this area has not been conclusive, it appears evident that the loudest alert signal has the greatest alerting potential.

4.4 WARNING MESSAGES

There is little information available regarding the format and content of the warning messages to be broadcast by the system. The messages recommended are based upon analysis of known responses of people to disaster warnings. The complete flexibility inherent in prerecorded messages allows the messages recommended to be changed as more experience is gained with the Radio Warning System. The messages transmitted are self-explanatory and can be changed without risk of loss of previous conditioning of the public. Therefore, the recommended messages can be changed even after the system is operational.

4.4.1 Perception of Speech

Developing message formats and content is further simplified by the nature of speech itself. A verbal communication is inherently resistant to distortion because of the high redundancy inherent in speech. The sound pressure level at which the message is presented is also relatively uncritical. There appears to be an optimum level for a voice message delivered over any communications system. Below this optimum level an increasing number of speech components fall below the threshold of audibility; above it the ear tends toward fatigue. Limited experimentation at System Development Corporation indicates that the sound pressure level of a warning message should be approximately 75 db at 10 feet. Beyond this point, the distortion inherent in a loud voice message sounded through a variety of small radio speakers became very annoying, perhaps because of the fatigue factor mentioned above.

A more critical factor that must be considered in assuring the quality of the message delivered to the public is the speed of delivery. Laboratory experiments have established 120 words per minute as the optimal rate of delivery. This rate is used in the time calculations associated with the proposed messages.

The final factor that must be considered in preparing warning messages is highly qualitative. A verbal message carries considerable information about the speaker. Studies have indicated that listeners often agree among themselves that an unseen speaker seems to be what he is not; these studies have often resulted in attributing qualities to a speaker with a consistency significantly greater than chance, but in the wrong direction. Not all the listener's information depends upon the speaker's choice of words; therefore, care must be exercised to assure that the delivery of the prerecorded message does not weaken the anticipated effect of the verbal content of the message.

4.4.2 Message Characteristics

An effective warning message should have the following attributes:

1. Official. The message should represent to the recipient the official policy of the warning agency. In the case of tactical warning, the agency is the federal government.

2. Impressive. The message should not be easily ignored. The danger inherent in the impending situation should be explicit. In part the effectiveness of the message itself can be favorably augmented by the prior presentation of a suitable alert signal; by effective delivery; and by repetition, over verbatim repetition.

3. Unequivocal. The message should be simple, clear, and direct. It should, furthermore, allow no possibility of inconsistent interpretation; any instruction given should be completely consistent and noncontradictory.

4. Personal. The message should convince the recipient that he personally is in danger and that the protective action prescribed applies directly to him.

5. Balanced. The message, in order to produce effective action, must balance the danger of attack with the protection afforded by taking the appropriate action. Failure to do this may produce ineffective, maladaptive action, or may result in an apathetic rejection of any action.

The tactical warning message is a true warning message: It warns of a specific threat (nuclear attack) for which specific protection is available (fallout shelters). Additionally, a tactical warning is time critical; an effective response to it must be prompt. The other messages disseminated by the system are not true warning messages; rather they are announcements of specific conditions warranting public attention. The tactical warning message and the other messages disseminated via the Radio Warning System are presented in Tables 1-2 through 1-6.

4.4.3 Rules for Message Formats

Certain rules have been devised for formatting messages. These rules are intuitive and have not been subjected to laboratory testing. They have been applied as consistently as possible to all messages.

1. Message Flags. These are one or two attention-getting words (repeated twice) that identify the general character of each type of message. Repetition is used to emphasize the message where appropriate; this is particularly true of the strategic warning message, which, if it has to waken a sleeping population, will have to do so without the aid of an alert signal.

2. Start-Stop Emphasis. Wherever possible, key words are placed at either the start of a sentence or at the end of a sentence. In all cases key words are placed at the end of a message.

3. Redundancy. Two types of redundancy have been built into the Radio Warning System messages: redundancy within each message; and redundancy through repetition of complete messages as long as the system operator feels that repetition can rouse more people to take protective action.

4.5 RECOMMENDED MESSAGES

Table 1-2. Proposed Tactical Alert and Warning Message

Item	Content	Word Count	Time (Sec.)
1	(Alert Signal)		40
2	ATTACK--ATTACK	2	
3	THE UNITED STATES IS UNDER NUCLEAR ATTACK	7	
4	I REPEAT--THE UNITED STATES IS UNDER NUCLEAR ATTACK	9	10
5	GO TO SHELTER	3	
6	GO TO SHELTER IMMEDIATELY	4	
7	YOU ARE IN DANGER--YOU CAN SAVE YOUR LIFE IF YOU IMMEDIATELY GO TO SHELTER	15	10
	Total	40	60

4.5.1 Tactical Warning Message

It is recommended that the verbal portion of the tactical warning message be presented at a sound pressure level of 75 db at 10 feet; the rationale for presenting the alert signal at a sound pressure level of 90 db at 10 feet has already been discussed.

It must be pointed out that the instruction GO TO SHELTER is predicated upon two assumptions:

1. When the Radio Warning System is implemented, there will be adequate shelter space for the total population, distributed so as to provide approximately 15-minute access time in urban areas.

2. As a result of specific and intensive educational efforts--reinforced by the installation of a shelter system and the Radio Warning System--the vast majority of the public will know in the time frame of the system the purpose of both the Radio Warning System and the shelter system, the nature of the attack hazards, and the proper response to an attack warning.

If either of these assumptions is not valid, then the instruction GO TO SHELTER cannot be effective. Instead the instruction TURN ON YOUR RADIO FOR INFORMATION would have to be recommended because of the degree to which this instruction would, within the obvious time constraints, allow local officials to reinforce the warning and direct the responses of the public.

4.5.2 Strategic Warning Message

The strategic warning message is not a true warning message: It only warns of a generalized emergency and, therefore, cannot prescribe specific protective measures (see Section 4.4.2). The response of the auditor generally need not be as timely as his response to a tactical warning. The strategic warning message should be official and unequivocal; but it cannot be personnel, impressive, or balanced, at least as these terms have been defined above. Because of the lack of a specific threat, balance is impossible; consequently, the message must play down the impressiveness of a warning over the warning receiver in order not to cause undue alarm and maladaptive responses. The alert signal is not used because of the necessity to reserve it for a tactical warning, which requires a time-critical response. It is recommended that the first cycle of the strategic warning message be broadcast at a sound pressure level of 90 db at 10 feet in order to increase the probability of attracting attention without the necessity of using an alert signal; subsequent cycles of the strategic warning message are to be broadcast at a sound pressure level of 75 db at 10 feet to increase the intelligibility.

The delivery of the message must connote immediacy, but not imminent danger. The strategic warning message is, therefore, more accurately characterized as an advisory announcement of a more specific warning to be disseminated via commercial radio and TV stations. Presumably the radio or television set, when the listener turns it on, will give him more information about a probable nuclear attack, but the strategic warning message, itself, is sufficiently general that it can be used for any purpose grave enough to warrant warning the entire nation.

Tables 1-3 and 1-4 contain the proposed strategic warning messages. Two different messages are proposed, one for areas served by a special low-frequency station (Table 1-3); the other, for areas served by local AM, FM, and TV stations (Table 1-4).

Table 1-3. Proposed Strategic Warning Message for Areas Served by a Low-Frequency Station

Item	Content	Word Count	Time (Sec.)
1	EMERGENCY--EMERGENCY	2	
2	THIS IS AN EMERGENCY	4	
3	I REPEAT--THIS IS AN EMERGENCY	6	
4	FOR INFORMATION TURN ON YOUR RADIO OR TV	8	
5	I REPEAT--TURN ON YOUR RADIO OR TV FOR INFORMATION	10	15
6-10	(SAME AS 1-5)	30	15
11	THE STATION YOU USUALLY LISTEN TO MAY NOT BE ON THE AIR--IN THAT CASE TUNE TO ANY RADIO OR TV STATION THAT IS ON THE AIR	27	12
12-16	(SAME AS 1-5)	30	15
	Total	117	57

Table 1-4. Proposed Strategic Warning Message for Areas Served by an AM, FM, or TV Station

Item	Content	Word Count	Time (Sec.)
1	EMERGENCY-- EMERGENCY	2	
2	THIS IS AN EMERGENCY	4	
3	I REPEAT--THIS IS AN EMERGENCY	6	
4	FOR INFORMATION TUNE TO RADIO STATION WXYZ, 1250 ON YOUR RADIO	11	
	--or--		
	FOR INFORMATION TURN ON TV STATION WXYZ-TV, CHANNEL 10	10	
5	I REPEAT--TUNE TO RADIO STATION WXYZ 1250--1250--ON YOUR RADIO DIAL FOR INFORMATION	15	Radio = 25
	--or--		
	I REPEAT--TURN ON TELEVISION STATION WXYZ-TV, CHANNEL 10--CHANNEL 10--FOR INFORMATION	14	TV = 25
6-10	(Same as 1-5)	Radio = 38 TV = 37	Radio = 25 TV = 25
	Total	Radio = 76 TV = 73	Radio = 50 TV = 50

Table 1-5. Proposed Cancel False Alarm Message

Item	Content	Word Count	Time (Sec.)
1	FALSE ALARM--FALSE ALARM	4	
2	THE ALART SIGNAL OR EMERGENCY MESSAGE YOU JUST HEARD WAS A FALSE ALARM	13	
3	I REPEAT--A FALSE ALARM WAS JUST SENT OUT OVER THE RADIO WARNING SYSTEM	14	
4	DISREGARD ANY ALERT SIGNAL OR EMERGENCY MESSAGE YOU JUST RECEIVED FROM YOUR WARNING RECEIVER	14	
5	I REPEAT--DO NOT CARRY OUT ANY EMERGENCY INSTRUCTIONS YOU MAY HAVE RECEIVED FROM YOUR WARNING RECEIVER	17	
6-7	(Same as 2 and 3)	27	44
8	IN ORDER NOT TO INCONVENIENCE YOU FURTHER, WE ARE NOW ENDING THIS FALSE ALARM MESSAGE	15	
9	WE HOPE YOU HAVE NOT BEEN BADLY INCONVENIENCED BY THIS FALSE ALARM	12	13
	Total	116	57

4.5.3 Cancel False Alarm Message

This type of message is not a warning message: it cancels a prior false alarm that reached the public. It may be time critical. If the false alarm was an apparent tactical warning, and the public has been trained to take shelter promptly, as has been assumed, then a timely cancel message will minimize the inconvenience and confusion by countermanding shelter-movement instructions. If, however, the false alarm was an apparent strategic warning, then the dissemination of a cancel message is less time critical because no shelter movement is involved. The message should be official and unequivocal, as defined above, but it cannot be impressive, balanced, or personal. Someone or something associated with the Radio Warning System delivered an "official" warning, indeed, a false alarm. There is no possibility of personalizing such a message; there is no danger for the listener to identify it as a threat to himself. The lack of threat, and the consequent cancellation of instructions to take protective action, invalidate the possibility of preparing an impressive or a balanced message. The message itself is critical because it aids in minimizing potential compromise of the Radio Warning System and of the entire civil defense system that may result from a large-scale false alarm.

Table 1-5 contains the text of the Proposed Cancel False Alarm Message. It is recommended that this message be presented only once, that it not be repeated as are the tactical warning and strategic warning messages, and that presentation be at a sound pressure level of 75 db at 10 feet.

4.5.4 Test Messages

Test messages are routine messages to which the public will be exposed with some frequency. The public response to these messages can be highly significant: The messages can help to 1) familiarize the public with the operation of the System, 2) locate failed or failing receivers, and 3) identify the System as a source of meaningful, potentially lifesaving information. These messages are time critical in a special sense; they should always occur at a time selected to reach the largest number of people. They should also have the characteristics of the tactical warning message itself, though to an extent limited by the fact that they are being used in tests. The test messages can be used to condition the public to the possibility of hearing a warning message over the Radio Warning System and to the need for each listener to take the protective action specified. Thus, while a test message is not, by itself, a critical message, an ineffectively designed or used test message can vastly degrade response to an attack warning when it is ultimately disseminated, while an effectively designed and used test message can enhance the response to an attack warning.

Tables 1-6 and 1-7 contain proposed test messages. The message in Table 1-6 is designed primarily to familiarize the public with the operation of the Radio Warning System and to help locate failing receivers. The message in Table 1-7, in contrast, is primarily designed to help condition the public to recognize and respond to the alert signal used in the tactical warning message.

It is recommended that the texts of both messages be presented at sound pressure levels of 65 db at 10 feet, and that the alert signal, when used, be presented at a sound pressure level of 60 db at 10 feet.

Table 1-6. Proposed Test Message Without Alert Signal

Item	Content	Word Count	Time (Sec.)
1	TESTING--TESTING	2	
2	THIS IS A TEST OF THE RADIO WARNING SYSTEM	9	
3	I REPEAT--THIS IS ONLY A TEST	7	9
4	ATTENTION TO THIS TEST MESSAGE COULD SAVE YOUR LIFE	9	
5	WE ARE TESTING YOUR WARNING RECEIVER	6	
6	IF YOUR RECEIVER DOES NOT SOUND RIGHT, PLEASE TAKE IT TO YOUR NEAREST FIRE HOUSE FOR TESTING OR REPLACEMENT AT NO COST TO YOU	24	19
7	IN AN EMERGENCY, A MESSAGE ON YOUR WARNING RECEIVER WOULD TELL YOU WHAT YOU SHOULD DO	16	
8	PROMPT RESPONSE TO A WARNING COULD SAVE YOUR LIFE	9	12
9	THIS CONCLUDES A TEST OF THE RADIO WARNING SYSTEM	9	
10	I REPEAT--THIS HAS BEEN A RADIO WARNING SYSTEM TEST	10	9
	Total	101	49

Table L-7. Proposed Test Message with Modified Alert Signal

Item	Content	Word Count	Time (Sec.)
1	TESTING--TESTING	2	
2	THIS IS A TEST OF THE RADIO WARNING SYSTEM	9	
3	I REPEAT--THIS IS ONLY A TEST	7	9
4	ATTENTION TO THIS TEST MESSAGE COULD SAVE YOUR LIFE	9	
5	IN CASE OF A NUCLEAR ATTACK ON THE UNITED STATES, THE FOLLOWING SIGNAL WOULD BE SOUNDED LOUDLY:	17	13
6	(Alert signal at low volume)		10
7	THIS IS ONLY A TEST	5	
8	I REPEAT--THIS IS ONLY A TEST	7	
9	IN A NUCLEAR ATTACK THE ALERT SIGNAL YOU JUST HEARD WOULD BE FOLLOWED BY THE INSTRUCTION TO TAKE SHELTER IMMEDIATELY	20	
10	PROMPT RESPONSE TO THE ALERT SIGNAL AND THE INSTRUCTION TO TAKE SHELTER COULD SAVE YOUR LIFE	16	24
11	THIS CONCLUDES A TEST OF THE RADIO WARNING SYSTEM	9	
12	I REPEAT--THIS HAS BEEN A RADIO WARNING SYSTEM TEST	10	9
	Total	111	65

5.0 SUMMARY OF CHAPTER FIVE: REVIEW AND EVALUATION OF NIAC SIGNALING METHODS

This chapter reviews and evaluates the activities to date of the Federal Communications Commission (FCC) in the development of civil defense alerting and warning techniques suitable for use by commercial radio and TV broadcast stations. Initially, the effort undertaken in early 1963 by a working group of the National Industry Advisory Committee (NIAC) attempted to devise techniques applicable to indoor public alerting and warning for use in individual homes, transient accommodations, and places of business. In March 1964, however, the NIAC effort was redirected toward development of signaling techniques for initiating EBS operations.

From thirteen proposals submitted in response to a public notice in February 1963, NIAC selected four for further development and testing. These were originated by Columbia Broadcasting System (CBS); Philco Corporation (Philco); General Electric Company (GE); and Zenith Radio Corporation (Zenith).

5.1 LIMITATIONS OF NIAC APPROACH

The mode of operation of NIAC is found to be inadequate because:

1. It lacks comprehensiveness. NIAC responds only to proposals and does not designate certain techniques as requiring further study.

2. It capitalizes upon the potential commercial profit that a successful proponent stands to gain from his effort. These commercial goals are largely inapplicable to the development of an alerting and warning system.

3. It lacks adequate guidance as to the requirements that such a system would have to meet. Thus, each of the four proponents proceeded to meet his own performance requirements.

5.2 POSITIONS TAKEN BY PROPONENTS

Each proponent prepared a final report that evaluated his effort in comparison with those of the other proponents. A brief review of these is included in the chapter, together with tables summarizing some of each of their key requirements.

5.3 NIAC TESTING TECHNIQUES

The NIAC tests of the proposed signaling techniques were divided into bench tests and field tests. These are summarized and found lacking because, though informative, they are unconvincing because they do not establish the fact that they were dealing with the total radio environment.

5.4 CONCLUSIONS

Lack of standardized requirements makes it impossible to select one system as superior to any other; in fact, it invalidates much of the work performed by NIAC.

NIAC attempted to establish through a combination of bench and field testing a severe environment in which to test receivers for false alarm and no alarm failures. The bench testing appears to have been rigorously planned and standardized, but without the establishment of precise test duration. The field tests were also carefully designed, but operated for so short a time as to make impossible any guarantee that the test environment exhaustively represented the full range of environments in which operational receivers would have to function.

While the NIAC effort provides some useful information, the lack of standardized requirements and of exhaustive testing make selection of alerting and warning signaling techniques and an associated receiver premature. This is true even if the receiver is used only for initiating Emergency Broadcast System (EBS) operations in the participating radio stations. Acceptance of one of the proposed techniques, even if it is only for controlling EBS, will tend to preempt signaling techniques used for home alerting and warning. It is likely that the implementation of one of the NIAC signaling techniques for EBS control will make the broadcasters reluctant to implement a second technique for home alerting and warning. If a technique is selected for EBS control before a technique is selected for public alerting and warning it is possible that the optimum public alerting technique may be incompatible with the EBS control technique.

6.0 SUMMARY OF CHAPTER SIX: PROBLEMS OF PREDICTING RECEIVER RELIABILITY

This chapter discusses the use (and misuse) of probabilistic models for predicting the false-alarm reliability of receivers for the Radio Warning System. What prompted the discussion was an examination of two such models derived by corporate members of the National Industry Advisory Committee (NIAC) Systems Analysis Ad Hoc subcommittee. One was devised by the Radio Receiver Department of General Electric Company; the other by Philco Corporation.

The General Electric model contains several critical errors of mathematical detail, which are demonstrated. More important, however, both models may be in error on more basic grounds: A mathematical model of a real process is only as valid as the assumptions upon which it is based; and the assumptions are valid only to the extent that they reflect the process they are attempting to model. In the problem at hand, that of predicting the likelihood of receiver false alarm, two broad areas of interrelationships between parameters are not known fully:

1. The relative impact of frequency, amplitude, and duration on the likelihood of false alarms is not clear.

2. The degree to which the above characteristics are mutually related in the likelihood of their assuming certain values is not known.

Therefore, it is recommended that either such empirical data be obtained, or that attempts at this kind of prediction through mathematical modeling be avoided in the future.

7.0 SUMMARY OF CHAPTER SEVEN: A TECHNIQUE FOR PREVENTING PROGRAM MATERIAL FROM FALSELY ACTIVATING RADIO WARNING HOME RECEIVERS

This chapter presents a method for preventing a broadcast station from ever transmitting demuting signals to radio warning receivers tuned to it during normal broadcast operations. The proposed method removes objections that station owners might have to using devices that could degrade their transmissions.

The technique uses notch filters to remove the demuting tones from broadcast material. The technique overcomes the objections of broadcasters by inserting the notch filters dynamically into the station programming line only when the demuting tones appear for a long enough period of time to threaten a false alarm. If a valid warning is required, the notch filters would be inhibited from insertion in the programming line before the demuting tones were transmitted. Thus, the notch filters would be in the programming line only as long as they were needed to prevent a false alarm and would not degrade the quality of normal program material. It is recommended, therefore, that all future planning for the Radio Warning System include dynamically controlled filtering technique.

8.0 SUMMARY OF CHAPTER EIGHT: COHERENT RECEIVER DEVELOPMENT

This method reviews and summarizes work performed in developing secure signaling methods for demuting home warning receivers. This effort evolved from an investigation of receivers developed by the National Industry Advisory Committee (NIAC).[1] Two deficiencies were found in the NIAC evaluations:

1. The attempt to enhance several of the reports with mathematical analyses based on unsupported assumptions about the noise and program material environments of the proposed receivers was thwarted by the lack of adequate information on the distribution of noise in the broadcase-frequency band.

2. Also lacking was any information on the time, duration, and frequency of tones that exist in commercial broadcast material.

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[1] Chapter Five, "Review and Analysis of NIAC Signaling Methods."

Since it is believed that such data are nonexistent in the form needed for a proper analysis of the effects of program material on receiver demuting circuitry and, furthermore, that any effort to collect adequate data would be time-consuming, costly, and inconclusive, it was decided to study the possibility of developing demuting circuitry that would respond only to unique signals that could not normally be produced by either natural or man-made sources.

8.1 CONCLUSIONS AND RECOMMENDATIONS

Several configurations involving special usage of single or dual transmitters with particular receiver designs were investigated. Three of the most noteworthy designs--a two-transmitter concept; a two-station coherent signal concept; and a single-station coherent signal concept are discussed and considered to be technically feasible, but are rejected for possible application in the Radio Warning System because of excessive costs.

A coherent receiver is presented that applies the coherency principle to reed relays as a means of bringing costs down to an acceptable level.

Although only part of the circuit described has been breadboarded and tested, it is believed that its principle is sound and offers the real possibility of improving the false alarm characteristics of the radio warning receiver. As comparative costing figures are still not available, it is not possible to place a dollar value on the costs of this design; however, the number and types of components used are comparable to those used in the conventional two-tone demuting circuit currently under development for OCD, and it is believed that the costs should be in the same range. More development work needs to be done to prove the operation of this circuit, but it is believed that such an effort would be worthwhile to the Radio Warning Program. It is recommended, therefore, that such developmental work be undertaken.

9.0 SUMMARY OF CHAPTER NINE: A COMPARISON OF NIAC AND OCD RECEIVERS

Three radio warning home receivers are compared in this chapter: those proposed by Philco Corporation and Zenith Radio Corporation to the National Industry Advisory Committee of the Federal Communications Commission, and the one that is being developed for the Office of Civil Defense.

The standard criteria that are used to compare these receivers, one with another, are derived from an authoritative document accepted within OCD which defines the operational requirements for the Radio Warning System (see Chapter One, "Interim Operational Requirements").

9.1 CONCLUSIONS AND RECOMMENDATIONS

Enumerated is a compilation of those requirements pertinent to the home receiver. There follows an evaluation of each receiver in relation to these

requirements, supported by a table listing the significant operating parameters of each receiver. The only real differences in the receivers are the logic of the demuting circuitry and the philosophy of operation. The OCD receiver design was the result of a careful consideration of the operational requirements as propounded and defined by numerous discussions and working group meetings with OCD technical personnel. On the contrary, the NIAC receivers were derived independently by individual manufacturers each working from his own definition of the operational requirements.

Using the requirements generally acceptable by OCD as a yardstick, it is evident that, of the three receivers compared, only the OCD-proposed one is compatible with the mission of a civil defense public warning system.

10.0 SUMMARY OF CHAPTER TEN: DETERMINATION OF CONTROL FREQUENCIES FOR THE RADIO WARNING SYSTEM

This chapter, which extends ideas previously presented in Chapter Six,[1] focuses on the following problem: Is it possible to arrive analytically at an optimum signaling technique, using conventional methods, that will minimize the probability of receiver false alarms caused inadvertently by normal broadcast program material?

The approach taken in solving this problem may appear to violate the conclusions previously presented in Chapter Six because mathematical models are used. However, the models are qualitative, not quantitative, and the conclusions drawn from them are based on empirical knowledge of the type of program material that the models describe.

10.1 CONCLUSIONS AND RECOMMENDATIONS

The result is a recommended signaling technique for controlling the public receiver components of the Radio Warning System. It may be summarized as follows:

1. Automatic Recovery From False Alarms

   Whatever signaling technique is used to activate the public receiver, it must be such that a receiver, accidently activated by noise in the radio environment that duplicates the effect of the transmitted control tones, automatically turns off in the absence of such noise.

2. "Subaudible" Control Tones

   The control tones used to activate the public receiver must be inaudible at the receiver output, lying either above or below that

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[1] "Problems of Predicting Receiver Reliability."

portion of the audio spectrum used by the human voice. Since "superaudible" frequencies are reproduced in practically all combinations in the course of musical programming, the "subaudible" spectrum appears to have greater potential for false-alarm-free control. This potential can be enhanced by the proper selection of control tones.

3. Parallel Operation

It can be demonstrated that a control signaling technique which uses n tones transmitted simultaneously is inherently more reliable than a technique which uses n tones transmitted in sequence.

4. Continuous Spectrum of "Musical" Tones

The musical scale must be considered as a continuous spectrum as far as analyzing the programming environment to which the public receiver will be exposed. In other words there are no frequencies that cannot appear as musical tones, not even in the "subaudible" range.

5. Characteristics of Demuting Signals

It is recommended that the signaling technique used to activate the public receiver in the Radio Warning System have the following characteristics:

a. Two Tone Simultaneous. The system should use two simultaneous tones.

b. Percent Difference. The higher tone should have a frequency 22 percent greater than the lower tone.

c. Octave Band of 50-100 Hz. The two tones should both lie in the octave band between 50 and 100 Hz, which is in the octave band approximately between A^3 and A^2.

d. Ten-Second Time Delay. The two tones should be transmitted for at least 10 seconds. The time delay of the receiver should also be at least 10 seconds.

It is suggested that two suitable tones for use in receiver control be 87.31 Hz and 106.52 Hz.

CHAPTER TWO

INTERIM OPERATIONAL REQUIREMENTS

1.0 INTRODUCTION

This chapter is a compilation of the operational requirements for the proposed Office of Civil Defense (OCD) Radio Warning System.[1] The major portion of these requirements is derived from discussions about the capabilities desired for the Radio Warning System among OCD personnel and the contractors concerned with the system.[2] These discussions have taken place at the three formal meetings of the Working Group for Radio Warning (6-9 July 1964, 29-30 September 1964, and 8-10 December 1964), as well as in several informal meetings involving OCD and contractor personnel during the six months prior to publication (1 February 1965).

2.0 CONCLUSIONS AND RECOMMENDATIONS

The operational requirements that are listed and explained in this chapter constitute a consensus of the best thinking that has been done to 1 February 1965 on the Radio Warning System. These requirements represent a statement of the areas of agreement that have been reached among responsible personnel of OCD and associated contractors as to the basic operation of the Radio Warning System. It is recommended that these operational requirements be accepted by OCD as the basic set of criteria defining the operation of the Radio Warning System.

Such acceptance by OCD will then become a recognition by that organization that the preliminary steps in the design of the Radio Warning System have been taken and that a foundation for all future development work has been laid. This recognition will then serve as notice to all design personnel that their designs must conform to the set of operational requirements that have been agreed upon if they are to be considered acceptable to the Radio Warning System development program.

While these operational requirements should be considered as defining the fundamental principles of the Radio Warning System and, therefore, should be binding upon all design personnel, they should not be considered immutable. The development program must be flexible enough to allow changes to be made when early estimates of requirements are found to be invalid in the light of increased knowledge gained in the system development process. The making of these necessary changes should not be inhibited by this set of operational requirements, but the discipline exercised by OCD in directing the development

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1. This chapter contains the same information as, but does not supersede, Radio Warning System Interim Operational Requirements, which was published as SDC TM-L-1960/021/02, dated 1 February 1965.

2. System Development Corporation; Stanford Research Institute, Menlo Park, California; and Gautney and Jones Communications, Inc., Washington, D. C.

efforts on this program should require that changes recommended by any member of the development team be coordinated with the other members. It is equally important to program discipline that steps be taken to amend the documentation of the operational requirements so that the design base for the system will always be up to date and available as a source of basic input to all members of the design team as well as to other interested agencies and organizations.

3.0 BACKGROUND INFORMATION

3.1 UNDERLYING PUBLIC REQUIREMENTS

Before the design and development of a system to warn the public of a civil defense emergency can be completed, the basic needs of the public as they affect the system must be determined. Without a firm understanding of what it is that the public wants and needs in the way of warning, any design and development efforts will be carried out in a vacuum. The needs of the public, as they affect the system, must be examined in two separate time frames: first, when a situation arises that puts life in immediate danger, and second, in the normal preemergency period when participation is needed to make the system operate effectively and to finance its installation and upkeep. The requirements derived from these needs apply to the entire Civil Defense Warning System, of which the Radio Warning System is a part, along with sirens, public address systems, NEAR, and any other techniques that may be used in various parts of the country. The public does not specify the means by which the warning is delivered so long as it is received.

3.1.1 Emergency Time Frame

In time of danger, when the alert signal sounds, a person wants answers to the following questions:

What is happening?

Is it the real thing?

What do I do about it?

He wants answers, and, in an age of nuclear peril, he needs them immediately. From these questions, it is possible to derive three basic system requirements that the user demands.

1. Coverage. The system must be designed to reach as many people as possible within the constraints of rapidly accelerating costs. It must deliver an alert and warning promptly any time of the day or night, any time of the year. It must reach members of the public in virtually any location where they may be in their normal activities. To be sure, these can only be design goals, but every individual citizen of the United States who cannot be reached by the system represents a compromise of this particular system requirement.

2. Credibility. Not only must the public receive the warning, the warning itself must be credible enough that the public will react as though the threat were real. If there is sufficient doubt, valuable time can be lost when minutes, surely, and even seconds may count. The system must be reliable in performance, and the warning process must contain self-authenticating features.

3. Content. The warning process must insure that direction as to what to do to meet the emergency is provided to the public. This presupposes the existence of protective measures and an interaction with the shelter system during the emergency planning process. It leads to a requirement that the system be capable of transmitting voice messages and that these messages be intelligible in a time of great stress. Finally, since there will be local variation in the planned course of action to be followed by the public, the system must be able to provide warning information and direction that is integrated with local protective measures. Again, it must be remembered that this requirement applies to the overall warning system, not necessarily to the OCD Radio Warning System itself. Local voice messages may be provided by another component of the warning system. If this is the case, however, the interface between the OCD Radio Warning System and such a component will require careful planning to insure an integrated functioning of the warning process.

3.1.2 Normal Time Frame

In the normal preemergency time period, the public will be called to support the system in several ways. First, and foremost, the public will have to pay for the system. This may be done solely through taxes -- each family may, in addition, have to buy a piece of equipment out of pocket. Second, the public may have to be called upon to interact with the system in a training or testing capacity. This may be necessary not only to train people in how to save their lives when an emergency arises, but also to insure that the warning system itself will operate effectively in the event it is needed. Finally, the public will probably be required to put up with some annoyance from the system, particularly any part of it located within the home. This annoyance may range from having a little black (or perhaps off-white) box creating an unsightly effect on the bedroom wall, to having this box fail and pour out 80 or 90db of rock-and-roll music at two o'clock in the morning.

The degree to which the public is willing to participate in supporting the system and interacting with it will be conditioned by two subjective probabilities. First, how likely is it that an attack will occur? In other words, is there a need for the system? Second, if an attack comes, are chances any better if the public receives a warning? In other words, will the system do any good? While OCD can have no control over the first factor, the second

one--Will the system do any good?--can be affected by the design of an effective system, by an educational campaign, and by related measures. The greater the public reliance on the warning system the more that members of the public can be expected to contribute in money and effort, the more they can be counted upon to participate in testing, and the more forbearance they can be expected to offer to inconveniences imposed by the system.

3.1.3 Conclusion

The public needs that must be met in the design of the Radio Warning System can be summed up in the form of three system requirements and one conditioning factor. Requirements are that the system must provide the maximum possible coverage, must have adequate credibibity, and, to the degree made necessary by the capabilities of the entire warning system, must be capable of directing the public to carry out a feasible course of action to meet the emergency. The conditioning factor is that only to the degree that these are provided can the public be expected to support the implementation and operation of the system and participate with it in working effectively toward their safety. In designing the system, the requirements must be met. The conditioning factor cannot be put in quantitative terms, but it will certainly impose constraints on system design.

3.2 THE ROLE OF OPERATIONAL REQUIREMENTS IN SYSTEM DESIGN

In the previous compilation of the operational requirements for the Radio Warning System (TM-L-1960/021/01A), a distinction was made between the terms operational capability and operational requirement. These terms were put forth in an attempt to distinguish between the general statements made during the early stages of system design describing characteristics desired in the system, and the more precise statements of minimum levels of performance in specific areas of system operation which set the standards which the system designer must meet. The former constitute, in the sense used in the previous compilation, operational capabilities, the latter, operational requirements. These terms are, however, somewhat confusing because they have been used in exactly the opposite sense in other contexts. The fact remains, however, that there is a difference between the set of operational requirements that are used in the actual design of the system and the initial "wish list" drawn up by the people who intend to operate the system, but who have not had a great deal of experience in the analysis and design of systems. The Annex to this chapter contains a list of desirable features for the Radio Warning System drawn up by the Directorate for Plans and Operations of the Office of Civil Defense. For the system operator, these constitute a set of operational requirements. For the system designer, however, they require further refinement.

The set of operational requirements which the system designer must have establishes the minimum standards which are to be used in determining which system configurations merit consideration for implementation. Any configuration which meets the operational requirements must be considered equal, at least for study purposes, to any other configuration which meets them. This means that the set of operational requirements must specify characteristics and levels of performance in every area of operation judged essential to carrying out the mission of the system, and, as importantly, only in such areas. While it is not possible in practice to prevent additional capabilities which a particular configuration may possess from entering into the evaluation process, it must constantly be borne in mind that if these are not essential to the system's primary mission they should not be weighted heavily in the evaluation. If it is decided they are necessary, then the requirements should be modified to recognize the need for these capabilities and all feasible configurations should be evaluated against them.

In order to illustrate the iterative process necessary to bridge the gap between the system operator's specification of broad operational requirements and the system designer's need of a more precise statement of these requirements, several examples of modifications that have been made to the requirements for the Radio Warning System are discussed below.

3.2.1 Population Coverage

It was previously specified by OCD that the system was to be designed to provide a signal to 100 percent (or nearly so) of the population of the United States. However, the number of people which the system will reach is not entirely within the control of the system designer. It is determined in large measure by the cost of the receiver and the temper of the population at the time the system is installed. Therefore, the choice of system configuration cannot be affected one way or the other by the number of people it purports to cover since no specification of population coverage can be claimed for any given configuration. To this factor must be added the decision by OCD initially to exclude automobile radios or personal receivers from the system. Estimates of the population in automobiles during peak traffic periods of the day range as high as 25 percent. Those located outdoors and away from radio receivers add a sizeable amount to this number. Therefore, even if the system designer could specify receiver distribution, it would still be impossible to specify a percentage of the population of the United States which the system would reach. As a result, there is no requirement included specifying the percentage of the population which the the system must reach.

3.2.2 Regional Networks and Initiation Points

Much discussion has been devoted to the problem of providing a public warning capability to the OCD Regions by means of the Radio Warning System. Until recently, it was believed by certain individuals within OCD that such a capability was essential to the system and a requirement to this effect

has been included in the previous two compilations of the operational requirements. However, it has recently been decided that this feature is not essential, however desirable it may be as a bonus benefit in any particular configuration. Therefore, the previously included requirements for regional initiation points and subnational networks have been omitted from this compilation.

3.2.3 Reliability

The system operators have specified only that the system be reliable. Before detailed requirements in this area can be written, consideration must be given to many interrelated factors which affect system reliability, (e.g., false alarm versus no alarm failures, redundancy in hardware components and communications channels, noise in the radio frequency environment, human reliability as it affects the system, methods of system testing, etc.). In TM-L-1960/021/01A, it was specified that the system be equipped with an automatic closed loop continuity checking feature which would virtually guarantee reliability of the degree which the operators desire. However, the inclusion of such a feature is not technically feasible in every configuration nor, because of radio frequency spectrum crowding, is it likely to be possible in any configuration. Therefore, this requirement has been withdrawn and replaced by a more general requirement specifying a minimum level of reliability, which must be met by any configuration regardless of the techniques used to insure its reliability.

3.2.4 Cost

System cost is, in effect, one of the criteria that will be used to judge between competing configurations that have met the other operational requirements. But it is not the only one. Time, ease of implementation, and compatibility with existing and planned systems are others. Political considerations may eventually enter into the determination of which configuration to choose as well. Therefore, it cannot be specified that the system configuration which meets all of the other requirements and can be installed for the least cost, will be chosen. Nor can a minimum receiver cost be established as a requirement. The $10.00 figure which has been discussed previously has always been regarded as a target figure. Furthermore, it has generally been treated as a cost F.O.B. the manufacturer's plant. The distribution costs have to be added to it. Since any given requirement has to be met by a given configuration on a go, no-go basis, and, since there is no reliable estimate of what the receiver will cost, there is nothing to be gained by including such a requirement in this compilation. Even if a $10.00 figure were established as a maximum cost for the receiver, past studies of public willingness to procure a receiver give every indication that the prospective market for the receiver will not be adequate without a major OCD educational campaign. Therefore, it is proposed that cost serve only as one of the criteria for judging between the proposed configurations, not as a direct constraint upon the design of such configurations.

3.2.5 Strategic Versus Tactical Warning

Opinion within OCD is divided as to whether system planning should include provisions for strategic warning or not. It is believed by some within the agency that the government does not presently plan to use strategic warning and that it would be unlikely that the government would ever risk its own domestic support as well as possible international reactions by mobilizing the public, so to speak, prior to the actual detection of an enemy attack. Others in the agency stress the potential use of the system for strategic warning. They believe that if given a ready means to communicate directly with the public, the government would be more likely to take advantage of it to increase the flexibility of its response in an international crisis, knowing that the public can be given emergency direction with no delay, if necessary. In this compilation, there are requirements as well as justifications of requirements included on the basis that the system will be used for strategic as well as tactical warning. None of these requirements significantly changes the configuration of the system from what it would be if only tactical warning were being planned. We believe that this approach allows for the fullest utilization of the capabilities of the system and assures the government that it will have a system capable of the greatest possible amount of flexibility.

3.3 GROUND RULES AND ASSUMPTIONS

3.3.1 Current System

The outdoor/indoor alerting and warning system based upon sirens and the Emergency Broadcast System (EBS) has been judged to be inadequate for future needs by OCD, in part, because it does not satisfactorily alert the indoor population. Consequently, the need exists for an automatic indoor system to augment the outdoor system.

3.3.2 Radio-Based

The NEAR program examined the feasibility of, and developed an indoor system based upon, power-line alerting. This system, however, has certain shortcomings.[1] The present program is directed toward the development of a radio-based alerting and warning system. Such a system has already been shown to be feasible.[2]

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1. System Development Corporation, Interim Report for the Office of Civil Defense: NEAR System Study, TM-L-1505/040/01, March 1964.

2. Lawrence Siegel, Interim Report to the Office of Civil Defense: Civil Defense Public Alert and Warning by Radio, Radio Corporation of America, 1965.

3.3.3 1968 Start Date

Installation of the Radio Warning System is planned to start as early as 1968 if deployment of such a system is approved.

3.3.4 Protective Measures

It is assumed that an adequate shelter program shall be available by the time the Radio Warning System is installed. No assumptions are made as to types of shelters or shelter-access time.

3.3.5 Nonhomogeneity

Although outdoor alerting techniques using sirens have been judged inadequate to do the entire alerting and warning job, they will still be a part of the system and may even be improved by the 1968 time period. In addition, the currently limited use of public address systems for voice warning may be expanded to include other geographic areas.

3.3.6 Emergency Broadcast System

The EBS is assumed in these requirements not to be a constraint on Radio Warning System operation. While all of the services currently provided by EBS will still have to be provided, this does not imply that EBS is a part of the Radio Warning System or that EBS will continue to exist in its present form.

4.0 INTERIM OPERATIONAL REQUIREMENTS

Listed below are the operational requirements for the Radio Warning System arranged under the following six categories:

1. Function. What does the system do?
2. Coverage. Whom does it reach?
3. Structure and Operation. How is it set up and how does it work?
4. Response Time. How long does it take to do its job?
5. Reliability. How well does it do the job?
6. Survivability, Security, and Sabotage. How difficult is it to put it out of action, jam it, or spoof it?

4.1 FUNCTION

The operational requirements discussed in this section are those which, taken together, specify the minimum number of functions which the Radio Warning System must carry out.

4.1.1 National Alert and/or National Warning

The Radio Warning System shall provide the public, through radio receivers located in dwellings, places of business, and institutions, a timely national alert and/or national warning of an enemy attack and/or the effects of such an attack.

That the system must provide warning of an enemy attack is axiomatic. That the system should provide only national warning is not. At the first and second meetings of the Working Group for Radio Warning, much discussion was devoted to the need for the delivery of local warning instructions by means of the Radio Warning System. It was finally determined that in the viewpoint of the representatives from the Directorate for Policy and Programs and the Emergency Operations Division in the Directorate for Plans and Operations, this feature was to be treated on a priority basis with first priority being accorded to the delivery of a national alert and national warning message, and second priority to the delivery of local warning instructions. However, only those operational capabilities which are essential to system operation can be specified in operational requirements. Therefore, in the operational requirements for the Radio Warning System there is no requirement for delivery of local warning instructions. It is noted, however, that there is a required interface between the Radio Warning System and the system which will provide local alerting and warning (see Sections 4.1.2 and 4.3.12). The ability to transmit local warning messages will exist through local broadcast stations. The Radio Warning System and the local broadcast stations designated to transmit local warning information will have to interact with each other. In all cases, the operation of the local broadcast station will have to be synchronized with the Radio Warning System in order that detailed local direction can be provided to the public immediately upon their receipt of the national warning. In addition, it may be necessary to provide some common programming links to the local broadcast stations to enable the delivery of lengthy messages of a national character to the public without taking up an inordinate amount of time on the Radio Warning System. This could be done by using network lines or the AP-UPI teletype circuits.

The Radio Warning System must be able to deliver an alert signal followed by a warning message, as well as a warning message alone without the alert signal. If the system is to be used for both tactical and strategic warning, the content of the two types of warning will be very different. The time limitations imposed upon the reactions of individuals will also be very different. Recipients must have some way of distinguishing immediately between the two types of warning. The presence or absence of the alert signal provides the necessary distinction. If the system is used only for tactical warning, it might be argued that it is possible to include a noisemaker in the home receiver rather than broadcast the alert signal. If such a configuration

were allowed, however, it would mean that every false alarm would result in the sounding of the alert signal and the way would be opened for certain types of receiver failure to have the same result. If this were allowed, there would be less public confidence in the urgency of the alert signal. (See Section 4.3.10)

In a strategic warning situation, time, while important, is not as critical as in a tactical situation. It is important that everyone get the message, but other means than the Radio Warning System can be used to accomplish this once it has been transmitted. Nothing is gained by preceding the message with the alert signal. In fact, there are compelling reasons for not preceding the strategic warning message with the alert signal. In an extended period of extreme tension, one characterized by a succession of crisis incidents, the government might want to use the system several times to convey strategic warning to the public. If the alert signal is used each time, the sense of urgency which it must convey will become increasingly diluted so that when an attack actually occurs, valuable time may be lost because the public does not immediately realize the true nature of the situation.

The urgency which the alert signal conveys must be reserved for use in tactical warning. Time is crucially important in areas which are actually targets, and is important from the viewpoint of local residents in areas which are considered likely to be targets. In such a situation, it is advantageous to have a means of conveying immediately a sense of the degree of danger which exists. Those who are trained can save valuable seconds, perhaps minutes, if they begin at once to move to shelter. There is the additional problem of awakening sleepers and gaining the attention of those in noisy locations; this problem is more important in the case of tactical warning than in the case of strategic warning. The alert signal provides both the indication of urgency and the means of overcoming inattention or sleep. Since this dual capability is needed only in periods of extreme time criticality, the alert signal must be reserved exclusively for tactical warning.

The requirement for a voice warning capability has two immediate consequences which affect system design. First, it precludes an alert-only system. Second, it imposes a vital restriction on the design of the home receiver. The most singular advantage that a radio-based warning system has over previously investigated systems is its ability to carry voice messages into the home. Radio warning makes possible a range of public responses in an emergency.

The amount of money which will be invested by the government and the public in such a system will be large regardless of whether the system is designed to deliver only an alert or both an alert and a warning. To restrict the system only to an alerting function would be a misuse of resources since it would fail to take advantage of the unique capabilities of radio, would limit the potential

flexibility available to the warning program, and would deny the American public a means of saving many lives in the event of a nuclear attack. Moreover, it is unlikely that such a configuration would be any less expensive. Many of the same receiver functions would have to be carried out in both configurations. The distribution costs would be such that the difference in final cost to the purchaser would probably not be significant. Finally, the installation of an alert only configuration, accompanied by the educational campaign necessary to convince the public to buy, would make it extremely difficult at a later date to modify the system to an alert and warning configuration. Having purchased one receiver, the average individual will resent being told that his receiver is no longer adequate and must be replaced. Planned obsolescence will have grave consequences if included in the Radio Warning System.

If it is to reproduce voice messages, the public receiver must be equipped with a loudspeaker of suitable bandwidth. If it is to be able to deliver both an alert and a warning, or a warning alone, it must be capable of selective response. While this does not preclude locating the noisemaker in the receiver, it does mean that the receiver must be capable of being unmuted with or without triggering the selfcontained noisemaker. This tends to put such a receiver at a disadvantage in terms of cost and complexity of circuitry.

4.1.2 Activate Other Systems

The Radio Warning System shall be capable of activating other public alerting and warning systems. Where several different selective alerting and warning functions exist in these systems, the Radio Warning System shall be capable of activating these systems in the appropriate functional mode.

The Radio Warning System itself must also be considered as a subsystem of a larger apparatus, which may be called the Public Warning System and which also includes as subsystems local siren and public address systems, the Emergency Broadcast System or its successor, and the NEAR System (if implemented). The Radio Warning System will have the broadest geographic coverage of any of these, will operate automatically once initiated, and, having been designed as the primary means of delivering public indoor warning, will be the logical system to which to synchronize all other public alerting and warning.

The geographic coverage of the Radio Warning System will make it possible to put a controlling signal into any alerting and warning device located in the United States or its possessions. The reliability of the system necessary to make it acceptable for home use also makes it ideal for controlling other devices. The ability to synchronize the operation of all of the components of the Public Warning System on the basis of a single decision to warn at the national level will result in a greater impact on the public of the alert and warning. The simultaneous activation of all systems will have the effect of authenticating the validity of the emergency.

The problem of Radio Warning System interfaces with other systems is a complex one. For instance, siren signals are not designed to deal adequately with strategic warning. The latest policy within OCD is, in effect, to use only the take cover signal in an emergency. If the Radio Warning System is used to provide strategic warning, its transmissions must not, in such a case, trigger the sirens. Public address systems are still in their infancy as regards their use in civil defense warning. It is not unlikely that they will use pretaped messages for warning in the future. In such a situation, it is not enough that the Radio Warning System be able to activate the public address system, it must also insure that the proper tape is selected. Flexibility is called for in these interfaces, especially since requirements for the other systems are not firmly established and may vary from locale to locale.

4.1.3 Hard Copy

The Radio Warning System shall be capable of transmitting information as hard copy where such information is needed to provide program material for voice messages to be delivered to the public. Hard copy will also be transmitted to provide immediate authentication of the automatic assumption of control of a facility's transmitter.

In most warning situations, it is contemplated that pretaped messages automatically triggered from the national level will be used. However, cases may arise where no existing tape covers the situation and a live message is necessary to inform the public. If the system configuration allows direct voice communication to the public from the national level, this can be handled without hard copy. Such a capability probably will not exist, however, due to the need for secure communications at the higher levels (see Section 4.6.3). Therefore, operating procedures must provide for the transmission of the message text to be read verbatim over the air at the subnational or local level (depending upon the configuration). When such a relay of information is necessary, hard copy must be provided to prevent errors and delays resulting from faulty copying and retransmitting of information and to insure national uniformity in the message received by the public.

In TM-L-1960/021/01A, it was argued that hard copy did not have to be provided to radio facilities to indicate that the system was assuming control over their operation. The argument was based on the fact that the operators of these facilities could not be allowed any discretion as to whether their facility would participate. Nevertheless, it has been decided that providing such hard copy will serve as more than a mere courtesy to the facility operator. It will provide a permanent authentic record indicating the time at which control of the facility was assumed by the system and the reason why it was done. Further, it is believed that the hard copy will provide a tool in trouble-shooting system malfunctions. Therefore, it is necessary that such hard copy be provided. Providing such hard copy does not, however, mean that the facility operator has been given any discretionary control over whether his facility will participate in the operation of the system.

4.2 COVERAGE

The operational requirements discussed in this section specify the coverage of the system both in time and area. For the reasons discussed in Section 3.2.1, no requirement is specified for population coverage.

4.2.1 Continuous Activation Capability

The Radio Warning System shall be capable of being activated any time of day, any day of the year.

This point has not been debated to date since it is self-evident that there can be no foreknowledge of the time of an enemy attack. While the end result of this requirement is the same as that included in the TM-L-1960/021/01A, the wording here represents a relaxation from the level of performance specified there. Much discussion was presented there of the need for full-period circuits to insure reliable system operation. The ideas expressed previously are no less true now. However, the likelihood of being able to secure full period circuits, or even circuits which approach them, with today's crowded radio spectrum, is small indeed. As a result, greater attention will have to be given to switching reliability, and monitoring of critical components to insure that the continuous activation capability will be achieved.

4.2.2 Geographic Coverage

The Radio Warning System shall provide adequate signal strength to activate public receivers located anywhere within the 48 contiguous United States. The Radio Warning System shall be capable of interfacing with the warning systems in the noncontiguous states, territories, and possessions.

The scope of this requirement represents a long range system goal, not a first stage implementation plan. There is no necessary requirement that the entire system throughout the broad range of coverage be homogeneous as to hardware components (see Section 4.3.6).

4.3 STRUCTURE AND OPERATION

The operational requirements included in this section specify the way in which the Radio Warning System will carry out its mission. The Section serves as an omnibus criterion containing specifications on numbers and locations of initiation points as well as certain characteristics of the signals used in the system. These are the minimum requirements which must be met by any configuration which is to do the job expected of the system.

4.3.1 Automatic and Semiautomatic Operation

The Radio Warning System shall be capable of operating both automatically and semiautomatically from the time of activation through the delivery of the alert signal and/or warning message to the public. Semiautomatic operation will consist of the transmission of live-voice messages to the public, and the manual transmission of hard-copy messages within certain portions of the system's control network.

Automatic operation is necessary in order that the alert and warning will be timely and the information in it accurate. The need for dispatch in broadcasting the alert and warning is obvious in an age when maximum warning time of an enemy attack may vary from zero to 30 minutes. Network activation must be automatic at all levels below the national to eliminate delays inherent in any manual tasks that must be performed by lower-echelon personnel. The urgency of the situation does not allow for discretionary action by those personnel, particularly if they are not subject to discipline by the federal government.

As mentioned previously, however, all contingencies in the area of warning cannot be planned for ahead of time. Therefore, it is necessary to build flexibility into the system. The warning message is the most difficult factor to preplan. To some extent this difficulty is minimized by the national character of the message and its consequent generality. Nevertheless, particularly if a strategic warning must be transmitted, the capability of altering the warning text must be provided. This is the reason for the specification of a semiautomatic capability.

4.3.2 National Initiation Points

The Radio Warning System shall have a primary national initiation point and one or more backup initiation points. The primary point will be located at the NORAD Combat Operations Center.

The wording of this requirement has been generalized from previous statements because of the state of change in which the warning program finds itself at this time. While the location of the National Warning Center appears to be firmly established at the NORAD COC, the location and status of the backup warning centers is not certain. It is currently propcsed that the OCD Region 5 Headquarters at Denton, Texas will be the first alternate and the Washington Warning Area Control Point (WWACP) the second.

4.3.3 Access to the System

Tactical warning points must be provided the capability to preempt the system in order to override a strategic warning already in progress. Except for this restriction, the national initiation points of the Radio Warning System shall have independent access to the system through the system's control network

transmitter(s); that is, communications channels from each of the points shall be provided directly to the control transmitters and no control over access to the system other than procedural shall normally be exercised over any initiation point by any other initiation point.

The requirement is established to improve system reliability and survivability, but since it also specifies certain network operation features, it is included here. It grew out of a requirement which was included in the first draft of this document and rejected by OCD personnel at the second meeting of the Working Group for radio warning. It was originally thought that a hierarchal arrangement, regulated by certain hardware features, was required to insure that one initiation point retained control of the system and delegated this control to the others as required. This idea was challenged by OCD and further analysis showed there was indeed weakness in it. Such a configuration not only added additional control equipment to the Radio Warning System with a consequent decrease in system reliability, it also tied the reliability of the system to that of the NAWAS or NACOM system which connects the national initiation points together because coordination would be necessary to effect a transfer of control. The arrangement presented here depends upon procedures to determine which facility will initiate the warning. The only controlling function built into the hardware is a preemption capability given to the tactical warning initiation points.

4.3.4 Selective Functions

The ability to perform the following six functions shall be provided as a minimum to the operator of the Radio Warning System at each of the national initiation points: alert and warn, warn only, cancel, test, preempt, and transmit hard copy.

The operator of the system must have the option of warning the public with or without an accompanying alert signal. As discussed in Sections 4.1.1 and 4.3.10, the alert signal should be reserved exclusively for use in the event of a nuclear attack. Since both primary and backup national initiation points will have the necessary intelligence to make a tactical warning decision, the capability of activating the alert signal should be provided to each. The activation of the alert signal on the Radio Warning System will automatically activate all other alert devices (sirens, NEAR, etc.), as well, because of the requirement contained in Section 4.1.2.

The warning message that is to be transmitted to the public through the Radio Warning System is designed primarily to authenticate the alert signal by giving a brief statement of the threat and direction as to a generally appropriate course of action to be taken by the public. It is believed that a set of such messages, adequate to cover a broad range of attacks can be prepared in advance and stored on magnetic tape to be selected automatically in the event of need and transmitted. The ability to prepare these messages in advance is most clearly feasible in the

case of a tactical warning. Strategic warning may provide somewhat more of a problem. But time works in favor of easing the problem since in strategic warning there will presumably be time enough to distribute, in hard copy form, the required program material necessary to insure that a uniform message is transmitted nationwide. The hard copy capability requirement insures that the means for transmitting such program material will exist in the system. (See Section 4.1.3.)

The ability to cancel a previous message by voice is one of the real advantages present in a radio-based system. It is invaluable in dealing with enemy spoofing, a threat to the system which cannot be guarded against in any other way. (See Section 4.6.3.) It also aids in counteracting the effect of an areawide false alarm, a feature unfortunately lacking in the present siren system.

The ability to test the system is required not only to check on the status of hardware, but to enable the exercising of the warning system as part of an overall civil defense training program. In order to check on the status of system hardware, any of the system initiation points must be able to originate a control signal for the test. If only one were able to do so, there would be no guarantee that any of the others could initiate an actual alert and/or warning in the event of need. One of the test messages must include a sounding of the alert signal, but probably at a lower level of intensity and not at the beginning of the message. Some explanation of the signal must also be included in the message. This is necessary to enable the public to identify the alert signal if it is ever sounded to indicate a nuclear attack. All of this implies that several test modes will be required. The number and types of such modes remain to be determined.

The ability of one initiation point to preempt the operation of the system by another initiation point is necessary in order that a time-critical warning may supersede a warning of a less critical nature during the course of its delivery. It might be argued that this capability is not needed since it is unlikely that a situation would arise in which it was needed. The opposite, however, would seem to be a more likely assumption. If a strategic warning were to be delivered to the public, the government would decide to do so only if a severe crisis in international affairs were to occur. In certain cases, the decision to deliver such a warning might be regarded by an enemy as a hostile act in itself or as an indication that the United States was about to carry out a first strike against him. One possible reaction from him would be a preemptive attack. Since the delivery of a strategic warning would involve the reiteration of the message several times over a period of time, even if the message only announces the fact that the President is to deliver an address to the country via commercial radio and television, the definite possibility exists of an enemy attack occurring during a series of strategic warnings. Carrying the examination of such a situation further, if a series of strategic warning messages is transmitted at regular intervals in order to maximize the coverage of a Presidential broadcast, the probability of a tactical warning having to

be delivered during the course of one of these messages increases with each successive one. While it would be possible to coordinate a change of control between the strategic initiation point and the tactical initiation point over the NAWAS, or a similar circuit, such a procedure would take time and would be dependent upon the reliability of the other circuit.

The need for and use of hard copy is discussed in Section 4.1.3. It must be stressed here that the operators at the national input points will have to be provided equipment which does not require that elaborate procedures be carried out to format and transmit the hard copy. To the extent possible, such messages should be precomposed and stored on tape with an automatic callup capability provided. Where messages must be prepared in real time, a message composer must be provided. On the other hand, the choice of operators for the system should certainly be based upon their ability to operate communications devices, since such devices are an integral part of an elaborate and sophisticated communications system.

4.3.5 Operational Status and Verification of Activation

The operational status of components at each level of the system shall be made available at the national initiation points. An indication of successful operation or failure of the system at any and all levels above the home receiver shall be provided to the operators at one or more of the national initiation points at the time of system activation.

This is a new requirement made necessary by the relaxation of the requirement for automatic, closed-loop continuity checking. Previously, it was thought that a means of monitoring the status of the system in real time as well as making a roll-call check of the operation of the system at the time of activation would be provided by the automatic continuity checking feature. With no such feature, the operator has no knowledge of the status of the system and whether it is in operational condition in a given locality. This information must be provided to him so that he can plan to take alternative means of delivering the warning to areas where system facilities are not operative. In like manner, once the system is activated, he must know those areas where it failed to operate so that he can take other measures to get the warning to them.

The means by which the status of components will be monitored and the roll call effected remain to be determined. A study of the alternative means of accomplishing this will be carried out by SDC.

4.3.6 Nonhomogeneity

The Radio Warning System may be a nonhomogeneous system, that is, different types of equipment may be used within different portions of the system to accomplish the same function.

This requirement is included in order not to restrict the Radio Warning System to a single type of configuration throughout its area of coverage. The system will span a vast geographical area which will include many different environments as well as different existing resources. The system designer should take advantage of whatever resources are available to keep the cost of implementation down and to maximize the number of people who can be reached by the system.

4.3.7 Muted Receivers

The public receiver component of the Radio Warning System shall normally remain in a muted condition, that is, the audio portion of the receiver will not operate until it is necessary to transmit a signal or message through the receiver to the public.

Two methods of standby operation have been proposed for the public receiver. The most generally acceptable method, suitable in any system configuration, is to mute the receivers in the standby condition. This method of operation requires that a special control signal be transmitted to demute the receiver before any program material is transmitted. It has been suggested that the control signal may also serve as the alert signal, but this is not possible, since it will be necessary to demute receivers without sounding the alert signal for strategic warning.

The other method was suggested at the second meeting of the Working Group for Radio Warning. It involves a simple squelch circuit which quiets the receiver in the absence of a signal on the channel. If the system is based on any configuration other than one which uses a dedicated (i.e., sole use) channel for OCD warning to the public, the squelch circuit is unsatisfactory since any nonwarning program material (i.e., regular broadcasting programs) will also demute the receiver.

If, on the other hand, it is used in a configuration which has a dedicated OCD warning channel, performance in fringe areas will be variable and the squelch circuit will have to be made adjustable to meet varying signal strengths. In some areas with extremely weak coverage the squelch may even have to be disabled, leaving an open channel which will broadcast all of the noise on the channel directly into the home. The noise problem on a low or medium frequency channel, particularly in stormy weather, will hamper the operation of the receiver even if the squelch circuit is functioning. Moreover, if the dedicated channel is also used for hard copy transmission, these signals will also cause the home receivers to demute. Finally, the use of a squelch circuit makes spoofing the system very easy. The enemy merely has to transmit any signal or message on the OCD channel, and home receivers will be demuted. If the squelch circuit is made selective, responding only to certain types of signals, then the configuration is the same as the required one, namely, one which uses a control signal to demute the receiver. The use of muted receivers is, therefore, the only satisfactory method of standby operation in the Radio Warning System.

4.3.8 Positive Control of Public Receiver

The public receiver component of the Radio Warning System shall be designed to operate under the positive control of the system operator; that is, the demuting and remuting of the receiver shall both be controlled by signals from the alert and warning transmitter.

Two alternatives to positive control of the public receiver have been proposed. The first would have automatic demuting of the receiver from the transmitter, but would require the owner of the receiver to remute it manually after the message has been delivered. The second method also has automatic demuting, but, instead of manual remuting, it depends upon a clock mechanism (mechanical or electronic) to remute the receiver after a preset time interval. Neither of these methods is satisfactory from an operational point of view.

Manual remuting implies that the receiver owner can disable the operation of the set, which means that it may be disabled at the time it is needed to receive a warning. Moreover, if a switch must be used to remute the receiver after every test of the system, then receivers at unattended locations will continue to operate at full volume even though such operation may be extremely annoying to others. Receivers located in apartments are particularly prone to this problem. It has been argued that this need not be a problem if the system uses a special channel for public warning; but, as pointed out in Section 4.3.7, the problem of fringe-area performance and noise makes remuting necessary even when a carrier is present to quiet the receiver.

A timed-off receiver is not satisfactory either. As pointed out in Section 4.3.11, it is impossible to establish time requirements for the delivery of the warning messages which the system will have to transmit. A strategic warning may take the form of announcing a Presidential speech to be transmitted over the commercial radio and television stations, such an announcement being repeated at regular intervals over a given period of time. The receiver in this case would have to be able to respond to relatively short messages. On the other hand, a tactical warning will have to be repeated many times to insure that everyone possible is notified of the emergency. It has been argued that extended messages can be handled by retransmitting the demuting signal at intervals determined by the timing capacity of the receiver. This argument is weak, however, since timing circuits are not 100 percent accurate, and there will always be variance in their performance. Given a certain mean-timing accuracy and variance, maintained by strict quality control, there will still have to be a periodic interruption of the warning message in order to transmit the demuting signal either to hold on receivers or to demute those that have gone off. Add to this the problem of time delay, which will have to be built into the receiver to protect against accidental demuting by transient noise, and the interruption of the messages can be quite extended. As an example, assume a timing circuit is designed to hold the receiver on for three minutes with a standard deviation of nine seconds (5 percent). In order to insure that at least 95 percent of the receivers will be controlled properly, the demuting signal will have to be transmitted for a period

of at least two standard deviations in each direction from the mean. This will require that the message be interrupted during the period from 162 seconds to 198 seconds after its start merely to deal with circuit variance. Assume further that the control signal must be integrated over a ten-second period before the receiver will demute. This means a total interruption of the message for 56 seconds out of every 198 seconds or about 30 percent of the message time being taken up with the mechanics of controlling the receiver. At a time when every second counts, this means that lives are put needlessly in danger. Therefore, positive control of the public receiver from the transmitter is required.

4.3.9 Location of Alert Signal Generator

The equipment used to generate the public alert signal for the Radio Warning System shall be located at the transmitter or control facility of the radio station that distributes the signal to other radio stations, or at the station that delivers the signal to the public, but not in the home receiver itself.

While an argument has been put forward in the past that it may be necessary to use a self-contained noisemaker in the public receiver in order to provide the sound intensity capabilities required by the system within the cost limits that have been imposed, it is apparent that the drawbacks present in such an arrangement far outweigh any benefits. Assuming that there may be as many as several thousand transmitters at the public level of the system and upwards of 70 million public receivers, putting the alert generator in the home receiver increases by five orders of magnitude the problem of keeping the alert signal uncompromised. The situation may even be worse, since the reliability of the public receiver is bound, by the cost constraints involved, to be of a lower order than that of equipment at the transmitting facilities. The way is left open, therefore, for receiver failures to cause the sounding of the alert signal in individual homes. Furthermore, there is no way of counteracting the effect of such accidents. If alert generating equipment located at the transmission facility fails, a far less likely possibility, but one which must be planned for nevertheless, a voice message can be transmitted which will have somewhat of a mollifying effect on the listeners even though the occurrence will probably shake public confidence in the system.

A further problem presented by the inclusion of the alert generator in the public receiver is that of controlling the noisemaker selectively in order to restrict its use to tactical warning situations. Although no rigorous examination has been made of the cost of such selectivity, it would appear reasonable to expect that given two receivers--one with a noisemaker and a loudspeaker that must be separately controllable, the other with just a loudspeaker--the former will cost at least as much as the latter, if not more, will provide no more capability, and will be at a disadvantage from a reliability standpoint. Therefore, the requirement that the receiver be capable of reproducing a voice message further strengthens the argument for keeping the alert generator out of the home receiver.

If the alert generator is located at the transmitter, a failure of the home receiver which causes it to come "on the air" will be immediately recognizable as a receiver failure. It will be an "annoyance alarm" not a "false alarm." It has been suggested that the concept of annoyance alarm merely sweeps an important problem under the carpet by giving it another name. No one, however, has a greater appreciation of the grave consequences which the outpouring of 80 to 90db of noise or normal program material into a home may have on the public tolerance of the system. Such an occurrence in the early hours of the morning or shortly after a mother has put her children down for an afternoon nap will probably result in the abrupt and summary removal of the offending instrument from the wall and perhaps an irate letter to local authorities. What are the alternatives? If one is going to suffer a 90db onslaught, white noise or even rock-and-roll is more easily endured than a raucous clatter which a person has been taught will only be heard in the event of a nuclear attack. Keeping the noisemaker out of the home will not solve the problem of shoring up public confidence in the face of receiver failures, but it will prevent the compromise of the alert signal for the vast majority of people whose receivers do not fail, or for those tolerant individuals who realize that, even though their receiver has failed once, it, or its replacement, may someday save their lives. The only answer to the problem of public tolerance is to be found in designing a receiver that is as reliable as possible and that is designed so that it is unlikely to fail by coming on the air, (i.e., a fail-safe receiver).

It appears necessary, therefore, to require that the alert signal generator be located at the transmitter rather than in the home. Indeed, operational factors would appear to make this necessary even at a slightly greater cost in the home receiver, which is not anticipated.

4.3.10 Alert Signal

The Radio Warning System shall be capable of transmitting messages to the public with or without the accompanying alert signal. (Preliminary studies indicate that an alert signal intensity on the order of 90 decibels at 10 feet will be required.)

Past experience in dealing with the ability of relatively untrained people to respond to coded messages indicates that simplicity is required in such messages. The public must not be expected to carry out different actions in response to different coded signals, nor should the impact of a coded signal be rendered ineffective by giving it more than one meaning. The alert signal must have but a single meaning if it is to have a maximum impact. Since it is necessary that this impact occur when the greatest danger is involved, the alert signal should be reserved for use in the event of an actual attack upon the United States. It may be argued that few individuals will begin to take protective actions on the basis of the alert signal alone without the confirmation and authentication provided by the warning message, but this is not the point. If the public is in doubt as to what the ensuing message is going to be about, they will tend to delay any action until they hear what is happening. If they are assured that the

only time they will hear the alert signal is when their lives are in danger, they will begin to act immediately and may very well save their lives by doing so. As a sort of worst case example, imagine a period of severe international crisis in which several messages of a strategic warning nature are delivered to the people over a period of time by the federal government. If the alert signal were to preface each of these transmissions, its meaning would deteriorate with each successive use. If an actual attack were to climax such a period of tension, the public response would be less effective than if the alert signal had not been used on the previous occasions. It might be argued that the likelihood of such a period of protracted tension, characterized by the government's willingness to share information with the public, is remote. Nevertheless, it is impossible at this time to determine what course the government may choose to take five to ten years from now in dealing with international crisis. It is not wise to degrade the effectiveness of the system by limiting its ability to perform in a situation which is definitely possible. Therefore, the system must be capable of transmitting a message either with or without the alert signal, and it is strongly recommended that the alert signal be used only in a tactical situation. This restriction on the alert signal does not jeopardize the effectiveness of strategic warning. Preliminary studies of the ability of a voice message to be self alerting indicate that such a capability exists and can be exploited for use in strategic warning. The proper choice of phrases delivered with the proper tone of urgency will probably be sufficient to call people's attention to the message, particularly if the time is not as extremely critical as in the tactical warning situation.

Performance standards as far as the ability of the receiver to deliver an alert signal cannot be set at this time. Some research was carried out by Midwest Research Institute (MRI) to establish such requirements for the NEAR receiver, and a brief examination of the subject has been made at SDC with regard to the Radio Warning System. The results of the MRI work showed that measuring the sound level in terms of db above the standard reference level is not satisfactory since it fails to consider the distribution of sound energy among the various octave bands. The solution requires that a measure of apparent loudness (phons or sones) be used. The preliminary studies were carried out by SDC employing signals commonly used for jamming CW messages (called "bagpipe jamming"). These signals consisted of four or five discrete tones of different frequency being sounded consecutively in an almost random order. The tones appeared to be in the octave range between 500 and 1,000 Hz. It was determined that such a signal would have to have an intensity of at least 90db measured across the entire audible spectrum at 10 feet from the source if it is to be considered a satisfactory alert signal. More work remains to be done before specifications for receiver loudness can be established.

4.3.11 Warning Message

The Radio Warning System shall transmit pretaped warning messages to the public whenever possible, but the capability to transmit live messages to the public

must also be provided to cover unusual situations for which standardized messages are inappropriate. The warning message shall be delivered by the public receiver with sufficient audibility and intelligibility to insure its being readily understood by a person in the same room as the receiver. (Preliminary studies indicate that a warning message intensity of the order of 75 decibels at 10 feet will be required.)

The use of pretaped messages is required in the system for two reasons. First, OCD operational personnel believe greater control over content and delivery can be had if the messages are prepared in advance. Messages can be written beforehand to direct the public to carry out protective actions planned by local civil defense officials. These messages can be recorded using inflections which will convey a sense of urgency without encouraging panic in the listener. There will be little chance of making a mistake in the delivery. The second reason for using pretaped messages is that it decreases the amount and complexity of the information which must be passed through the system's control network. Simple control signals can be used to select one of several messages stored on tape at the local or regional transmitter rather than having to transmit the voice message itself, or hard copy of the material to be included in the message. Even if pretaped messages are used however, these messages cannot cover every conceivable situation which must be warned against. It is necessary, therefore, that a backup to the pretaped messages be provided which enables an announcer to go on the air with a live message. In order to increase the accuracy of these live messages, and insure uniformity throughout the area to be warned, the material to be broadcast must be provided as hard copy and read by the announcer verbatim.

Preliminary investigations carried out at SDC indicate that the voice message, if delivered through a small loudspeaker, should not be at the same intensity as the alert signal. Again, a broadband measurement of the sound intensity indicated that above 75 db distortion is sufficient to render the message unintelligible. These measurements were made with a three-inch loudspeaker. This problem is a particularly knotty one which may yield to solution only with the use of a special purpose loudspeaker that utilizes the mechanical amplification provided by speaker cone resonance to reproduce the alert signal at sufficient volume while still reproducing the warning message at an intelligible level.

Some discussion is in order on the relatiionship between the alert signal and warning message. This was discussed in TM-L-1960/021/01A in connection with a requirement specifying the order of the alert signal and warning message. This requirement has been dropped for two reasons. First, it is of a procedural nature and, therefore, belongs in the document on procedural requirements still to be written. Second, it was felt that a decision on the order of the alert signal and warning message would constitute a policy decision and should, therefore, not be stated as a requirement, but made a recommendation. The alerting and warning process cannot be terminated until there is good reason to believe that every one has received the warning. Due to the wide range of environments

within which the alert signal and warning message must be received, and the wide range of individual capabilities to receive them, there must be a repetition of these signals. To sound them only once or twice would deny many people the information they need for survival. Even if empirical studies were carried out to determine the mean time required by an individual to receive an alert and warning in a variety of environments and this time were extended to two, three, or four standard deviations from the mean, there would still be many people who would miss the signals if only because they were out of range of any alerting and warning device. These individuals may not come within hearing distance of a device for half an hour or an hour, may still not be in danger from attack effects at that time, and will still be in a position to benefit from warning. Further, the repetition of the signals will not have any degrading effects on the public response since the public will presumably move to shelter or to evacuation areas immediately. Therefore, it is necessary to continue the repetition of the signals for as extended a period as is reasonable. The alternating of the alert signal and warning message also aids in overcoming the ambient noise level by causing regular variations in that level which call attention to the signal.

Since the Radio Warning System does not have to transmit local warning information, (this task is carried out by the local broadcast station), the repetition of the alert signal and national warning message can be carried out without depriving the public of detailed local direction. If the Radio Warning System is also required to transmit local warning information the situation becomes more complicated because some time division between national and local messages is required. It might be argued that this division must still be made in a system which utilizes commercial broadcast stations for delivery of the national alert and warning since some stations must also be used for delivery of local warning information. Such a system configuration would operate in one of two ways; either the national alert and warning would be repeated for a given period of time (some empirically derived mean plus two or three standard deviations) followed by local warning instructions exclusively, or the national alert and warning would be alternated with the local warning instructions in a repetitive process. Neither of these methods is completely satisfactory. The first method penalizes the individual who is alerted early in the process by making him wait until the completion of the national alert and warning before he can get any local instructions. It also penalizes the person who fails to receive the national alert and warning before it is terminated, since he is forced to extract the information about the emergency from the highly specific local instructions being delivered as warning information. His natural incredulity about the situation is reinforced by the lack of any clear statement of what is going on. The second configuration suffers, since, by increasing the length of the alert warning cycle, the efficiency with which the alert signal can attract people's attention is decreased. In a time when information must have a maximum impact, and should therefore be simple, this configuration increases the amount of information being transmitted and adds to its complexity. Therefore, it is felt that the only satisfactory method of carrying out both the national alerting and warning process and the local warning information process is to divide

them between two channels. In this configuration, the national channel can be devoted to the single task of attracting people's attention to the danger at hand, and authenticating the existence of that danger. The local channel, which begins operation simultaneously with the national channel, can be used to direct people's action and instruct them on other necessary procedures. The individual who is alerted early in the procedure can switch to the second channel and receive directions immediately. The person who cannot be alerted immediately need not worry about the signal being cut off the air before he has received it.

This discussion has important ramifications for configuration design. It requires that a second channel be available for local instructions and that the interface between the Radio Warning System and the local warning information systems be considered in planning the configuration. It, therefore, increases the attractiveness of the OCD low frequency radio network configuration as a means of delivering the national alert and warning, since this frees the commercial broadcast stations for the job they can do best, delivering local instructions. While this division can still be accomplished by designating certain commercial stations as national stations and others as local, this is not wholly satisfactory in areas where there are not a sufficient number of stations to fulfill both tasks. This requirement also strengthens the argument for home receivers with special purpose low fidelity loudspeakers which are designed to maximize the intensity of the alert signal and deliver an adequate, but perhaps not optimum, voice warning. Since the voice message will be limited in content with no detailed information included, the difficulty of intelligibly reproducing a lengthy voice message is avoided. The longer message can be received over the wider-band loudspeaker located in the home radio set. Finally, it precludes the use of a timed-off receiver for alerting and warning. Since the national alert and warning itself cannot be timed off because of the reasons presented above, the receiver designed to deliver the alert and warning into the home cannot be timed off. Therefore, a positive control of demuting and remuting is required from the transmitting facility. (See Section 4.3.8.)

4.3.12 Interaction With Other Systems

Provision shall be made in the Radio Warning System for the exchange of information, either automatically or manually, with those systems that are involved in the warning process either as sources for warning intelligence or as complementary means for transmitting warning and/or warning information.

Two sources for warning intelligence must be planned for: the tactical warning source and the strategic warning source. The NORAD system, SAGE (416L), and the 425L Combat Operations Center (COC) System, as well as any future air defense systems, will provide the input of information necessary for the declaration of an air raid warning (tactical warning). At present, it appears that the interface with the Radio Warning System here will be manual, but, at least at the COC level, there is the possibility in the future of automatic decisions being made in accord with programmed SOPs.

The source for strategic warning is not difficult to pinpoint. It will undoubtedly be the White House. However, there are at present no formalized systematic channels over which strategic warning intelligence will flow. If the system is to be used for such warning, the interface with the originating authority must be planned. Consideration should be given, therefore, to possible interaction between the Executive Office of the President and the Radio Warning System. In addition, since a major operational interface between the Office of Civil Defense and the Department of Defense will exist in the National Military Command System (NMCS), this serves as an ideal point of exchange for intelligence related to warning that may develop in the Washington, D. C. area.

The NAWAS and its successor will be the system over which civil defense organizational warning and operational information will circulate. It is certain that the NAWAS and the Radio Warning System will interact at the national level. If NAWAS terminals are ever established at commercial radio stations, presently a remote possibility, there may also be an interface at lower levels. All of these points of contact must be considered in the design of a particular configuration to insure that no incompatibilities in the operation of the two systems are allowed to exist.

The EBS or its successor will be the primary channel for transmitting local warning information, Presidential messages, state warning information, and national news and programming to the public in an emergency. Its operation is initiated by OCD personnel in the NORAD COC or in the WWACP. Since the EBS is the channel for local warning information, it is imperative that it work synchronously with the Radio Warning System (i.e., they must be activated simultaneously and must begin broadcasting to the public as nearly simultaneously as possible). At present, the activation of the EBS cannot be done on a timely basis due to technical difficulties. Therefore, the interface between the Radio Warning System and the EBS (or its successor) appears to be a natural place to insert an automatic link which will insure synchronous operation as well as overcome the present technical difficulties in EBS activation.

4.4 RESPONSE TIME

The single requirement in this criterion specifies the response time of the Radio Warning System. It should be noted that the term has been redefined. Response time is now considered to run from the time of the decision to warn until the receipt of the alert signal (or warning message, if no alert signal is sounded) at a public receiver which is in normal operating condition.

4.4.1 Maximum Reponse Time

The response time of the Radio Warning System shall be such as to insure that an alert and warning can be provided to target areas within a time period approaching one minute as a maximum and to nontarget areas within a time period approaching three minutes. Variation in response time between target and nontarget areas

shall be allowed only if radio frequencies must be shared by several facilities within the system on a time-division basis or if some similar technical sacrifices must be made.

The times specified above are target figures for the system. They are chosen for two reasons; first, they conform to the basic design objective that the shorter the response time, the more lives the system will save, and, second, they appear to be feasible within the state of the art of communications technology. A problem area here is the determination of what constitutes a target area. The problem is raised because the difficulty in securing radio frequency channels may require that several facilities which have adjoining areas of coverage share the same channel. The result will be that areas of interference will occur within which no signals can be received. The only way that this problem can be overcome, without going to very sophisticated receivers, is for the radio facilities to share the frequency in time. The method that has been proposed is to broadcast the warning initially on all the transmitters, ignoring the interference areas, then subsequently on one transmitter at a time. If this method is used, the public in the interference areas will not receive the initial warning, but will receive one of the subsequent transmissions. In order to conform to the wording of the requirement, it will be necessary to position the transmitters in locations such that the areas of interference do not contain any civilian population concentrations which are likely to be enemy targets. In practice, this will probably have to be interpreted to mean any major urban areas, since it is difficult to decide what an enemy may choose as a target.

4.5 RELIABILITY

This section includes the requirements necessary to specify the features which must be included in the Radio Warning System to make it reliable. The requirements, as stated here, do not appear to follow directly from previous discussions of reliability that have taken place among OCD personnel and the radio warning contractors. OCD specifications in this area have been vague. Beyond the statement that a single national false alarm will seriously impair public confidence in the system, and the constant concern about receivers coming on the air and flooding households with torrents of sound at 80 to 90db, there has been no explicit request for features to be included in the system that will bring about the type of reliable operation which is desired.

4.5.1 Minimum Performance Level

The reliability of the Radio Warning System shall be such that the expected number of people put at risk by failures in the system shall not exceed 0.1 percent of the entire population. The figure of merit to be used in calculating the expected number of people put at risk shall be the instantaneous availability of the system, i.e., the probability that the system will function in a completely satisfactory manner upon activation.

In accordance with Department of Defense policy on specifying the reliability for proposed systems, this requirement must initially be met by any configuration with a confidence level of 60 percent.

The number of people put at risk by a failure in the system is the number of people who do not receive a satisfactory warning because one or more components in the system do not function at the levels specified in the operational requirements. In the probabilistic sense, this number is a random variable and its value is a function of the reliability of the system. If the system operates satisfactorily, its value is zero; if the system fails completely, its value is the total population covered by the system. For any single facility or group of facilities in the system there is a similar variable whose value is determined by the reliability of the facility or facilities concerned. The expected number of people put at risk by failures in the system or, on a lower level, by a failure at any facility, is the mean or average value of the random variable associated with the system or facility. It is calculated by multiplying the number of people covered by the system or facility by the probability that the system or facility will fail. This number provides an excellent means of specifying a particular level of system reliability. It is a meaningful number because it measures lives potentially in danger as a function of the reliability of the system. As a means of establishing a reliability requirement for the system it has merit because it sets a limit on the reliability of the entire system while allowing variation in the reliability of the facilities which comprise the system. It insures that those facilities which are critical in warning areas of large population concentration will have as a minimum a greater reliability than facilities which serve a smaller number of people. Using this number as a measure of system reliability also makes it possible to include the public receiver in the specification of the system's level of performance and provides a link to the receiver testing requirement (see Section 4.5.5). Finally, this method of measuring system reliability can be applied to any system configuration regardless of the techniques utilized in the system to insure reliable operation (i.e., automatic continuity checking, redundant communications channels, etc.).

It is natural to question whether the level of performance specified in the requirement, not more than 0.1 percent of the population at risk, is both adequate and realistic. As to its adequacy, based on a projected 1970 population of 210 million people, the figure represents 210,000 people, the population of a city the size of Albuquerque, New Mexico, or Des Moines, Iowa. Using the data developed during the Department of Defense cost-effectiveness study of the fallout shelter program, this figure represents about 0.2 percent of the number of expected survivors in a medium sized attack on mixed military and civil targets and about the same percentage of the number of expected fatalities. While it is difficult to have to admit that there might be any added people at risk because of system failures, it is believed that the level stated is an adequate maximum number, certainly as an initial goal. As to whether it is a realistic level, in a hypothetical system which utilized a single facility to warn the entire population, the specified performance level would require a

figure of merit of .999 for the facility's instantaneous availability. If two facilities providing redundant coverage were utilized, however, the figure of merit for each would only have to be .968. In a system as important to the national welfare as the Radio Warning System, it is doubtful that a figure of merit less than .990 would be tolerable for any component included in the control circuit. Therefore, assuming that there will be redundant coverage provided in critical areas not only within the Radio Warning System itself but by other elements in the Public Warning System (sirens, public address systems), it a appears that it will be possible to reach the specified level of not more than 0.1 percent of the population at risk.

4.5.2 Redundant Equipment

Redundant equipment shall be installed in the Radio Warning System above the public receiver level when indicated as necessary by an engineering evaluation of system reliability. Where such redundancy exists, automatic switchover to standby equipment shall be provided in the event of a failure in the active equipment.

If, as specified in Section 4.2.1, the system is to have a continuous activation capability, components will have to be ready to operate at all times even if maintenance personnel cannot be obtained immediately. The decision to install two or more components at a given point in the system will depend on the reliability of the component and its criticality to system operation. The survivability requirement (Section 4.6.1) has a bearing on the decision to stockpile redundant equipment for system reconstitution. Such equipment might even consist of mobile units stored in hard locations away from the original facility site and capable of being used for warning and communications in the postattack environment.

4.5.3 Fail-Safe Equipment

All equipment used in the Radio Warning System shall be designed to maximize the probability that components will fail in a silent or safe condition, not in a condition which simulates system operation.

Equipment used in the Radio Warning System must be designed to have a maximum fail-safe tendency. A component failure in the system's control network which resulted in activation of the system at all lower levels could have grave consequences. It is in the contol network, however, that the most elaborate precautions can be taken in designing the equipment to the proper standards without an undue increase in system cost. It is not possible, however, to guarantee completely fail-safe operation in any hardware. All that can be done is to employ close analysis of circuitry using probabilistic techniques and choose only those circuits that have the least probability of being activated by the failure of a component used in the system. This is particularly the case with the public receiver. It has been suggested that the requirement stated here is unnecessary, since most home radios, when they break down, do so by failing to

operate when turned on. The vast majority of home receivers are not, however, left standing in operation with only their audio circuits inoperative as are the warning receivers. This mode of operation complicates the problem as does the cost factor. Within the cost limits that have been imposed on this piece of equipment, the inclusion of such features as monitoring of key components to determine their condition is impossible. Failure to detect receivers which are inoperative increases the likelihood of no-alarm failures in the event the system must be operated, but the effect on the owner of the receiver which would be caused by its being activated by a component failure would probably be even more deleterious to system operation. For the cumulative effect of a great many such failures would be to seriously undermine or destroy public confidence in the system. Since it is assumed that the public receivers will stand idle for a far longer time than they will be in operation delivering an alert or warning, it is not desirable that they should call attention to themselves in the event that they suffer a component failure. This apparently contradictory statement is true because: first, the receiver may fail at any time of day or night, and the noise which will be generated by their being activated is undesirable during much of that time; and second, the likelihood of the receiver being needed to provide an alert or warning during any given period in which it is inoperative is slight. If the receiver, then, is more likely to fail by becoming silent, how can the no-alarm potential which these failed receivers represent be detected and corrected? The answer is through an effective testing program which schedules tests at a frequent enough interval to insure that the expected number of failed receivers is kept below a given percentage of the total number which has been distributed to the public. (See Section 4.5.5.)

4.5.4 Receiver Protection

The public receiver component of the Radio Warning System shall be designed to withstand the wear and tear which can be expected in an exposed location in an average household which may be situated anywhere within the wide range of environments found in the various climatic areas of the United States. Further, it shall be assembled in such a way as to discourage or prevent a person from tampering with it.

Essential to the security, as well as the reliability, of the Radio Warning System is protecting the public receiver from the effects of the environment in which it is placed. As with any piece of electronic gear, certain components will have a greater degree of susceptibility to damage by these effects than others. Consequently, the receiver is always in danger of being damaged not only by such physical violence as being hit by furniture or kicked, but also by such passive agents as grease, moisture, and dust in the air. These sources of damage are all accidental. There is in addition the problem of idle hands, either those of children or of inveterate adult tinkerers. The most comprehensive solution to all of these problems is to encapsulate the electronics of the receiver, but there remains the loudspeaker which must have access to the air to operate. The possibility of special purpose loudspeakers has already been mentioned for other reasons and may be required to meet this problem as well.

4.5.5 Testing Program

The Radio Warning System shall be tested down to and including the public receivers on a frequent basis. The frequency of these tests shall be determined so that the expected number of public receivers that are allowed to become inoperative between tests shall not exceed a fixed percentage of the total number of receivers.

(The allowable percentage of inoperative receivers remains to be determined.)

As is mentioned in Section 4.5.3, the testing program is an integral part of the reliability design of the public receiver in the Radio Warning System. However, the implications of such a program must be considered in designing all of the equipment to be used in the system.

Any measure of the reliability of the system must consider the likelihood of two types of failures, false alarm and no alarm. A false-alarm failure occurs when the system is activated at a time when no such activation is desired. A no-alarm failure occurs when the system activation fails at a time when such activation is intended. At the public receiver level, the tendency toward each of these types of failure is normally dependent upon receiver sensitivity. If the receiver is made difficult to activate by using complex signaling techniques, false alarms are protected against, but no-alarm failures are more likely. If, on the other hand, the receiver is easy to activate because simpler signals are used to overcome the no-alarm potential, the receiver is automatically made more prone to false alarms from random noise in the atmosphere or from program material on the channel. The result is that the tendency of the receiver to false alarm and its tendency not to alarm must be balanced off against each other; they cannot both be minimized simultaneously using the same technique.

If, however, different techniques are used to deal with each tendency, they can both be minimized simultaneously. Two methods of doing this have been discovered. The first is to minimize the possibility of false alarms in the receiver through the use of circuits which tend to fail by going into a silent condition rather than by coming on the air. This will, however, increase the possibility of a no-alarm failure in the event of an emergency unless the owner of the receiver can determine that his receiver is inoperative. In order to provide him with this information, a testing program must be introduced which will provide frequent opportunities to test the receiver. This method requires the active participation of the receiver owner in utilizing the tests to his advantage. The frequency of the tests is based upon the mean time before failure (MTBF) of the home receivers and the probability distribution which the receivers will experience in their failures. Given these data, the testing frequency can be scheduled in such a way as to keep the expected number of failed receivers below a certain percentage of the whole.

To illustrate, assume that 70 million public receivers are in the system, that these receivers have a maximum life expectancy of ten years (an MTBF of five years) and that they fail on a random basis. Further, assume that they have been designed so that the probability is .99 that when they fail, they will do so safely, i.e., without coming on the air. As an example, assume the requirement established is that no more than 10 percent of these receivers will be allowed to be inoperative at any time. Then, the mean number of receiver failures per day will be 20,000 of which 200 will not be fail safe. In order to assure that not more than 7 million receivers will be out of service, a system test down to and including the public must be made at least every 39 days, or, to keep it on a regular basis, once a month.

4.5.6 Maintenance

The failure of equipment used in the Radio Warning System at levels above the public receiver shall automatically be indicated to maintenance personnel.

In a system as important as the Radio Warning System, failed equipment, even if backed up by spares, cannot be allowed to remain unrepaired for any length of time without a consequent decline in system reliability. For example, if the probability is .001 that a piece of equipment will fail, and if it is backed up by a similar piece of equipment, the probability of both failing in succession is .000001. If one piece of equipment has already failed, however, and if the probability of the second piece failing is independent of the first having failed, then the probability of the second piece failing and causing an entire portion of the system to fail, reverts to .001 or an increase of three orders of magnitude. Therefore, automatic indication of failed equipment is necessary. No requirement is included here about regular maintenance schedules or the actual arrangements which must be made for providing maintenance personnel. That regular maintenance procedures will be established according to good practices is assumed, but this will be spelled out in greater detail when procedural requirements are established. As for procurement of maintenance personnel, this subject deserves special study to determine the most effective method on a cost basis. It is not possible to say, at this time, whether contract or in-house maintenance should be used, though the latter appears to offer certain advantages in terms of insuring the presence of maintenance personnel in the event of an emergency.

4.5.7 Dual Operator Positions

Provision shall be made in the Radio Warning System to require the actions of two individuals to activate the system from any national initiation point.

(The exact method that will be used to carry out this requirement remains to be determined.)

During the first meeting of the Working Group for Radio Warning, there was a lengthy discussion of the means which could be used to make a false activation of the Radio Warning System by a berserk operator impossible. Methods employing automatic features, challenge and response procedures, multiple actions by a single operator, and use of two or more operators were suggested. While no final decision can be made without further investigation, it appears that the most feasible method, from a cost-effectiveness point of view, involves the coordinated actions of two or more operators to activate the system. Whether these two operators should be located in the same or different facilities has been questioned by OCD personnel and remains to be determined during future studies.

4.6 SURVIVABILITY, SECURITY, AND SABOTAGE

This Section contains requirements specifying the needed survivability of the Radio Warning System in the event of an enemy attack and the features which must be included in the system to protect it from covert enemy actions and mischief directed against it from nonenemy sources. The requirements are only those which have an effect on hardware design. It is assumed that procedural measures for protecting against physical sabotage such as providing guards for facilities will be specified later in procedural requirements. The main items of concern under covert enemy acts are, therefore, jamming and spoofing. The security of the system also involves devising some means to prevent its being activated by sensation-seeking individuals; this comes under the heading of spoofing which cannot be prevented, only counteracted after the fact, because of the widespread distribution of receivers. When the system is implemented, legislation will probably be required to make the intentional transmission of signals which activate the system a criminal offense. Otherwise, there will always be the danger of another invasion-from-Mars hoax, this time using the Radio Warning System for its delivery.

4.6.1 Survivability

The Radio Warning System shall be survivable in the following sense: in the event of an overt attack on the United States (except for an undetected attack directed against the Radio Warning System itself), the system shall be capable of surviving in operating condition for a period sufficient to enable the delivery of the national alert and warning. Following the attack, the planned reconstitution capabilities of the system shall be sufficient to insure a continued public warning capability with minimum interruption due to attack effects. Reconstitution planning shall determine the means of increasing the likelihood of the continued operation of facilities originally included as system components, as well as the means by which other communications facilities which might survive an attack might be utilized to provide warning to the public.

The Radio Warning System cannot be made survivable in the generic sense of the word. Its operation is dependent upon antenna systems which, without incurring unreasonable costs, cannot be constructed to withstand the effects of an attack,

particularly antenna systems designed to operate in the low- and very-low-frequency ranges. For the reasons indicated below, however, the system does not have to be survivable in the same sense that a hardened command post or a weapons control center is survivable. The Radio Warning System is designed to deliver automatically an alert signal and warning message to the public in the event of an enemy attack. The system is designed to meet the needs of civil defense in a worst-case situation, namely, a completely unexpected attack. It is because of this fact that the system is automatic at the public level and has a voice warning message for authenticating to the incredulous nation the fact that the attack is indeed taking place. Given a long crisis buildup prior to the actual attack, a system with less capability would undoubtedly be as effective as would the present one in a surprise attack. By the same token, given a strategic buildup, the effectiveness of the Radio Warning System will probably be much greater than if no such buildup occurs. The crucial point here is, however, that once an attack on the United States takes place, the context within which the warning process operates will never be the same again. The changes in the public frame of mind which will take place between the preattack and postattack periods will have a tremendous impact on warning system requirements. In the preattack period, the unwillingness of the public to admit the need for their participation in civil defense programs, caused in part by their lack of any historic experience of an enemy attack, in part by the awful premonition of what such an attack would mean, raises a formidable barrier of unbelief between the consciousness of the individual and the warning process. The warning system, to be effective, must be structured to surmount this barrier; but after an attack has been taken place, the barrier will be toppled in the minds of those who survive. Through experience, the survivors will have become more carefully attuned to the information which the warning system is designed to provide. Indeed, if the system is unable to furnish such information due to the effects of the attack itself, the people will probably devise some other method of obtaining this information until the system can be restored. Therefore, it is fair to say that although the system is not designed to operate on a one-shot basis, it will never again have to do the job as well as it does the first time around.

There are many techniques available for insuring that the system will be restorable. Redundant communications channels including survivable landline trunks, mobile radio units, and quick erecting antennas are but a few of these techniques.

The important factor here is that after the first attack, the public will be listening and the problem of getting the warning out to them will be drastically simplified as a consequence. The caveat in the requirement about a surprise attack on the system itself is, in a sense, tinged with irony. It is unlikely that any warning system could survive a surprise attack directed against its key facilities. It is equally unlikely that an enemy faced with a broad spectrum of key targets and possessing only a fixed number of weapons, would choose to direct his attack against the system. Unlikely, that is, unless one or more of three situations exist. The enemy may choose to act irrationally. He may have a surplus of weapons available to him for the first strike. Or, he may

wish to attack the population directly, but believes that its civil defense capabilities are so effective that if the system is not taken out by surprise, such an attack will not have sufficient payoff to make it worthwhile. The first situation cannot be controlled. The second requires integrated planning within the Department of Defense to insure that the enemy will always have too many targets to shoot. The third situation is more problematical, since it implies that the more effective the civil defense program is, the more likely the Warning System is to be a target.

The problem of the vulnerability of the Radio Warning System has been given a preliminary analysis by SRI.[1] The conclusions of that study concerning the danger of designing the system with a few critical nodes are sound. However, the problem is not one of a few critical nodes in a system which is threatened with collateral damage or with direct destruction as part of an overall attack on the country's communications capability. It is the vulnerability of even a widely dispersed alerting and warning system to a carefully planned surprise attack designed to carry out a strategy of destroying the population. The question then becomes, what kind of a civil defense program would have to be implemented in order to draw an enemy's fire to the warning system? In view of past public and Congressional disinterest in civil defense, one might answer, not the kind of program that would be implemented in the United States. But what if such an effective program were implemented? It would have to be based on the enthusiastic support of both the government and the public. It presumes a common belief that the threat of a direct attack on the United States is real and perhaps imminent; it presumes an elaborate system of protective measures; and, for an enemy to direct his surprise attack against the warning system instead of directly against the public, it presumes that the entire civil defense apparatus will operate only upon direction of the warning system.

The enemy could then have one of two goals in mind in carrying out an attack of the type contemplated here, wanton destruction or blackmail. The first would require a massive attack on population centers either simultaneously with or directly after his attack on the warning system. Any delay in attacking the population would increase the probability of warning being spread by alternative means and, in such a splendidly defended society, a consequent decrease of significant proportion in the effectiveness of his attack. Furthermore, a society so conscious of the existence of an enemy threat would not be without active defenses and retaliatory capability. Therefore, an enemy who carried out such an attack would be almost sure of annihilation due to his having had to spare military targets in carrying out his strategy. Such a strategy would be carried out only by a desperate or irrational enemy and the payoff would not seem to be worth the price.

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1. Dan G. Haney, National Radio Warning System: A Note on Survivability, Stanford Research Institute, June 1964.

The second strategic goal the enemy could attempt to achieve would be blackmail. Given that the civil defense program depended so heavily on the warning system, he could destroy it by surprise and then make his demands backed up by threats against a presumably defenseless population. But if public opinion was enthusiastic enough to support the implementation of a civil defense program of the scope contemplated here, people would merely proceed to their blast shelters and sit out the period of the threat or the period until the warning system could be reconstituted either by rebuilding the original components or, far more likely, until an expedient system could be established using other components. For such a strategy to be successful, an enemy would have to destroy or disrupt very seriously the entire communications capability of the United States. In order to do this, he would have to carry out an attack of tremendously greater scope than merely attacking the warning system. Such an attack would probably be detected in time for the civilian population to be warned. Moreover, an attack of this size would not be carried out by an enemy intent upon blackmail. It would result in retaliation, not negotiation.

In either strategy there would be no inherent advantage in taking the warning system out by surprise. Therefore, it seems reasonable to expect that the system will survive long enough to transmit the alert and warning and that it will meet both the public need and the operational requirement.

4.6.2 Jamming

The control portion of the Radio Warning System shall be provided with antijamming capability. The RF sensitivity of the public receiver component of the system shall be made adjustable and shall be maintained at a level no greater than that which is necessary to receive legitimate signals from system transmitters.

Jamming may take two forms in this system. An enemy may attempt to jam the control signals, either those used in the control network or those which are transmitted to activate the home receivers, thereby preventing the transmission of the warning, or he may attempt to jam the audio signals transmitted to the home receivers, thereby preventing the public from receiving an intelligible message. The degree of antijamming capability to build into the control network (frequency diversity, multiple paths, etc.) will have to be based on an analysis of the tradeoff involved in the cost of such features versus the likelihood of an enemy attempting to jam the system. Here, as with survivability, the likelihood of enemy jamming appears relatively remote due to the low payoff in view of the great risk. For upon detection, an attempt to jam the system would certainly be considered a hostile act.

The second part of the requirement is designed to make jamming as difficult as possible within the cost constraints of public receiver design. If the receiver is relatively insensitive to signals which have less power than those transmitted by the system facility whose job it is to activate it, then the enemy is

put at a disadvantage. He cannot hope to jam a very large part of the system sucessfully without having a very powerful transmitter located close to the area where the system is to be jammed. The choice of the method by which receivers are to be activated can also affect the jamming potential of the system. For instance, if the key to the receiver involves the transmission of several tones in a time sequence, with both the presence and absence of tones at particular times being critical to unlocking the receiver, then the enemy can prevent the activation of the receiver by transmitting the proper tones steadily and preventing any timed sequence of tones from turning the key. If, on the other hand, the key involves merely the transmission of several tones with no sequence being involved, the enemy is put at a disadvantage. For if he concentrates the RF energy used for jamming into the sidebands around the control tone frequencies, he will activate the receivers. If, instead, he used broadband jamming (white noise), legitimate control signals which concentrate their energy into the proper frequency bands should be capable of activating the receivers. Once the receivers are turned on, it may not be possible to receive an intelligible message, but the mere fact that the receiver has been turned on should be sufficient to alert the public that something unusual is occurring. If, in addition, sirens and other alert devices can be activated, the total effect should send an average individual to his regular radio to find out what is going on.

4.6.3 Spoofing

The control portion of the Radio Warning System shall be made sufficiently secure to prevent its being spoofed. The system shall be designed to enable the rapid detection by system operators of any attempt, whether belligerent or mischievous, to spoof the system. The system operators shall be provided with the ability to inform the public of the situation as soon as possible using the Radio Warning System itself as well as other means of communicating with the public.

The voice warning capability of the Radio Warning System provides an effective means of overcoming the effects of spoofing by an enemy. In the event an enemy succeeds in activating a portion of the system and broadcasting a false message, the system operator can can at the very least transmit a message to the public nullifying the enemy's message immediately after the enemy has completed his message. In fact, the system operator can do better than that in view of the receiver requirement included in the previous section on jamming. Upon learning of an enemy spoofing attempt in progress, the system operator can activate the transmission of a message immediately. The result will, in effect, jam the enemy's spoofing attempt, alert the public that something unusual is happening, and enable the system operator to use other means of communicating with the public, such as commercial broadcast stations, to transmit a counteracting message. This method will be effective since public curiosity as to what is happening will be aroused by the sequence of transmissions through the warning receivers. Further, if the sirens are controlled by signals which are kept secure and cannot be activated by the enemy, the lack of sirens signals

will provide an indication that the situation is not the same as it would be if the system were being jammed. In order to overcome enemy spoofing, however, the system operator must be able to detect any spoofing attempts. This requires that the frequencies used in the system be monitored in all the local areas. Police stations, fire stations, full-time EOCs and similar facilities can carry out this function. Reports of spoofing attempts can be made over KAWAS or whatever civil defense communications system is available to the monitoring agency.

The transmission of voice messages can also be used to overcome the effects of a false alarm in a major portion of the system. One of the greatest contributing factors to the degradation of the siren alerting systems has been the inability of the public to determine whether or not accidental triggerings of the sirens have been false. This need not be a problem with the Radio Warning System if feedback on false alarms which affect entire areas can be provided. Of course, false alarms caused by the failure of individual receivers cannot be handled in this way.

ANNEX TO CHAPTER TWO

OPERATIONAL REQUIREMENTS FOR A HOME ALERTING AND WARNING SYSTEM

The home alerting and warning system must be:[1]

1. Capable of alerting and warning the greatest number of people on a 24-hour basis at home and in buildings (apartments, hotels, offices, industry, etc.) where outdoor warning devices are not effective.

2. Capable of activation on a nation-wide basis from a primary and at least two alternate locations. (National Warning Center, Washington Warning Center, and Office of Civil Defense Region 5 Federal Center).

3. Automatic with instantaneous and simultaneous alerting capability.

4. Reliable.

5. Secure from dissemination of false alerts, accidental alerts, and denial of alert issuance.

6. Capable of authentication to insure the transmission of valid alerts only.

7. Capable of quickly recalling or cancelling a false alert if such is transmitted.

8. Capable of testing both transmission and reception to insure effective operations.

9. Economically feasible for the public.

10. Saleable to the public.

11. Designed to permit immediate follow-up by voice announcement of the reason for the alert and the actions to be taken or cancellation.

12. Designed to positively catch the ear of the public with sufficient volume to awaken the normal person, if sleeping.

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1. Source: John W. McConnell, Assistant Director of Civil Defense (Plans and Operations), Memorandum for Acting Deputy Director of Civil Defense; Subject: Operational Requirements - Home Warning System, 25 September 1964, p. 4.

13. Designed, if radio, to turn on the radio if off, or some other feasible arrangement to alert a person to turn on the radio.

14. Designed so the alerting signal cannot be compromised by imprudent use.

15. Constantly explained to the public to acquaint it with its purpose and operation.

CHAPTER THREE

ALTERNATE SYSTEM CONFIGURATIONS

1.0 INTRODUCTION

1.1 PURPOSE

This chapter presents the main characteristics of three possible Radio Warning System configurations.[1] Each configuration is based on a somewhat different interpretation of the Radio Warning System mission, and on differences in the relative weighting of such parameters as reliability, survivability, and security.

The principal aims of this chapter are to indicate that there are alternative means of meeting the Radio Warning System operational requirements, and to stimulate constructive thought on the relative merits of some techniques that have not previously been formally evaluated.

In addition to a discussion of alternate configurations, this chapter proposes redefinition of some of the operational requirements that have been specified in an earlier chapter.[2] This redefinition is the result of greater insight into problem areas gained by continuing exposure to the ongoing development program activities. Inputs from related studies have also contributed to the sharpening and refining of some of the Radio Warning System concepts. This redefinition is even more directly the result of a deliberate effort to strip the operational requirements to the bare essentials necessary to accomplish the basic mission of the system. The motivation for this is the realization that only by restricting the capabilities of the system to the absolute minimum, will acceptable levels of reliability be attained at a reasonable cost.

In the process of redefining some of the requirements, a few of the problem areas have been investigated and discussed. Solutions to some of the problems are offered based on the assumptions and arguments developed in this document. If the assumptions and arguments are not acceptable, but are believed, instead, to conflict with established OCD policies, then further dialogue is required in order that the constraints imposed upon system design by such policies may be fully understood by those involved in the development of the Radio Warning System.

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1. This chapter replaces Radio Warning System Alternate Configurations, which was originally published as TM-L-1960/031/00, dated 30 June 1965.

2. Chapter Two, "Interim Operational Requirements."

1.2 MISSION OF THE SYSTEM

The mission of the Radio Warning System is to provide the public, through radio receivers located in dwellings, places of business, and institutions, a timely national alert and voice warning of an impending enemy nuclear attack. The purpose of this alert and warning is to enable the public to take protective measures to increase the probability of their survival.

The need for the Radio Warning System obviously arises because of the lack of an adequate existing system capable of alerting and warning the public. There are existing warning systems, some of them quite extensive and costly. Examples are the Emergency Broadcast System (EBS), NAWAS, and local siren systems. All of the existing systems, however, have reaction times that are too slow for the nuclear age. The enemy ICBM capability has reduced the time available for warning, after detection of an enemy attack, from days or hours to minutes. Some of the existing systems such as EBS have no capability of alerting a person unless his radio is already turned on and tuned to the alerting station. Other systems, e.g., local sirens, can alert the public, but have poor coverage of the population, particularly at night when most of the public is indoors.

It was to fill this gap that the Radio Warning System project was inaugurated. What sets the Radio Warning System apart from all previous warning systems is that it has the following four capabilities all existing in one system:

1. The Radio Warning System has a quick reaction time. It eliminates all of the decision points, manual relays, and local actions that characterize current, siren systems. The Radio Warning System receiver is, in effect, always on even though muted until an alert is disseminated.

2. It has the capability to alert the public by generating a distinctive, attention-getting sound. This capability allows the Radio Warning System to alert even a sleeping population.

3. It has the capability of delivering a voice message to the public. This is important for authentication of the alert and for disseminating instructions.

4. It has broad population coverage capability. This is provided by bringing the alerting sound and warning message into the home where the majority of the population will be during certain critical hours of the day.

The Radio Warning System will not replace the existing warning systems. They each have their own unique contributions to make in the overall warning situation. The local sirens will still be needed to warn those people who are out-of-doors when the warning is given. They also serve the purpose of backing up or authenticating to the public the validity of the warning received via the Radio Warning System. The EBS or its successor will still be needed for

the dissemination of local instructions and for strategic warnings (defined as non-time-critical warnings of enemy actions). These other systems, however, will be affected by the existence of the Radio Warning System, and all systems will be made to complement each other and contribute toward providing a complete warning capability.

1.3 CONSTRAINTS

No attempt to define a command and control capability as part of the Radio Warning System has been made in this chapter. The configurations described have only the capability of accomplishing the alerting and warning mission as defined in the last section. Guidelines for the development of the Radio Warning System, as laid down by OCD, restricted the system to an alert and warning function only. These guidelines have not been altered, nor is sufficient information available on the requirements for a command and control function for this system to permit consideration of these added capabilities in the configurations discussed in this document.

The level of detail of the system configurations presented is not sufficient to allow adequate cost analyses to be made at this time. Also, and equally important, effectiveness criteria for the various prescribed system capabilities have not been established to the point where effectiveness ratings of the various configurations can be made. No effort is made in this presentation, therefore, to compare one configuration with another on a cost-effectiveness basis. This activity, as well as the development of more detailed designs, will be reserved for future studies.

It should be pointed out that the inherent characteristics of the Radio Warning System insure that any system configuration will be naturally divided into two distinct interfacing subsystems. One is the broadcast subsystem concerned with the transmission of warning messages to the public via the home alert and warning receiver. The other subsystem is the control network which carries the control signals down from the initiating points at the national level to the transmitters that broadcast to the public. The designs of these two subsystems present entirely different types of problems, and the design details of one only indirectly affect the design details of the other.

In this document only variations in the control network subsystem will be discussed. The radio facilities for broadcasting to the public will be considered to be the same for all three configurations. Advantage is taken of the fact that the two subsystems can be studied more or less independently. This is not meant to imply that all of the problems with these facilities have been solved or that the subsystem can in any sense be considered to be optimum.

As more precise definition of some of the parameters of the broadcast subsystem depends upon the evaluation of field strength and noise measurements yet to be made, more detailed studies of this part of the configuration have been deferred until a later time. All of the control network subsystems presented are

considered to interface with a broadcast subsystem consisting of eight low-frequency, subnational transmitters plus approximately 60 commercial broadcast stations. All 68 stations will operate in a broadcast mode. Some details of the broadcast subsystem will be described in conjunction with the description of the first configuration presented and will not be repeated as part of the descriptions of the other configurations.

2.0 CONCLUSIONS AND RECOMMENDATIONS

Of the three different system configurations that have been examined in some detail all appear to be technically feasible. A number of problems remain to be solved before an operational system can be implemented. More precise definition of the system requirements, and a rationale for weighing their relative importance should be developed as soon as possible to allow meaningful cost-effectiveness comparisons to be made of the different configurations. It is recommended that the principles of value engineering, as developed by the Department of Defense, be applied to the development of the Radio Warning System. This will ensure that OCD will develop a system that has all of the basic capabilities needed to accomplish the mission but will not be burdened with excessive costs in providing capabilities with only marginal utility.

3.0 RADIO-BASED CONFIGURATION

This configuration is based upon use by OCD of the low-frequency (60 kHz) time-standard station, WWVB, at Fort Collins, Colorado, modified to increase power output and reliability, for disseminating the control signals from the national initiation points to the transmitters that broadcast the alert and warning message to the public. NBS is the normal everyday user of the station, broadcasting at 60 kHz to the public with time signals derived from the NBS cesium atomic frequency standard. During an alert situation OCD will assume control of WWVB and will transmit frequency shift-keyed teletype signals to control the subnational and commercial broadcast stations.

This configuration was first formally presented and discussed at a joint contractors' meeting held in Santa Monica, California, on 10-12 December 1964.[1]

This description reflects the basic system configuration as it was presented at that meeting with some modifications resulting from additional information gained since that time from telephone calls and personal contacts with contractor and OCD personnel. The System Development Corporation has not performed a comprehensive analysis of this configuration, nor were operational feasibility studies made. As a result, the configuration is only representative of the system as conceived by the participants at the December meeting, with the exception of the changes and additions previously mentioned.

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1. J L Autery and Samuel Weems, Report on the Radio Alerting and Warning Meeting, System Development Corporation, TM-L-1960/027/00, 16 February 1965.

A control message is transmitted through the system in the following manner: An alert action initiated by an OCD operator at one of the three National Warning Centers[1] results in a switch closure being sent to a programmer. The programmer selects one of a number of teletype tape readers with a prepunched teletype tape containing a control message code prepositioned under the send head. The programmer will cause this and other control messages to be transmitted in a timed sequence to accomplish the following train of events.

The first tape message will be encrypted by a KW7 cryptographic device and transmitted to the NBS transmitter, WWVB, at Fort Collins, Colorado, by means of a microwave communications channel. At WWVB the control message will be decrypted by another KW7 and fed to a teletype page printer and stunt box. The decrypted message code actuates the stunt box, which then provides a switch closure to a controller. The controller provides the timed sequences of switch closures required to change over the WWVB transmitter, modulator, antenna, and related equipment to the OCD mode of operation. When this has been accomplished, the programmer at the National Warning Center will initiate the sending of another code group. This code group, after being decrypted at WWVB, will cause the stunt box to start the transmit KW7 sending synchronizing signals to the modulator for transmission at 61.15 kcs (center frequency) to the subnational and commercial broadcast transmitter stations.

After sufficient time has elapsed for all of the receive KW7s at the lower echelon stations to become synchronized with the transmit KW7 (about 8 seconds), the programmer will cause the tape reader to send another code group. This group is decrypted at WWVB, reencrypted by the transmit KW7, sent down to the subnational transmitter stations and there decrypted. The decrypted message code is fed into a teletype page printer-stunt box-controller ensemble similar to the one at WWVB. This causes the subnational transmitters to switch on plate power and begin to radiate carrier on their assigned frequencies. Similar ensembles at the commercial stations also cause the broadcast transmitters to begin operating in the OCD mode as a result of the switching of subsystems. The programmer will then, after allowing time for all of the lower echelon stations to have switched over to the OCD mode of operation, cause the tape reader to send another code group. This group, when received, will cause the stunt box to provide a switch closure to a selected voice tape deck which feeds the prerecorded audio alert signal/warning message to the modulator for transmission to the public.

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1. For the sake of simplicity, this description will be limited to a discussion of initiation from the National Warning Center at NORAD COC in Colorado Springs only. The details of initiation from alternate initiation points are described in a later section.

Monitor receivers at the National Warning Center determine if the transmitters at the lower echelon function properly and display this information on a status board at the operator's console. The operation of WWVB in the OCD mode is monitored by means of a 61.15 kcs FSK receiver feeding its output into a receive KW7 with the decrypted code groups being printed on a page printer adjacent to the operator's console.

3.1 FUNCTIONAL SUBSYSTEMS

This configuration is shown in Figure 3-1. The major subsystems in this figure are described below. They are grouped together under the site at which they are physically located.

3.1.1 National Warning Center

The equipment configuration shown in Figure 3-1 is typical for all of the National Warning Centers though it actually indicates the configuration for the National Warning Center at NORAD COC. Any differences existing between the several National Warning Centers will be the result of their physical location rather than any difference in function. Not shown in the figure are the communications and other equipment which provide the interface between the three National Warning Centers. As backup to the primary mode of operation there will be two alternate National Warning Centers: National Two Warning Center (N2WC) at OCD Region Five Headquarters, Denton, Texas; and National Three Warning Center (N3WC) at the present location of the Washington Warning Area Control Point (WWACP).

Below is a list of the principal subsystems at the National Warning Center:

Programmer
Teletype tape reader
KW7-T (Cryptographic equipment operating in the transmit mode)
Microwave terminal
61.15 kHz receiver (monitor)
*KW7-R (cryptographic equipment operating in the receive mode)
*Teletype monitor page printer
*Subnational low frequency receiver (monitor)
*Commercial broadcast receiver (monitor)
Status display

The following paragraphs describe the subsystems listed above except those labeled with an asterisk, which are standard commercial equipment whose function is well known.

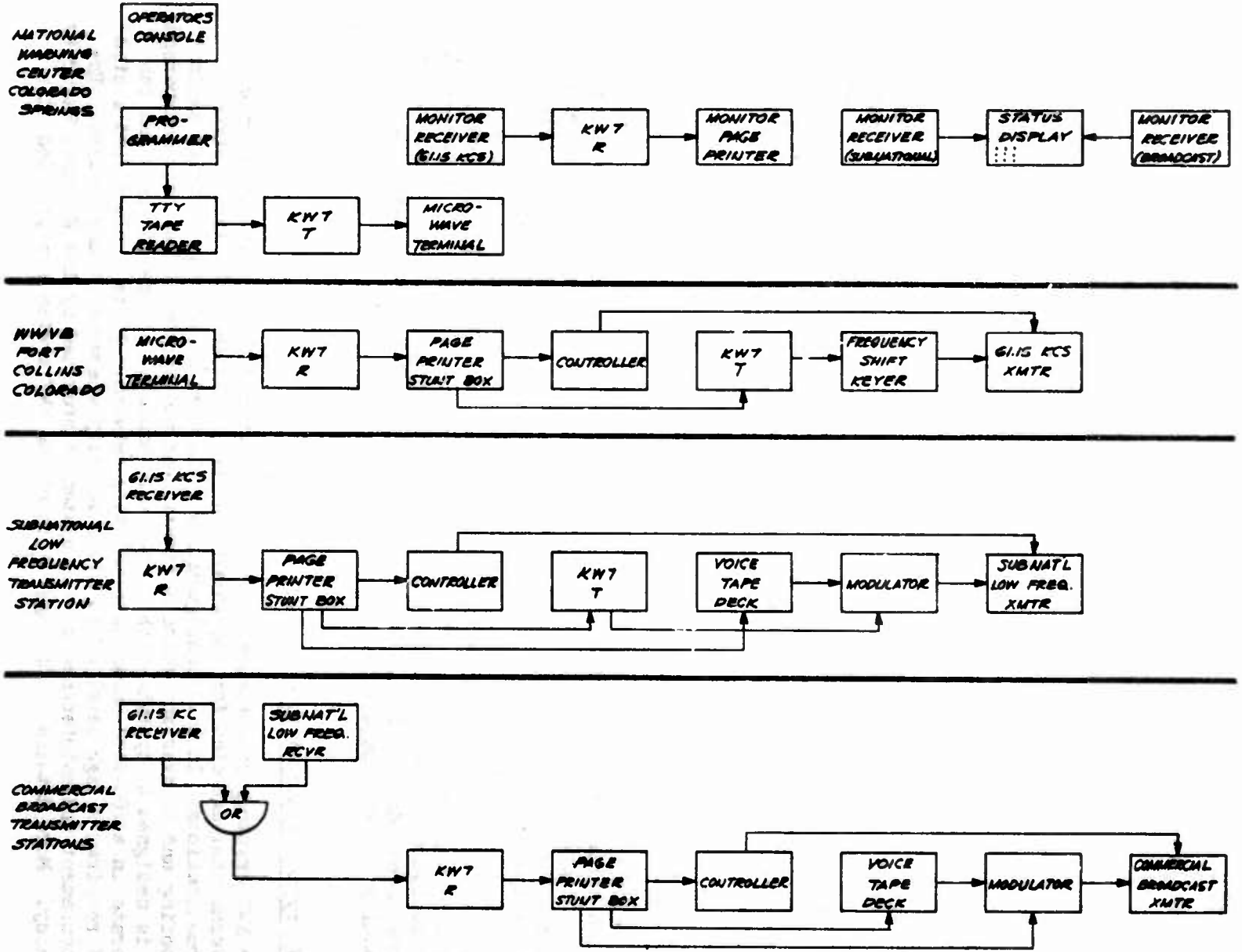


Figure 3-1. Radio-Based Systems

Programmer

This subsystem provides the automatic code selection, time sequencing, and overall control of the actual transmission of the control signal once the initiation action has been taken by the OCD operator. The programmer accepts one of a number of switch actions from the console, selects the proper tape reader corresponding to a particular switch action and starts that tape reader transmitting a code group to the transmit KW7 cryptographic device. (All control messages originating at the National Warning Centers are encrypted.) It sets a timer and at preset intervals it selects and starts other tape readers that transmit other coded messages to initiate functions at a lower echelon at prescribed times.

The actual logic to be incorporated into this circuit has not been worked out in detail. Provision will be made by the programmer for sequencing normal control codes interspersed with ad lib teletype messages originated by the OCD operator for live voice reading by designated personnel at input points to the transmitters that broadcast to the public. Possible interface with some type of automatic message composer must be considered in the design of the programmer.

Teletype Tape Reader

The teletype tape reader is connected to the programmer and is activated by switch actions from the programmer. Upon activation, it reads a selected, prepositioned teletype tape and converts it into electrical teletype coded signals that are fed into a cryptographic device. It is a standard teletype, paper-tape, transmitter-distributor modified for special OCD use. It may consist of one tape read head for each coded message which the programmer can start and stop in accordance to its internal logic. It could also consist of a single tape reader with a tape search device under control of the programmer for positioning the proper code group under the read head. In either case a manual override capability should be provided to enable the operator to manually control the device.

KW7 Cryptographic Device

The KW7 cryptographic system is furnished by the National Security Agency to governmental agencies for the purpose of providing security for teletype communications. In this configuration it is used to provide security against spoofing and inadvertant false activation of the system by unauthorized persons. It is designed to operate with five-level, Baudot, telegraphic code and can operate in a 100-word-per-minute teletype network. It is a classified system and requires a high level of physical security wherever it may be used. The procurement and maintenance of the system is provided by the National Security Agency. More details on the operation of the KW7 system are provided in a

previously issued SDC document[1] that lists information on the system obtained from an interview with National Security Agency personnel.

Microwave Terminal

All communications between the National Control Center at NORAD COC and the NBS transmitter site at Fort Collins, Colorado are by means of a full-period microwave channel. All messages will be encrypted by means of a KW7 cryptographic device operating in the transmit mode at the National Warning Center and another KW7 operating in the receive mode at Fort Collins. The two KW7s will be maintained in synchronism at all times so that no time delay in transmitting the alert and warning message to the public will be caused by the use of cryptographic devices on this communication link. The means of transmitting the control signals from the other two national initiation points to the primary transmitter, either at Fort Collins or in Virginia may well differ from the means used between NORAD COC and Fort Collins. The suggested options for accomplishing this function will be discussed in a later section.

Monitor Receiver

The monitor receivers monitor the outputs from the various system transmitters and inform the OCD operator whether these subsystems are performing properly. The 61.15 kHz receiver monitors the OCD alert and warning frequency on which the NBS transmitter will transmit the encrypted control code groups to the lower echelon transmitters. This is an FSK receiver which furnishes encrypted teletype signals to the KW7 cryptographic device for decryption and printing on the monitor page printer. Another possible use for this receiver, as previously mentioned, would be to monitor the beginning of the power emission from WWVB on 61.15 kHz and provide a switch closure to the programmer as a signal to begin transmission of the code group that starts the transmit KW7 cryptographic device at WWVB sending synchronizing pulses to the KW7s at the lower echelon transmitters.

The low frequency and broadcast receivers are designed to recognize the special coded transmissions put out by the subnational and commercial broadcast transmitters for demuting the home receivers. They differ from the home receivers in having greater sensitivity and reliability. Also instead of demuting the audio portion of the receiver the demuting gate, when opened, will provide a switch closure indication to the status board that some particular transmitter is performing satisfactorily. Each National Warning Center will monitor as many lower echelon transmitters as is technically feasible and will pass these status data on to the other national warning centers.

1. J L Autery and Samuel Weems, Trip Report, System Development Corporation, TM-L-1960/004/00, 22 April 1965.

Status Display

The status display will be some kind of visual display board that indicates the status of each element of the Radio Warning System. The OCD operator, at a glance, should be able to pick out the transmitters that have not begun to transmit an alert and warning message so that he may, with a minimum of delay, take such means as may be available to him to correct the deficiency.

3.1.2 WWVB Transmitter Station, Fort Collins, Colorado

The equipment described here for Fort Collins will be representative of the equipment that will be required for the second NBS low-frequency station in Virginia. The functions of the two stations are practically identical except for their areas of geographic coverage. The Fort Collins transmitter will control the lower echelon transmitters west of the Mississippi River and the Virginia transmitter will control the lower echelon transmitters in the Eastern part of the country. Of course, there will be a large overlap in coverage and the actual station assignments will depend on field strength and noise measurements now being made. The two stations should be operated on different frequencies to prevent interference in the overlap areas. This would obviate the necessity of transmitting sequentially in time with the resultant time delay in getting the alert and warning message to the public.

The following list of equipment represents the major functional units at WWVB that are involved in the OCD mode of operation.

*Microwave terminal
*KW7-R (cryptographic equipment operating in the receive mode)
Page printer-stunt box
Controller
*KW7-T (cryptographic equipment operating in the transmit mode)
Frequency shift keyer
61.15 kHz transmitter

The subsystems with asterisks are not described in detail as they are essentially identical to subsystems previously described.

Page Printer-Stunt Box

The teletype page printer with stunt box has two functions to perform. It provides a permanent record of the control messages received from the National Warning Center, and it acts upon these messages by furnishing switch closures to the controller. The first message received from the National Warning Center will be a command to switch over the NBS transmitter to operation in the OCD mode. This command is passed to the controller by the stunt box and a record of the command is printed out on the page printer. All later control messages are passed on to the transmit KW7 cryptographic device but are monitored and printed out by the page printer. The stunt box ignores these messages but continues to monitor the line until a control message is received ordering the NBS transmitter to be restored to the NBS operating mode. The stunt box will send a switch closure to the controller to effect this switchover.

Controller

The controller has the function of changing WWVB from its normal NBS operating mode to the OCD alert and warning mode, and back again to the NBS mode. Both changes are initiated by switch closures input from the stunt box as a result of commands sent from the National Warning Center. The changeover from one mode to another involves switching modulators or possibly transmitters if a standby transmitter is provided. It will require retuning of the transmitter and antenna from 60 kHz to 61.15 kHz or vice versa and possibly other housekeeping chores incident to the changeover in type of operation. The controller may have an internal timing device, but this will only be for the purpose of timing its own sequence of operations. All external timing will be under control of the programmer at the National Warning Center.

Frequency Shift Keyer

This modulator receives the encrypted control message in normal teletype code from the KW7 cryptographic device in the form of electrical impulses and converts them into frequency shift keyed modulation of the 61.15 kHz transmitter for transmission to the lower echelon transmitter sites. The KW7 cryptographic device is designed to operate normally with a special tone keyer when used on radio circuits[1], but tone keying is considered to be less efficient than frequency shift keying for the center frequency and band pass characteristics of WWVB.

1. Autery and Weems, op. cit., pp. 1-2.

61.15 kHz Transmitter

This is the WWVB transmitter when used in the OCD mode. It is normally operated at a center frequency of 60 kHz with special modulation carrying standard frequency and time standard information for broadcast to the public. A special OCD modulator for producing frequency-shift-keyed signals will replace the normal modulator when operating in the OCD mode. This transmitter at Fort Collins and a companion transmitter located in Virginia will provide the primary means of transmitting a control message down to each of the subnational low-frequency and standard broadcast transmitters. Redundant equipment will be added to the station to bring the reliability[1] of the transmitting system up to OCD requirements and the radiated power will be increased to about 100 kilowatts.

3.1.3 Subnational Low-Frequency Transmitter Stations

These low-frequency OCD dedicated broadcast stations are the primary means for broadcasting an alert and warning message to the public. They will operate in the frequency range between 180 and 220 kHz to take advantage of the long-range ground wave radio coverage characteristics of these frequencies.

Present plans indicate there will be eight of these subnational transmitters located in or near the following cities:

Bend, Oregon
Billings, Montana
Richland Center, Wisconsin
Portsmouth, New Hampshire
Olney, Maryland
Bainbridge, Georgia
Knox City, Texas
Henderson, Nevada

Two different functions are planned for these stations. The first is, as stated, the primary responsibility for broadcasting the alert and warning message to the public. The second is to serve as a relay station to transmit the encrypted control message from the NBS low-frequency transmitters to the commercial broadcast stations. It has been proposed that these two functions be performed simultaneously by sharing the available bandwidth of the transmission channel between tone-keyed teletype signals and the voice warning message. Some problems are forseen if this is attempted, e.g., audio interference at the home receiver from the teletype modulation, and degradation of both teletype signals and audio alert and warning signals due to the sharing of the modulation power of the transmitter. The functional subsystems for

1. See Section 5.2.3, footnote 1.

performing the teletype relay operation are included in Figure 3-1, however, and in the list of subsystems below:

Receiver (61.15 kHz)
*KW7-R (crypotographic equipment operating in the receive mode)
Page printer-stunt box
Controller
*KW7-T (cryptographic equipment operating in the transmit mode)
Voice tape deck
Modulator
Subnational low-frequency transmitter

Only the items without asterisks are described.

Receiver (61.15 kHz)

This receiver is designed to receive frequency shift-keyed signals from one of the low-frequency NBS stations at Fort Collins, Colorado, or in the State of Virginia, depending on which transmitter provides the strongest signal at the receiver location. The receiver will convert the received signals to normal teletype signals for input to the KW7 cryptographic device. Other than a requirement for high reliability, this receiver will be of standard commercial design.

Page Printer-Stunt Box

The page printer with stunt box has three functions to perform. (1) The page printer provides a permanent record of the control messages received from the National Warning Center via the NBS low-frequency transmitter. (2) The stunt box acts upon these messages by furnishing switch closures to the controller. The first message received from the National Warning Center via the NBS transmitter will be a command to switch on plate power at the subnational transmitter. This command is passed to the controller by the stunt box and a record of the command is printed out on the page printer. All later control messages that are destined for the commercial broadcast stations are passed on to the transmit KW7 cryptographic device but are monitored and printed out by the page printer. The stunt box ignores these messages but continues to monitor the line until a control message is received ordering the NBS transmitter to be restored to the NBS operating mode. The stunt box will send a switch closure to the controller to effect this switchover. (3) In response to a control message the stunt box will provide one of a number of possible switch closures to the voice tape deck to select the proper message for transmission to the public via the subnational transmitter.

Controller

The controller has the function of putting the subnational transmitter on the air. As this transmitter has no secondary mode of operation, it will remain in a ready state at all times so that it is only necessary to switch on the plate power to be ready for operation. The controller will turn the transmitter on and off under the control of the stunt box.

Voice Tape Deck

Each subnational and commercial broadcast alert and warning transmitter station will have an identical library of official OCD magnetic alert and warning tapes. The voice tape deck will be the subsystem where the tape handling operations are performed. The tapes are stored with the start of each taped message under a separate read head. When the control message specifying a particular tape is received and decrypted, the stunt box sends one of a number of switch closures to the voice tape deck. This selects and starts one of the tape drives which sends audio alert and warning signals to the modulator. The message will be on an endless tape so that when the message is completed it can immediately be repositioned with the beginning of the message under the read head. As the format of the messages, the number of repetitions of a message and the sequencing of messages has not been determined it is not possible to give more details on the operation of this subsystem. It can be said, however, that some simple logic circuits and a timer will be required to perform the function of this subsystem, even if the only complexity is to repeat a given message a specified number of times.

Modulator

The modulator has the primary function of amplitude modulating the transmitter with the alert signals and voice messages input from the voice tape deck. It has a secondary function of converting encrypted teletype signals from the KW7 cryptographic device into tone-keyed modulating signals for the transmitter. The voice warning message is a direct broadcast to the public and the tone-keyed teletype signals are control signals for activating those commercial broadcast stations that are within transmission range of the subnational transmitter and are part of the Radio Warning System. The problem is that both functions are equally urgent and one should not be delayed in favor of the other. The apparent solution is to broadcast both simultaneously, assigning parts of the available audio bandwidth to each function. This means, however, a division of the available transmitter power between functions and both may suffer. This is an area which must be studied more closely.

Subnational Low-Frequency Transmitters

These eight transmitters will be OCD dedicated, unmanned facilities with radiated power outputs of from 50 to 100 kilowatts. Their primary function will be to provide broadcast radio coverage of the alert and warning message to the entire continental United States. Their frequency range of operation (180-220 kHz) should provide adequate strength of the groundwave signal for reception by a simple economical receiver up to 500 or 600 miles from the transmitter. Whether any single receiver can receive the transmission depends on many factors, not the least of which are the ground conductivity between the transmitter and receiver and the ambient noise level at the receiver. These parameters are subject to diurnal, seasonal, or other variations which make it difficult to generalize on the coverage that can be expected from these transmitters. It is certain, however, that these transmitters will not provide sufficient signal strength to be useful in the large metropolitan areas where ambient noise levels are high. It is planned to fill in the coverage of these high noise areas with commercial broadcast stations. This then imposes a secondary function on the subnational transmitter; that is, to disseminate a control message from the NBS low-frequency transmitter to the commercial broadcast stations. This will be required at all of those broadcast stations that cannot receive control signals directly from either of the NBS low-frequency stations.

3.1.4 Commercial Broadcast Transmitter Stations

Commercial broadcast transmitters will be used to disseminate the alert and warning message to the public in those large metropolitan areas where the signal-to-noise ratio is too low for reliable reception of the subnational low-frequency transmissions. It has been estimated that approximately 60 broadcast stations will be required to cover all of these high noise areas. The actual number needed and their location will be determined on the basis of field measurements of signal strength and ambient noise now being made. Where possible, the commercial broadcast stations will receive their control signals directly from the NBS low-frequency transmitters. This will save several seconds in the time required to disseminate the alert and warning message to the public by eliminating the relay operation at the subnational transmitter. The possibility is recognized, however, that this direct coverage of all commercial stations by the two NBS low-frequency transmitters may not be feasible. Some stations may receive reliable signals only from the NBS transmitter; others may be able to receive only from a subnational station. Still other commercial broadcast stations may be so located that signals from the nearest NBS station and the nearest subnational station are both marginal. Figure 3-1 represents this type of commercial station where the two receivers feed into an OR gate which selects the one with the most reliable signal. This type of station is probably atypical, but is shown in the figure as it represents the more general case. Most of the commercial stations will probably have only one receiver, of one type or the other.

The following list is of the major subsystems at a commercial broadcast station that are involved with the OCD alert and warning function:

*Receiver (61.15 kHz)
*Receiver (Subnational)
OR Gate
*KW7-R (cryptographic equipment operating in the receive mode)
Page printer-stunt box
Controller
*Voice tape deck
*Modulator
Commercial broadcast transmitter

Only the subsystems without asterisks are described below.

OR Gate

As mentioned previously, only those stations that are in geographical areas where reception is marginal from both the NBS and the subnational transmitters would have two receivers with an OR gate. The OR gate would operate in such a manner that whichever channel first presented a usable, recognizable signal would be switched to the input of the KW7 cryptographic device and the other channel would be ignored. The gate must operate in this manner as the cryptographic devices on the two channels make it impossible to obtain information from either channel unless the receive KW7 cryptographic device was on-line for the start of the transmission when the synchronizing pulses were being transmitted.

Page Printer-Stunt Box

The teletype page printer with stunt box has three functions to perform. (1) It provides a permanent record of the control messages received from the National Warning Center via the NBS transmitter directly, or via relay through the subnational transmitter. (2) It acts upon these messages by furnishing switch closures to the controller. The first message received from the National Warning Center will be a command to switch over the commercial broadcast transmitter to operate in the OCD mode. This command is passed to the controller by the stunt box and a record of the command is printed out on the page printer. (3) In response to a control message the stunt box will provide one of a number of possible switch closures to the voice tape deck to select the proper message for transmission to the public via the commercial broadcast transmitter.

Controller

The controller has the function of converting the commercial broadcast transmitter from its normal commercial mode to the OCD mode of operation or, if the commercial broadcast transmitter is off the air, to switch it on the air in an OCD mode. It also has the function of returning the transmitter facility to its normal operating mode when the OCD alert and warning function has been completed. The functions to be performed in effecting a change in the mode of operation will vary from station to station depending on each station's configuration. It may be necessary at some stations to switch modulators; at others, it may only be necessary to switch the program lines into the modulator. If notch filter monitoring devices[1] are used at the station to prevent program material from causing false alerts, these must be removed from the system when used in the OCD mode. These and other considerations may necessitate the controller being a custom made device for each installation. It may, however, be possible to design a controller with general circuitry which can be adapted to the variety of station configurations that will be encountered.

Commercial Broadcast Transmitters

These transmitters will be used to broadcast the alert and warning message to the public in the high noise metropolitan areas where the signal-to-noise ratio of the subnational transmitter signals are too low for dependable reception by public receivers in that area. These stations will generally be 50 kilowatt stations with good coverage of the high noise areas that they service. They will transmit on their assigned frequencies when operating in the OCD mode. If they are not 24-hour stations, they will be required to leave filament power on and all subsystems in a "ready-to-go" condition when signing off the air at the end of their regular broadcast day. This is necessary if alert and warning messages are to be disseminated with the minimum of delay at any time of the day or night. To increase reliability each station will be required to have a standby transmitter and an auxiliary power supply, both with automatic switchover capability in case of failure of the main transmitter or commercial power. Redundancy in other subsystems will be required on a station-to-station basis depending upon the particular configuration of each station.

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1. See Chapter Seven, "A Technique for Preventing Program Material from Falsely Activating Home Receivers."

3.2 SYSTEM OPERATION

The OCD operator at a National Warning Center will implement his decision-to-warn by pressing one of a number of push button switches on the operator's console. From that time on the propagation of the alert and warning to the public will be automatic. The following sequence of events illustrates the interactions that take place among the previously described subsystems when the Radio Warning System is activated by the OCD operator.

The switch closure from the operator's console starts the transmission of a coded message over the first link of the control network. This first link, from the National Warning Center at NORAD COC to the NBS transmitter at Fort Collins, will be a full-period, microwave channel. The first link from the N3WC at the WWACP to the primary transmitter in Northern Virginia will also be a full-period, microwave facility. The first link from N2WC at OCD Region Five Headquarters in Denton, Texas, to Fort Collins is less firmly established. It has been suggested that a full period microwave link be provided from N2WC to the subnational transmitter at Knox City, Texas. The control messages would be transmitted from N2WC via the microwave link to Knox City and there relayed via the subnational transmitter, operating in a single sideband mode, to the primary transmitter at Fort Collins. An alternative means of providing communications between N2WC and Fort Collins is by secure land line. This link could then be a full-period channel.

Backup communication channels from the NWC and the N2WC to the primary transmitter in Northern Virginia and from N3WC to the primary transmitter in Fort Collins will have to be provided. Secure wire channels would appear to offer the best solution for these backup facilities.

On those first-link channels that allow full-period operation, the KW7 cryptographic devices will be maintained in synchronism at all times. This will eliminate the delay associated with the synchronizing of cryptographic devices when a channel has not been in service for a period of time. If initiation is made from N2WC, this synchronization delay cannot be avoided. Although the microwave link from N2WC to Knox City can be maintained as a full-period channel, the link provided by the subnational transmitter cannot, so the KW7s on the Knox City to Fort Collins link must be synchronized each time the channel is activated. The time required for this synchronization, added to the time needed to get the subnational transmitter switched on the air, will add approximately 10 seconds additional delay in getting the warning message to the public.

The purpose of the first control message is to activate the primary transmitters at Fort Collins and in Northern Virginia by putting them on the air in the OCD mode of operation. As neither of the two primary transmitters is capable of covering the whole of the United States with reliable teletype signals, both transmitters must be activated for all alerts. This implies communication from each of the national initiation points to both of the primary transmitters.

It has been suggested that the primary transmitters could be used to relay control messages to each other, thus eliminating a need for a communication channel from each of the National Warning Centers to a second primary transmitter. This method of transmitting the control signals to the second primary transmitter, however, is not recommended as it would nullify the redundancy inherent in having two primary stations. For example, if NWC were connected only to Fort Collins, and the Fort Collins transmitter failed, NWC could not activate the Northern Virginia transmitter without having a separate backup communication channel to that transmitter. If backup channels from each of the National Warning Centers to a second primary transmitter are needed, they should be made primary channels so that both primary transmitters could be simultaneously activated from any of the three initiation points. This would increase the reliability of the Radio Warning System control network and eliminate the difficult timing problems that would arise with operation of the primary transmitters in a sequence of different modes.

The programmer controls the dissemination of the control message once the initiating action has been taken by the OCD operator. It times and sequences the code groups that make up the control message. The first part of the control message will be a conditioning code to ready the teletype stunt box at Fort Collins to receive instructions. This conditioning code will consist of a two-to five-letter code group. The second part of the control message is a three-letter code group that causes the stunt box to initiate changeover to the OCD mode. The controller, when activated by a switch closure from the stunt box, will accomplish the necessary switching and retuning that is required to change WWVB into the OCD mode of operation. While this is taking place, a short teletype message sent down from the NWC and printed out on the page printer will authenticate the warning to the NBS operators.

The programmer puts in a timed delay to allow for completion of the hardware switching, and to enable WWVB to be ready to start transmitting on 61.15 kHz in the OCD mode. The programmer then initiates the sending of the second message which causes the stunt box to provide a switch closure to the transmit KW7 cryptographic device at WWVB. This switch closure causes the KW7 to send synchronizing signals via the 61.15 kHz transmitter to synchronize all of the KW7s at the lower echelon stations. After 8 seconds, the sending of synchronizing signals is stopped by another code group received at the stunt box from the NWC. An alternate means of timing the start of transmission of the second message could be provided by furnishing the programmer with an input from the 61.15 kHz monitor receiver. When WWVB completed its changeover to the OCD mode of operation, it would radiate carrier power on 61.15 kHz indicating to the programmer that the transmitter was operational in the OCD mode. The programmer could then start sending the next code group without waiting for a timed switch action. Some message delay time might be saved by this alternative. This operation is followed by a three-letter code group (Inhibit Code) that prevents the stunt box from responding to any characters in the text material that follows

except a particular code which will be used to reset the stunt box for receiving further instructions. This particular code will always precede new instructions such as cancel, reset, stop transmission, or return transmitter to NBS control. The channel is now clear for transmission of control messages from the NWC down to the transmitters that communicate directly with the public.

With a communication channel established to the subnational and commercial broadcast transmitters, a code group causes the stunt boxes to activate the controllers at each of these lower echelon transmitters. At the subnational transmitters, which are OCD dedicated and have no other mode of operation, the controllers have only to switch on the plate power supply and the transmitters are ready to broadcast to the public. At the commercial broadcast stations the controller has to switch program lines, modulators, plate power and possibly other equipment, depending on the configuration of each station. The end result will be the same, however, even though the switchover takes longer for the commercial broadcast stations than for the subnational transmitters, i.e., all stations will be put in a condition to broadcast the OCD alert and warning message to the public.

The next code group will be interpreted by the stunt boxes at all stations to be the selection of the correct alert and warning tape drive unit from the voice tape deck. The selection of the tape unit will be followed by immediate read out of the taped alert and warning message to the modulators of the transmitters for broadcast to the public. This message will be on an endless tape and will repeat the contained message until ordered to stop by a new command from the stunt box in response to a cancel code group sent down from the NWC.

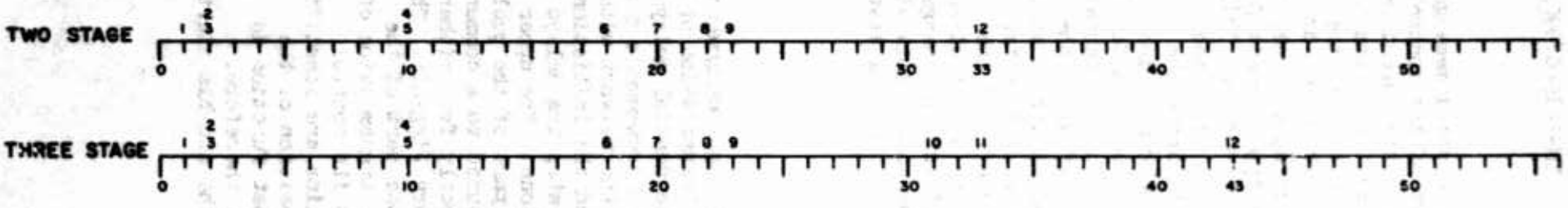
Once the alert and warning broadcasts have been started at all of the subnational transmitters and commercial broadcast stations, a teletype authentication message is sent down from the NWC to all commercial broadcast stations and printed out on the local page printers.

The above description of the system operation was limited to the "two-stage" option, so-called because the control message was delivered to all of the transmitting stations in two steps or stages. The first stage is the link from the national initiation point to the primary transmitter at Fort Collins or Northern Virginia. The second stage is from the primary transmitter to the transmitting station that broadcasts to the public. There is some uncertainty that all of the commercial broadcast stations can be activated directly by the two primary transmitters. This uncertainty arises from estimates of inadequate signal strength of the primary transmitters in some parts of the country, particularly in the high-noise metropolitan areas where the commercial broadcast stations will be located. To counter this probable coverage deficiency by the primary transmitters, a three-stage option is proposed. The three-stage option differs from the two-stage option in that the subnational transmitters will be used to relay the control message to those commercial broadcast stations where the signal-to noise ratio of the transmissions from either one of the

primary transmitters is too low for reliable reception. The control message will be different for the three-stage option. The first part of the control message will be the same as for the two-stage option, but when the subnational transmitters begin to broadcast to the public one more step must be taken to set up the third transmission link from the subnational transmitter to the commercial broadcast station. For this purpose a narrow frequency band is notched out of the voice frequency spectrum of the public warning message. The modulator provides tone keying of the incoming encrypted teletype signals for transmission in the notched t portion of the voice message spectrum. This transmission will be simulta ous with, and independent of, the alert and warning message transmission, except that the two signals will share the modulation power in the broadcast transmission. The same synchronization procedure will be required for this tone keyed channel as was employed for the frequency shift keyed channel between the primary transmitter and the subnational transmitter. The programmer at the NWC will send down a code group at the proper time that will cause the transmit KW7 at the subnational transmitter to synchronize all the receive KW7s at the commercial broadcast stations under its control. After eight seconds the synchronizing signal will be switched off and the channel to the commercial broadcast stations will be assumed to be established. The programmer will then send a code group down which will effect the change-over of the commercial broadcast station to the OCD operating mode. This will be followed by an authenticating message to the owner of the commercial station that will be printed on the page printer.

3.3 TIME DELAYS IN THE SYSTEM

The operation of the system configuration shown in Figure 3-1 was analyzed to determine the extent of the delay that might be expected in transmission of a warning to the public. This delay is the total of all the sequential delays inherent in the various components of the system. Figure 3-2 represents a time chart of the sequential functions that must be performed in the network with time zero equal to the completion of the decision to warn and the initiation by the operator of the warning sequence. This chart illustrates the delays that could be expected for each of the two different network options. The upper chart illustrates the delay that would be expected for that part of the public that has low-frequency receivers or whose home receiver is tuned to a commercial broadcast transmitter that receives its control signals directly from either one of the primary transmitters at Fort Collins or in Northern Virginia. The lower chart indicates the delay that would be expected for the part of the public in the large metropolitan areas that depends, for the transmission of the warning, on a commercial broadcast station that receives its control signals from a subnational transmitter. Numbers above the line are identifiers that refer to the functions listed below the charts. The position of the function number on the time scale indicates the time when that function is completed. The position of the last number in the sequence, therefore, indicates the total time lost in the control network until the audible alert signal is available to the public.



ZERO TIME STARTS UPON COMPLETION OF DECISION TO WARN
NUMBERS ABOVE THE LINES IDENTIFY THE TIME OF COMPLETION OF THE FUNCTIONS LISTED BELOW
NUMBERS BELOW THE LINES INDICATE THE TIME IN SECONDS

1. TRANSMISSION OF 2-5 LETTER CODE GROUPS (CONDITIONING CODE)
2. TRANSMISSION OF 3 LETTER CODE GROUP (SEIZE AND RETUNE 60 KC TRANSMITTERS)
3. TRANSMISSION OF 3 LETTER CODE GROUP (INHIBIT CODE)
4. RETUNE WWVB, SEND HARD COPY TO NBS
5. RETURN READY-TO-GO SIGNAL TO NORAD
6. CYCLE KW7'S AT SUBNATIONAL STATIONS
7. CONDITIONING CODE TO SUBNATIONAL STATIONS
8. PUT SUBNATIONAL STATIONS ON THE AIR
9. SELECT TAPE
10. CYCLE KW7'S AT BROADCAST STATIONS
11. CONDITIONING CODE TO BROADCAST STATIONS
12. RECEIVER TIME DELAY

Figure 3-2. Transmission Delays

3.3.1 Two Stage (Figure 3-2, Upper)

The first link in the network, from NORAD COC to the NBS transmitter at Fort Collins, Colorado, is a full period microwave link. The KW7s on this link are synchronized at intervals and maintained in continuous synchronism so that no time delay is anticipated in transmitting a message to WWVB. The first part of the warning message will be a conditioning code to ready the teletype stunt box at NBS to receive instructions. This conditioning code will consist of a two-to-five-letter code group. A nominal time to complete this operation was set at one second, though the actual time would probably be less. The second part of the message is a three-letter code group which causes the stunt box to initiate seizure and retuning of the NBS transmitter. This is followed by a third code group (Inhibit Code) that prevents the stunt box from responding to any characters except a particular code which will be used to reset the stunt box to receive further instructions. Functions 2 and 3, just described, together were estimated to account for a one-second delay.

The fourth function, retuning WWVB plus the necessary switching of modulators and other hardware, is estimated to introduce an additional eight seconds maximum delay. These eight seconds will be utilized to send a short hard copy verification of the warning to NBS operators. At the conclusion of the hardware switching, a ready-to-go signal will be received at NORAD COC via the 61.15 kHz monitor receiver. This function is nearly instantaneous so no delay is charged to it. Upon receipt of the ready-to-go signal, function six is initiated. This function introduces an eight-second delay during which all of the KW7s at the subnational transmitters are cycled and brought into synchronism with the KW7 at NBS. Following synchronization of the KW7s, function seven is initiated. This consists of sending a conditioning code from NORAD COC down to the stunt boxes at the eight subnational transmitters. Allowing time to get all eight stunt boxes in the ready condition imposes a two-second delay. Function eight activating the transmitters, introduces only a two-second delay as the transmitters are standing by and do not require a warm-up period or extensive switching or retuning. Function nine introduces a one-second delay when a code group causes stunt box selection and switching of a tape drive unit to deliver the appropriate audio message (warning, test, or other) to the public.

The above delays are inherent in the control network. In addition, there will be a delay at the low-frequency home receiver (probably 10 seconds) for integration of the demuting signal to inhibit false activation on noise. Adding these two types of delays, the total system delay from the time of activation of the system at NORAD COC, until an audible alert signal is present in the low-frequency home receivers, is 33 seconds.

3.3.2 Three Stage (Figure 3-2, Lower)

The three-stage configuration is the same as the two-stage configuration except that an additional operation is added. This consists of including some number

of commerical broadcast stations in the warning network to deliver the warning message to the public in the large metropolitan areas. The first nine functions are the same as for the two-stage system. However, simultaneously with the broadcasting of the warning message, the subnational transmitters will also transmit coded signals to the commercial broadcast transmitters to initiate transmission of the warning message to that part of the public that has receivers tuned to the broadcast frequencies.

This additional operation will introduce more time delays in the sequence of operations required to deliver the warning message to the home receivers in the large metropolitan areas. Function ten introduces an eight-second delay necessary to synchronize the KW7s at the broadcast stations with the KW7 at the subnational transmitter to which they are tuned. Function eleven is a two-to-five-letter conditioning code that must be sent from NORAD COC down to the commercial stations to ready the stunt boxes (as in function seven). It is estimated that two seconds delay is required to accomplish this function. These two added functions impose an additional ten-second delay. This delay plus the delays for functions one through nine and the ten-second delay at the receiver make a total delay for the three-stage configuration of 43 seconds.

4.0 AUTOMATIC DIGITAL NETWORK (AUTODIN) CONFIGURATION

The heart of the previously discussed Radio Warning System configuration is the low-frequency station WWVB at Fort Collins, Colorado, and its east coast counterpart. The sole function of these stations is to activate the warning system. It is proposed that this function could be performed in a much more efficient manner, from a control viewpoint, by the use of a redundant landline system. In this section the feasibility of utilizing the AUTOmatic DIgital Network (AUTODIN)[1] for this purpose will be examined. Since AUTODIN is an existing, operating system, no attempt will be made to describe the inner workings of the system, but rather more attention will be paid to the terminal facilities available.

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1. F. B. Falknor, "AUTODIN-Technical Control Facility," Western Union Technical Review, 17(4), October 1963, pp. 150 ff. H. A. Janssan, "AUTODIN-System Description, Part I-Network and Subscriber Terminals," Western Union Technical Review, 18(1), January 1964, pp. 38 ff. H. A. Janssan, "AUTODIN-System Description, Part II-Circuit and Message Switching Centers," Western Union Technical Review, 18(2), April 1964, pp. 68 ff. R. L. Snyder, "Message Protection in The AUTODIN Message Switch," Western Union Technical Review, 18(3), July 1964, pp. 118 ff. See also: AUTOMATIC DIGITAL NETWORK (AUTODIN) OPERATING PROCEDURES, JANAP 128, 1 July 1964 (as amended).

AUTODIN is an automatic switching network operated by the Defense Communications Agency consisting of nine switching centers and interconnecting trunk lines. The network is designed to provide high speed, flexible communications for Department of Defense and related users. It can be used for Radio Warning System control if tributary lines are added from the switching centers to the National Warning Centers, subnational warning transmitters, and possibly the local broadcast facilities. The advantages of AUTODIN are manifold, but for the particular application of controlling the Radio Warning System, the concern is mainly with speed, physical security, and reliability.

AUTODIN Speed. The timeliness of warning is, of course, of paramount importance in the warning process; and AUTODIN's speed fits well within the time constraints of warning. AUTODIN is designed to deliver high priority messages to any recipient within six seconds.[1]

AUTODIN Security. Another requirement of any warning system is that it should not be subject to seizure, either for overt or covert purposes. The AUTODIN switching centers are secure facilities and therefore are not accessible to unauthorized personnel. Also, traffic between the centers is encrypted, thereby making it virtually impossible to seize lines between centers. While it is true that unclassified lines to terminals are accessible at the common carrier tests boards, only a small segment of the system could be compromised.

The critical links in the system are the ones from the National Warning Centers to the Switching Centers. If these were seized, a national false alert or no alert situation could arise. One solution is, of course, to use encrypted messages for the entire system. This problem is discussed in Section 6.0. Another solution would require modification of the computer programs in the switching centers to the extent that they would process encrypted messages from the National Warning Centers and transmit them in the clear to the other elements of the Radio Warning System. The latter is probably not feasible because DCA would most likely not agree to special purpose modifications to the Switching Center computer programs.

1. Source: Mr. J. R. Miller of the Defense Communications Agency, in a personal communication on 29 June 1965, indicated that the normal round-trip time for Flash messages from the Pentagon to Hawaii and back to the Pentagon is three to four seconds. This includes two non-AUTODIN relays in Hawaii.

AUTODIN Reliability. AUTODIN is an extremely reliable system. This is due mainly to three facts. The first is that its lines are common carrier lines that are maintained on a continuous basis. It is also able to seize lines from the AUTOmatic VOice Network (AUTOVON) in case of overload, etc. The second contributing factor is that AUTODIN is a distributed network, i.e., every switching center is connected directly to every other switching center. Thus, redundant routing is possible in case of line outage or switching center failure. The third reason is that messages sent between switching centers (and certain other terminals, see below) are confirmed and acknowledged. This provides protection against noise on the lines and guarantees receipt of the message.

4.1 AUTODIN SYSTEM OPERATION

When completed, AUTODIN will have nine solid-state switching centers located at:

1. Andrews AFB, near Washington, D. C.
2. Gentile AFS, near Dayton, Ohio
3. Tinker AFB, Midwest City, Oklahoma
4. McClellan AFB, Sacramento, California
5. Norton AFB, San Bernardino, California
6. Ft. Detrick, near Hagerstown, Maryland
7. Albany, Georgia
8. Ft. Leavenworth, Kansas
9. Hancock Field, near Syracuse, New York

See Figure 3-3.

The first five are presently in operation and the other four will be in the system by May, 1966. Centers are interconnected by major trunklines, each center having direct connection with every other center. Each center processes inputs from and outputs to outstations connected directly to it, as well as traffic to and from other switching centers. Inputs and outputs are processed by either message switching equipment, circuit switching equipment, or a combination of both to interchange information among message switched and circuit switched outstations. Present capacity of the switching centers is 50 message switching lines and 50 circuit switching lines with the exception of the Tinker AFB Center, which has 100 message-switching lines and 50 circuit-switching lines. The expansion plan calls for an increase in switching capacity at existing centers so that the system will handle 2000 outstations by 1966.

The input terminals of the message switching equipment can accept messages in the format of most teletypewriter and business machine codes. These codes are converted into common-language code for transmission between switching centers. The output terminals convert the messages in the common-language code back into

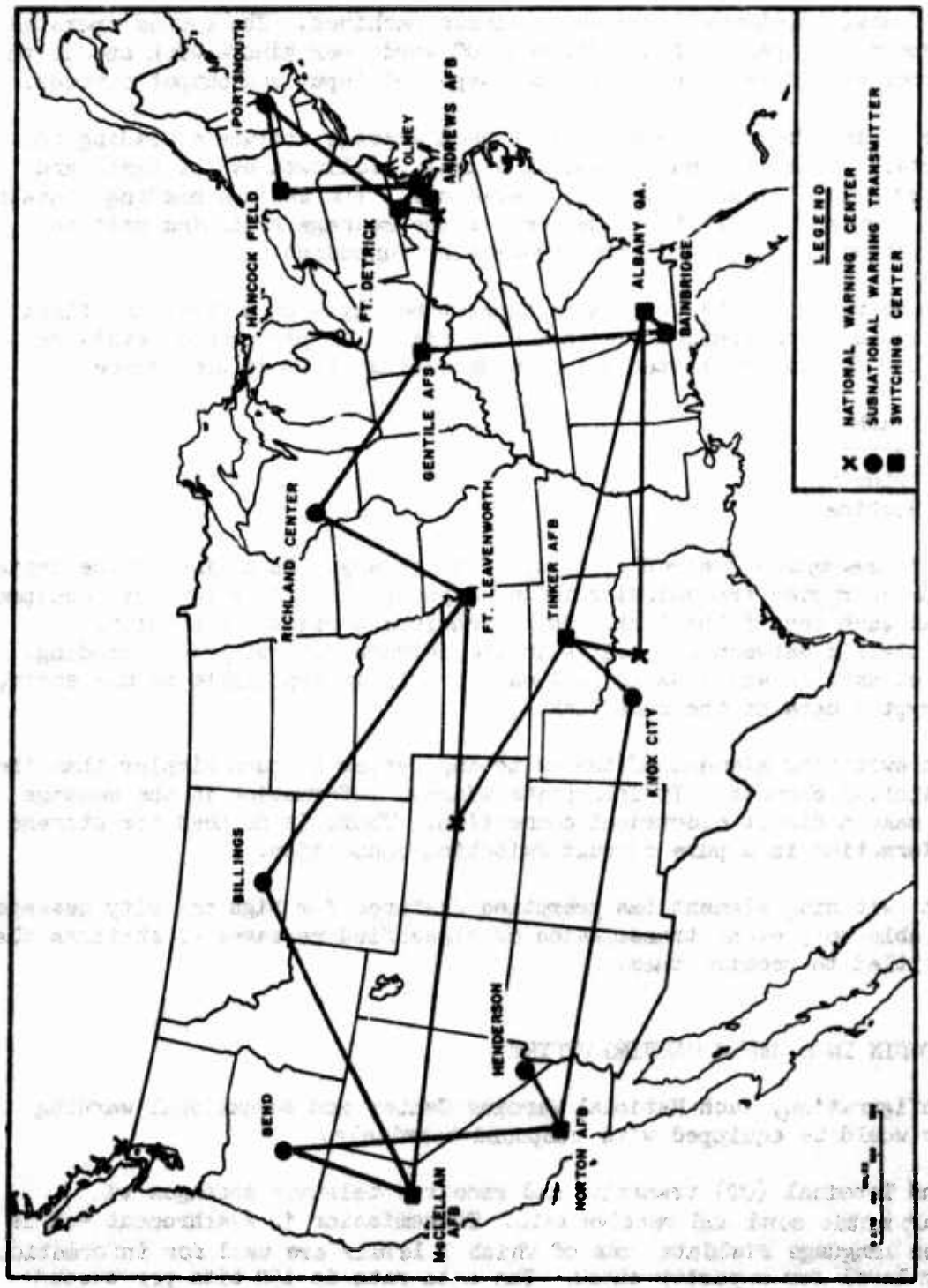


Figure 3-3. AUTODIN Control Network Showing Connections with National Warning Centers and Subnational Transmitters (AUTODIN Switching Center connections not shown.)

the codes of most teletypewriters and business machines. The system operates with teletypewriter speeds of 60, 75, and 100 words per minute with speeds to 2,400 bits per second available for other types of input and output devices.

The message format employed requires that each message include a heading containing certain predetermined procedural signals, followed by the text, and terminated by specific end of message characters. The message heading contains the required control information that causes the message switching unit to perform switching, routing, and other processing functions.

The message switching units queue and dispatch messages on a first in, first out basis within predetermined precedence levels. The precedence levels recognized by the system are listed below in decending order of precedence.

1. Flash
2. Urgent
3. Priority
4. Routine

Flash traffic preempts a desired circuit, if necessary. Each link of the system provides for encrypted transmission through synchronized cryptographic equipment installed at each end of the link. This technique permits the handling of classified traffic between any points in the network without prior encoding. Encrypting of data on any link is optional, but it is impossible to mix encrypted and nonencrypted data on the same link.

The circuit switching element of the switching center is much simpler than the message switching element. It interprets address information in the message heading to make a direct electrical connection. There is no need for storage of message information in a pure circuit switching connection.

The circuit switching element has premption features for high priority messages. It is also able to prevent transmission of classified messages to stations that are not entitled to receive them.

4.2 AUTODIN IN A RADIO WARNING SYSTEM

In this configuration, each National Warning Center and subnational warning transmitter would be equipped with compound terminals.

The Compound Terminal (CT) transmits and receives teletype messages via modified automatic send and receive sets. Transmission is synchronous and in 8-bit common language Fieldata code of which 7 levels are used for information and the 8th level for a parity check. The data rate is 150 bits per second requiring twice the band width of a standard teletype channel.

Data are transmitted in 80-character groups, preceded and followed by two unique block control characters called framing characters, thus making the unit of transmission (line block) 84 characters. The first three framing characters refer to the type of block (first block of message, intermediate block of message, or last block of message) and type of message being transmitted. The last framing character, used solely to verify the accuracy of the transmitted block is called the block parity character. It is so configured that even longitudinal parity is maintained for all 8 bits of the characters in the line block. The first framing character is excluded from the longitudinal check.

Each data block must be correctly acknowledged before the next block is transmitted. If an error is indicated by the reply (ER code), the block is retransmitted. If no answer is received, a repeat code (REP) is generated by the transmitter to recall the last reply sent by the receiver. Alternate acknowledgement codes (ACK-1 and ACK-2), are used to uniquely identify to which of the two consecutively transmitted line blocks the acknowledgement pertains. If the wrong acknowledge is received in response, a repeat code to the block is repeated; if the correct acknowledge code is received the next block is transmitted.

Other unique control codes to halt transmission (WBT) or reject a message (RM) may be generated by the receiver in reply to a line block or REP. Transmission of a discard message signal (DM) by the transmitting station instructs the receiver to ignore the incomplete message and sets up both terminals to process a new message.

Note that the line block format is chosen to coincide with the 80-character IBM card. Teletype messages are blocked similarly into line blocks by the control section of CT. In the special case of the end of message block, where the last character of the message may appear anywhere in the block, the block is filled with a special throw away character called ignore (I).

Core storage of two 84-character blocks is provided for both the transmit and receive side of the terminal to permit blocks to be retransmitted automatically when errored and to overlap line transmission with device input/output. Code Conversion is included in the terminal for Teletype to/from Fieldata, and Hollerith to/from Fieldata conversions.

The CT operates either as a message switch or circuit switch terminal. For circuit switching use, the terminal is equipped with additional facilities required for supervisory signaling with the CSU.

The local broadcast facilities will be equipped with both their own LF receiver, and/or an AUTODIN Teletype Terminal looped with other facilities for authentication purposes, and as a back up for manual initiation of warning transmissions if, for some reason, the LF link from the subnational transmitter is inoperative. The Teletype Terminal transmits and receives messages in the 5-channel Baudot code. Transmission is by standard telegraph means. Characters are sent asynchronously in bit serial form. Start and stop bits indicate the start and end of each character.

The terminals may operate either as one-way (simplex) or full-duplex MSU terminals. No provisions, however, are included for error detection and correction.

4.3 SYSTEM OPERATION

The low-frequency (LF) subnational and broadcast transmitters will retain their present function of providing the radio link to the public, but may or may not be used to transmit control signals to commercial broadcast stations. Figure 3-3 shows the general scheme of operation. The three national initiation points at Colorado Springs, Colorado; Denton, Texas; and Washington, D. C. are each connected to AUTODIN by landline links to at least two alternate switching centers. Alternate links are provided to add redundancy and increase the reliability and survivability of the system. All traffic on these lines is encrypted to insure the same level of security as that afforded by the AUTODIN circuits. Drops from AUTODIN will be furnished to the subnational warning transmitters in their proposed locations, (see Section 4.4). The local broadcast facilities may be provided with an AUTODIN drop or they may depend on the subnationals for activation, or both. This point will be discussed further below. Note that each of the National Warning Centers has full and complete access to the system at all times, as well as having communication with each other through AUTODIN as well as NAWAS.

Note also that any of the National Warning Centers can activate the system. However, since activation should be centralized and controlled, only one National Warning Center at a time will be designated as the National Warning Center. This can be accomplished, however, by SOP, thus minimizing the need for special system interlocks.

When the system is activated for any reason, two Flash messages will be initiated at the National Warning Center. One will be to the local broadcast facilities indicating that OCD has assumed control of their facility and indicating the reason. The reason must be included in order for them to initiate manual activation in the case of failure of the LF link as noted above. The second message must contain the time the message was initiated from the National Warning Center in order that the LF transmitters can synchronize their transmissions in case of conflicting frequency allocations causing zones of interference. (See Section 6.4 below.)

4.4 UTILIZATION OF THE SUBNATIONAL TRANSMITTERS

There is essentially only one problem inherent in the use of the subnational transmitters for control purposes in this configuration. This is the fact that the local facilities are utilized for the simple reason that the low-frequency noise level in the areas covered by the local facilities is high. This

certainly implies that the radio link between the subnational transmitters and the local facilities is not as reliable as a landline link. There is no reason, if a suitable means can be found for sending both control and warning messages from the subnational facilities, that the subnational transmitters could not be employed as back-up for a primary AUTODIN control network.

4.5 POSSIBLE CONFIGURATIONS

4.5.1 General Configuration

In any AUTODIN Radio Warning System configuration there is a certain degree of commonality which can be established. The subnational transmitters and certain large metropolitan areas are equipped with compound terminals to insure receipt of the warning. The rest of the local broadcast facilities are looped with ordinary teletype terminals. The subnational transmitters are always activated by AUTODIN; the local broadcast facilities are not necessarily configured this way. The discussions on speed, reliability and security in 4.0 above apply to all configurations. The main differences in applying AUTODIN to the Radio Warning System is in the configuration of the local facilities. It is here that we have the options of hardcopy output, automatic takeover of the facility by AUTODIN via a stunt box, and whether or not the subnational transmitters should be utilized for seizure of the facility. It is to these three topics that we now address ourselves.

4.5.2 Hardcopy output

AUTODIN is essentially a teletype system and thus provides a hardcopy capability. It provides the local facility with the authentication desired and, more importantly, provides it with the information necessary to initiate transmission of warning messages if all else fails. By utilizing the teletype capability of AUTODIN in this fashion, the system is provided with a comparatively slow, but highly reliable manual backup capability. It can be argued that the hardcopy drop should be at some other location than the local broadcast facility, say the EOC, but here there would, of necessity, have to be provided another communications link, literally a hot-line, to the broadcast facility. It is, therefore, recommended that hardcopy be provided, and the most logical place to provide it would be the local broadcast facility where immediate action can be taken.

4.5.3 The Stuntbox

By utilizing a teletype stunt box, it is possible, by the use of certain code words (or plain language, for that matter), to seize broadcasting facilities for warning purposes. This versatile device can be employed in any remote control situation that can be controlled by switch closure. There are at least two ways it could be employed in the AUTODIN Radio Warning System configuration depending on the degree of sophistication desired.

The lowest level of usage would be to have the stunt box, upon receipt of the proper message, simply seize the facility for warning purposes. This could be accomplished with or without the simultaneous production of hardcopy output.

At the other end of the spectrum of usage, the stunt box could be employed as a small switching center for a somewhat more sophisticated "logic device." This device would not only turn on the transmitter, but also monitor its performance. For instance, the following method of operation might be employed.

1. The alert and warning signal is received by the teletype drop and the stunt box. This signal is then fed into the "logic device". The signal would be repeated an optimal (to be determined) number of times before the "logic device" would seize the transmitter involved.

2. After the transmitter is seized, the stunt box would block the reception of any other message except the "clear" message. The "clear" message will stop all transmissions and essentially wait for further instructions.

3. When the transmission of the warning message has started a monitoring receiver will start to monitor the transmission. It will note the demuting signals, and the end of one full warning message transmission (mechanically timed) and if it is still in the receiving mode, it will signal a teletype transmitter to send a confirmation message that the warning has been disseminated to the controlling agency. This would provide positive confirmation that the warning had not only been received but also had been sent from that station.

4. As an ancillary function, of course, hard copy would be produced to function as in 4.5.2 above.

It should be noted that a new concept has been introduced at this point. With the normal teletype drop, no feedback information is provided the controlling agency; with the compound terminal, feedback information is limited to message receipt. With the above described stunt box/"logic device" setup, definite information concerning the status of transmission is provided. Therefore, with the stunt box and some additional hardware, it is possible to secure all the advantages of a compound terminal and more.

One further note, the stunt box/"logic device" hardware would be provided to the subnational transmitters and certain local facilities whose population coverage exceeds that of the least population coverage of any of the subnational transmitters. These selected local facilities would then be the "lead" station in loops with other local facilities. Thus, a reply back from a "lead" local facility would also indicate that the message had gotten into the loop successfully.

4.6 CONCLUSIONS AND RECOMMENDATIONS

There can be little doubt from the above discussion that AUTODIN can be satisfactorily employed as the control facility for the Radio Warning System. The exact configuration to be used, however, would necessarily be based on cost-effectiveness studies, propagation surveys, etc. It is evident, though, that AUTODIN provides the speed, security, and reliability necessary for such a control facility. It also provides for the necessary communications between the National Warning Centers.

It can be envisioned that the ideal utilization of AUTODIN would be along the lines indicated for the sophisticated stunt box logic with hardcopy output and subnational transmitter backup. In this fashion, redundancy is provided against station equipment failure (hardcopy output), AUTODIN failure (subnational transmitter backup), and subnational transmitter link failure (AUTODIN).

Another very desirable feature of AUTODIN is the fact that it exists and is in daily use.

5.0 LANDLINE - RADIO CONFIGURATION

This configuration is based upon use of the NBS transmitting station WWVB and a low quality leased wire line to disseminate the control signals from the national initiation points to the transmitters that broadcast the alert and warning message to the public.

Following is a brief description of how a control message is propagated through the control network from national initiation point to the transmitters that broadcast to the public. A more detailed explanation of the system operation is reserved for a later section.

An alert is initiated at the operator's console in the NWC. This action provides identical switch closures to a programmer on the WWVB radio channel and an encoder on the wire line (Figure 3-4). These two devices translate a switch closure into the selection of a stored control message for transmission to the subnational transmitters and the broadcast stations. The programmer has some additional message time sequencing and monitoring chores that must be performed incident to automatically converting WWVB to the OCD mode of operation.

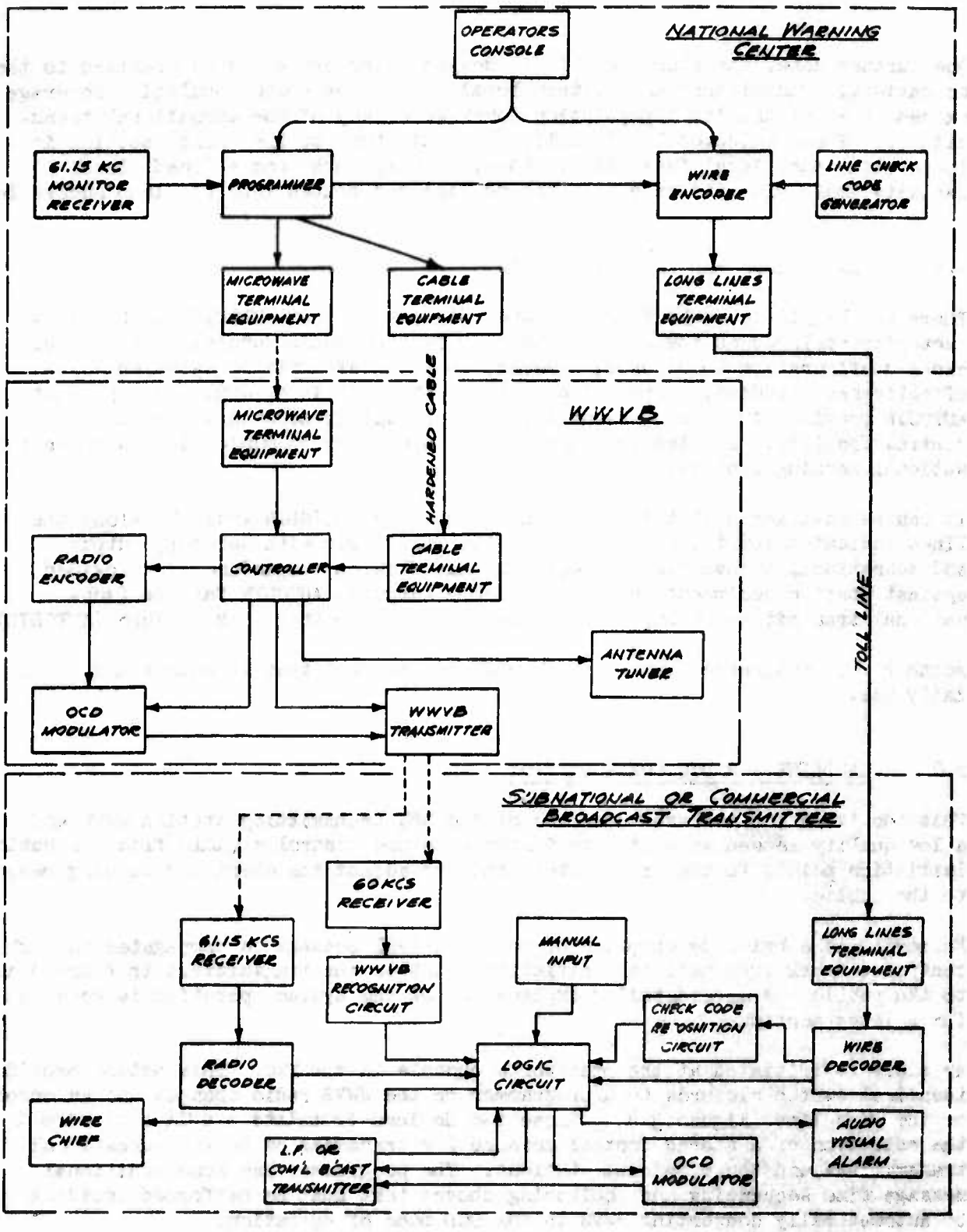


Figure 3-4. Landline - Radio Configuration

At the transmitter sites, the two incoming control messages are fed into logic circuits where they are identified, examined, to insure that they are identical, and checked for differences in time of arrival. Both channels are also inspected to determine whether they are in the standby or operate mode. On the basis of these checks the logic circuits determine which of the following situations exist: 1) a legitmate alert has been sent, 2) the system is being spoofed or is otherwise behaving abnormally, or 3) one or both of the channels is inoperative. In case of a real alert, the logic circuit activates the subnational or broadcast transmitter and supplies the modulator with a pre-recorded alert signal and warning message. In the case of a suspected spoof the logic circuit stores the control message, but does not act on it. Instead it sends an alarm to the agency responsible for that transmitter. This agency must determine through NAWAS or other means if an alert has been sent. If an alert was intended, the agency can insert an override into the logic circuit which will initiate the stored command. This manual intervention can only take place when the logic circuit check indicates a spoof.

5.1 FUNCTIONAL SUBSYSTEMS

Figure 3-4 is a block diagram of the configuration. Those blocks in the diagram whose functions are not obvious are described in the following paragraphs. Included in this group are:

Programmer
Radio Encoder
Wire Encoder
Line check code generator
Controller
Logic Circuit

5.1.1 Programmer (Figure 3-5)

The programmer has the function of translating one of several possible switch closures received from the operator's console into suitable signals for transmission to the NBS transmitter at Fort Collins, Colorado, via a microwave link and a redundant hardened cable link. The hold circuit converts a momentary switch closure into a dc voltage level at the input to the gate circuit and holds it there until it is accepted by the gate. The hold circuits for those functions which require the NBS transmitter to be switched over to 61.15 kHz (all but the "cancel" function) provide a switch closure to the start code generator. At the time a hold circuit is energized all other hold circuits are dumped to ensure that only one function generator is energized when the gates open. When triggered by a hold circuit the start code generator outputs a code group to the microwave terminal equipment for transmission to WWVB. If WWVB is already in the OCD mode, the 61.15 kHz monitor receiver will provide an

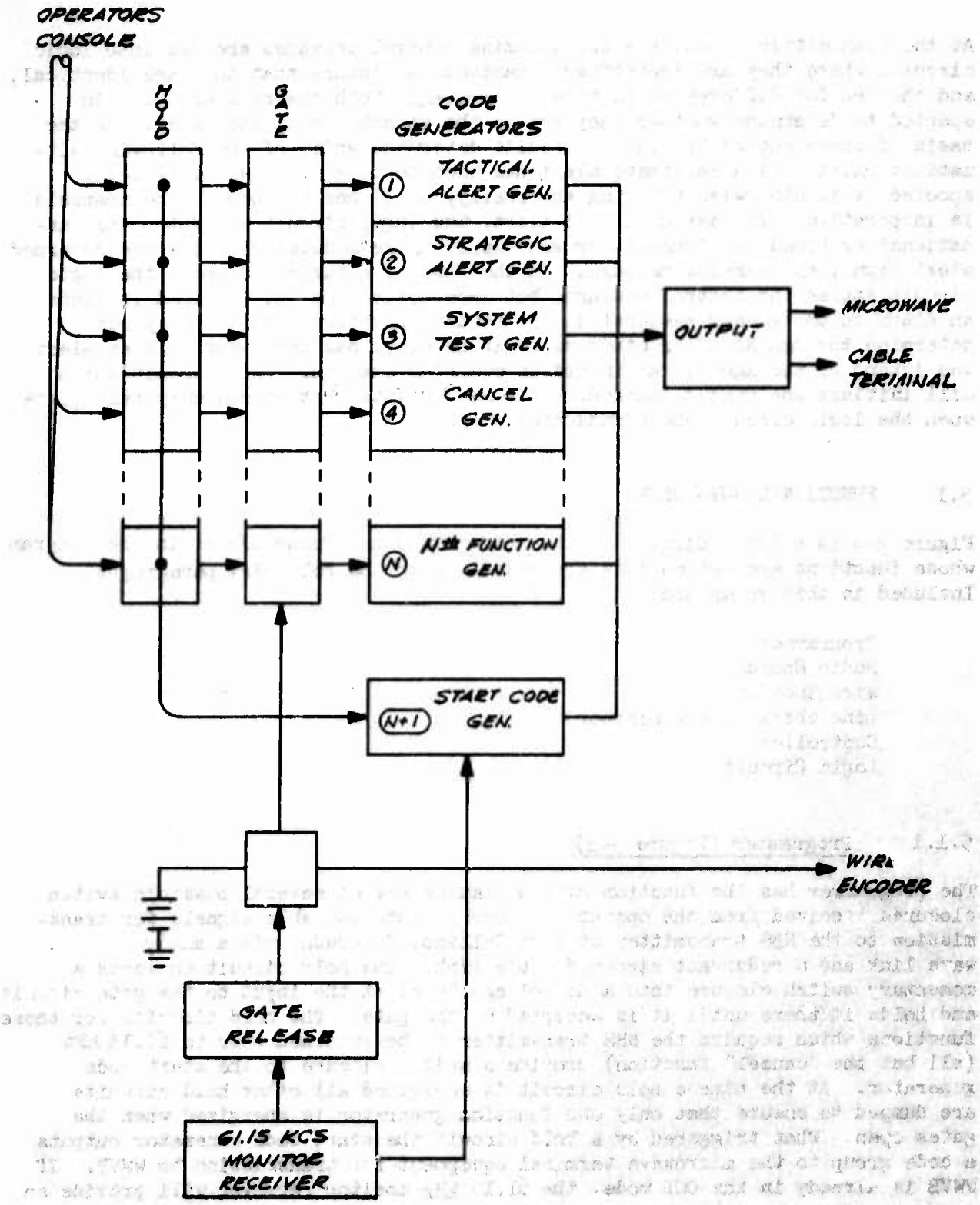


Figure 3-5. Programmer Block Diagram

"inhibit" switch closure to the start code generator. When WWVB has been switched to the OCD mode the 61.15 kHz monitor receiver will energize the gate release circuit and open all of the gates including the gate which furnishes a start signal to the wire encoder. This start signal is to ensure that the signals on the radio channel and the leased wire channel are in close time synchronism.

5.1.2 Wire Encoder (Figure 3-6)

The wire encoder has the function of translating one of a number of switch closures received from the operator's console into suitable signals for transmission to the ultimate transmitters via the toll wire channel. The hold circuits when activated provide a switch closure to a timer instead of to a start code generator. This timer provides an override to the gate release circuit. While it is desirable that the control signals propagate through the two channels of the control network in time synchronism, it is even more important that if one channel fails the other channel must transmit the control message with minimum delay. The timer is set to release the gates if the release signal is not received from the programmer within some nominal time, e.g., five seconds.

5.1.3 Line Check Code Generator (Figure 3.4)

In its simplest form the line check code generator provides a distinctive code to be transmitted down the wire channel from the national level. This code is transmitted at regular intervals, on the order of 2.5 or 5 seconds, and, by its presence, the logic circuits at each of the ultimate transmitters will know that the wire channel is operative. The line check code generator output is switched off line by the output gate in the wire encoder just prior to the transmission of a function code. When the transmission of the function code has been completed, the line check code generator output is switched back onto the line.

A better type of line checking would be one that provides a response back to the source for each line check code group that is sent down the line. This is closed loop checking and it has some of the advantages of fully automatic continuity checking. It is not the same, however, as only one transponder is used on the end of a partyline circuit, and continuity to each transmitter from the national level could not be assured. This type of closed loop checking is not essential in this configuration because the radio channel provides a redundant path that can be used to get the message through, even if the wire line becomes inoperative. It is not operationally necessary that the OCD operator even know if the wire line is in service. He is really only interested in knowing if the message gets through to each of the transmitters. It is one of the functions of the line check code generator to make it possible for each

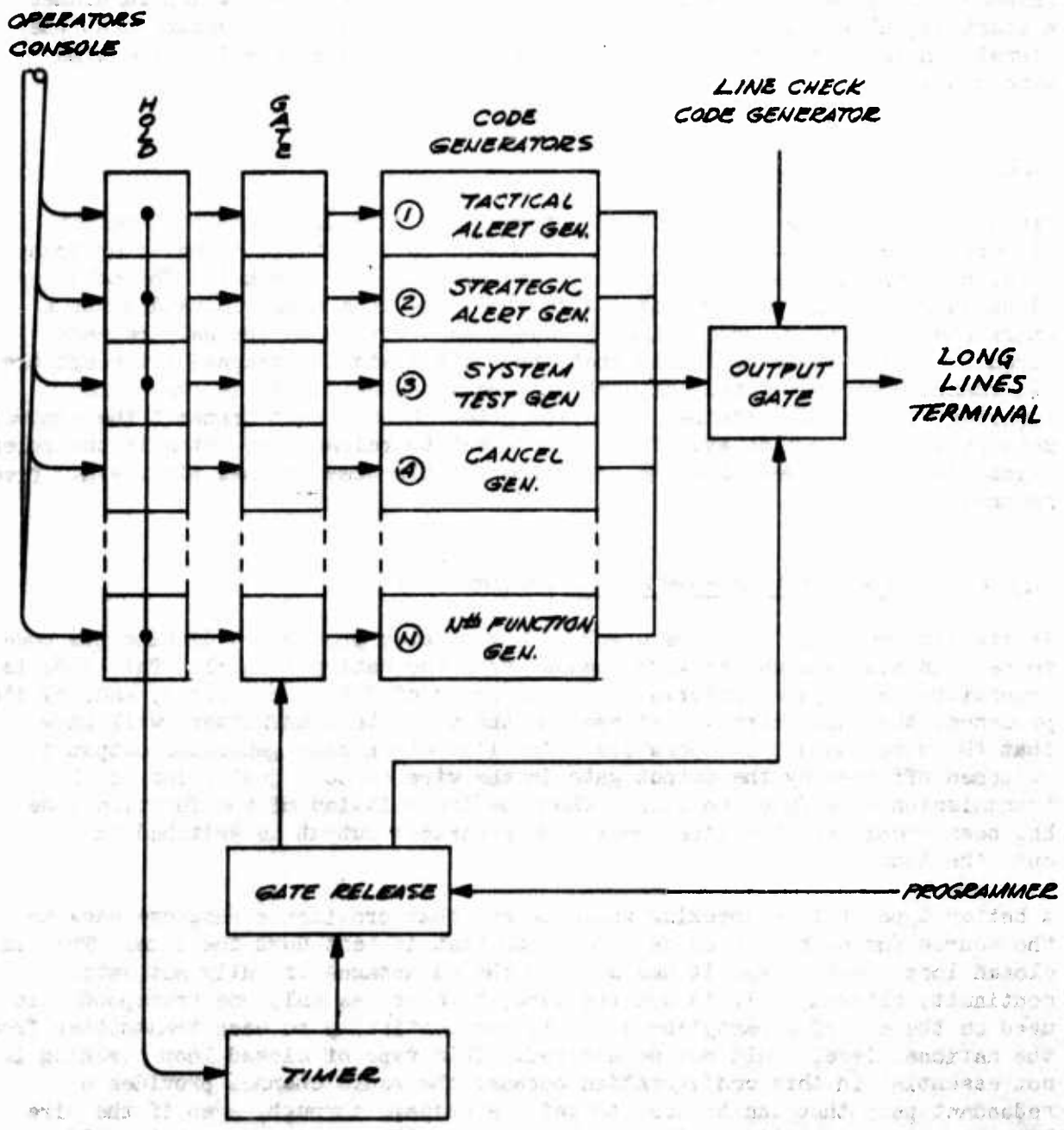


Figure 3-6. Wire Encoder Block Diagram

transmitter logic circuit to "know" if its wire channel has failed so that steps may be taken to get it back into service. Of course, sufficient redundancy must be provided in the wire facilities to insure a basically high level of reliability for the wire channel.

5.1.4 Controller (Figure 3-4)

The function of the controller is to translate coded commands sent down from the national initiation point into switch closures for accomplishing the switching and retuning functions necessary for changing WWVB to an OCD mode of operation. The control signals from the national initiation point come in by redundant paths to an OR circuit. The first command received will be for the purpose of effecting the switchover from 60 kHz to 61.15 kHz. When this has been completed the controller remains passive, transferring remaining control messages through the radio encoder for transmission to the lower echelon transmitters. The controller circuitry, however, continues to monitor the incoming circuits and can recognize and act upon the cancel function which terminates any of the other functions. Though not shown in Figure 3-4, the transmitter will be duplexed to increase reliability. Automatic switchover in case of transmitter failure is a requirement. The controller could be instrumented to handle this function in addition to the functions described above. The controller has no internal clock. All timing of code sequences is done by the programmer at the initiation point.

5.1.5 Radio Encoder (Figure 3-4)

The function of the radio encoder is to translate the coded control commands generated by the programmer at the initiation points into the proper form for input to the modulator. This encoder may be part of the modulation equipment rather than a separate entity. The two are shown separately in Figure 3-4 to indicate that some of the signal processing may be done at low power levels in the encoder prior to being input to the modulator.

5.1.6 Logic Circuit (Figure 3-7)

The logic circuit has the function of making the determination, based on the the data received from the two input channels, whether to broadcast an alert immediately, or introduce a delay while manual procedures are exercised to confirm the authenticity of the alert control signals. The critical part of the logic circuit is the decision circuit. This circuit is furnished with data from four different sources. These data must be processed in such a way that a decision can immediately be made to take some action, with the assurance that the action taken will be appropriate to the existing situation. The four information sources are the two decoders and the two recognition circuits. The decoders will translate the codes received on their particular communication

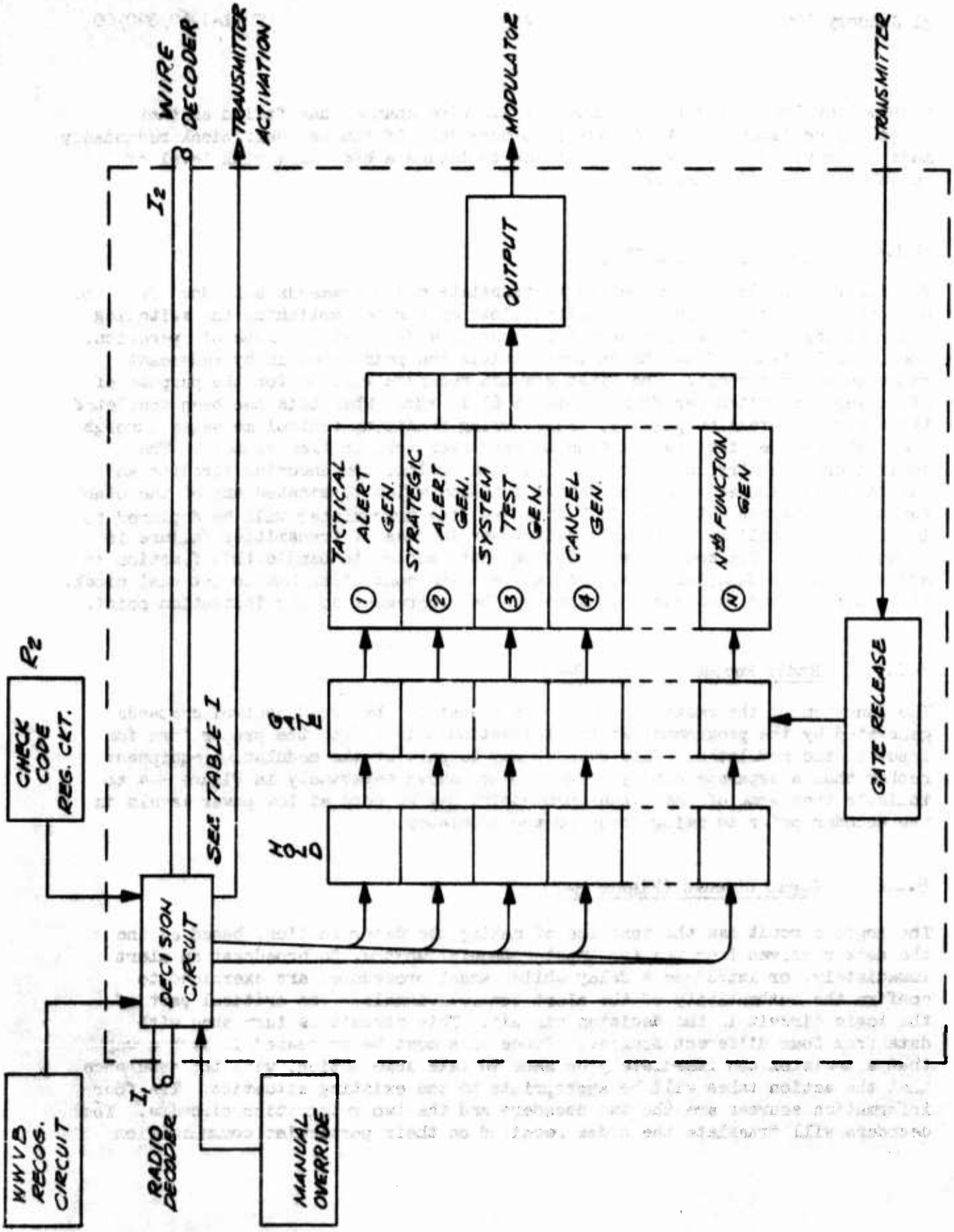


Figure 3-7. Logic Circuit Block Diagram

channels and translate them into one of several possible switch closures for presentation to the decision circuit. The decision circuit will determine if both received codes specify the same action. If so, a voltage is stored in the proper slot in the hold circuit. If the messages specify different actions, or the received time relationship between the two messages is not within specified limits, the decision circuit will not energize one of the hold slots, but will sound an alarm at the agency responsible for the transmitter. This causes a manual procedure to be implemented to determine if an alert was intended. If an alert was intended, a manual input is required to initiate the alert.

In addition to the above checks, the decision circuit continuously monitors the status of the system as evidenced by the inputs (or lack of inputs) from the four interfacing circuits.

As there are four input circuits, and each circuit can be in one of two states, there are 16 different situations which the decision circuit must recognize. These are shown in symbolic form in Table 3-1 along with the responses to each situation generated by the decision circuit. Although there are 16 possible states that could occur, the probabilities associated with the occurrences vary widely between states. In general, response "A" is associated with a high probability of a genuine alert control signal having been sent so the action of the decision circuit is to initiate an alert. Response "B" is associated with a low probability of an alert having been sent, but with a high probability of a spoof, either deliberate or inadvertant. The "B" response of the decision circuit is to initiate an alarm signal indicating a need for manual determination of the alert status, and to enable a manual override of the decision circuit logic if it is found that a genuine alert was intended. Response "C" is associated with a simple failure of either or both of the communication channels, there being no reason to suspect either a genuine alert or a spoof. Response "D" represents the action taken by the decision circuit to alert the responsible Wire Chief if the landline communication channel fails, whether the failure is associated with a legitimate alert, a spoof, or with a simple failure. Response "N" is really no response at all as it represents the system in its normal, nonoperative, selfchecking mode.

5.2 SYSTEM OPERATION

When the decision-to-warn is implemented by the system operator, parallel switch closures are sent from the operator's console to the programmer that interfaces with the radio channel, and to the wire encoder that interfaces with the wire channel.

Table 3-1. Symbolic Representation of Decision Circuit Functions

1.	$I_1 \times I_2 \times \bar{R}_1 \times \bar{R}_2$	A	
2.	$I_1 \times \bar{I}_2 \times \bar{R}_1 \times \bar{R}_2$	A, D	
3.	$\bar{I}_1 \times I_2 \times \bar{R}_1 \times \bar{R}_2$	A	
4.	$\bar{I}_1 \times I_2 \times R_1 \times \bar{R}_2$	B	
5.	$I_1 \times \bar{I}_2 \times \bar{R}_1 \times R_2$	B	
6.	$\bar{I}_1 \times I_2 \times R_1 \times R_2$	B, D	
7.	$I_1 \times \bar{I}_2 \times R_1 \times R_2$	B	
8.	$I_1 \times I_2 \times \bar{R}_1 \times R_2$	B, D	
9.	$I_1 \times I_2 \times R_1 \times \bar{R}_2$	B	
10.	$I_1 \times I_2 \times R_1 \times R_2$	B, D	
11.	$I_1 \times \bar{I}_2 \times R_1 \times \bar{R}_2$	B, D	
12.	$\bar{I}_1 \times I_2 \times \bar{R}_1 \times R_2$	B, D	
13.	$\bar{I}_1 \times \bar{I}_2 \times \bar{R}_1 \times R_2$	C	
14.	$\bar{I}_1 \times \bar{I}_2 \times R_1 \times \bar{R}_2$	C, D	
15.	$\bar{I}_1 \times \bar{I}_2 \times \bar{R}_1 \times \bar{R}_2$	C, D	
16.	$\bar{I}_1 \times \bar{I}_2 \times R_1 \times R_2$	N	

Legend

I_1	Control signal in channel #1 (radio)
I_2	Control signal in channel #2 (landline)
R_1	Channel #1 in NBS mode (radio)
R_2	Channel #2 in standby mode (landline)

A	Valid command, will initiate alert
B	Probable spoof, inhibit alert initiation
C	Either one or both channels inoperative
D	Landline inoperative, notify wire chief
N	Normal operation, both channels operative

5.2.1 Radio Channel

The radio channel is based upon the use of the NBS, WWVB, 60 kHz radio transmitter at Fort Collins, Colorado. Upon receipt of a switch closure, the programmer sends a start code group to the controller at Fort Collins that initiates the changeover of the NBS transmitter from operation in the NBS mode to operation in the OCD mode.

This code is sent by redundant paths to the controller, which has an internal OR gate. One path is via microwave link. The other path is via hardened cable and its associated terminal equipment. When the controller receives the control signal from the programmer on either input channel, it provides switch closures to the transmitter, modulator, and antenna tuner that initiate the changeover to the OCD configuration. This includes changing the transmitter carrier frequency from 60 kHz to 61.15 kHz, retuning the antenna, and switching modulators.

When this changeover is completed, the transmitter begins radiating carrier power only at a frequency of 61.15 kHz. At the National Warning Center, the monitor receiver that is tuned to this frequency provides an input signal to the programmer that initiates the second output, i.e., the tactical alert control message. The radio encoder converts the control message to a form which is compatible with the modulator and is optimum for the bandwidth and available power of the NBS 61.15 kHz radio channel. This message is transmitted by the NBS transmitter and received at each of the transmitter sites that broadcast to the public where it is decoded and fed into the logic circuit.

5.2.2 Wire Channel

The wire channel is based upon a narrow-band (15 Hz), leased-wire circuit with sufficient built-in redundancy to provide a high degree of reliability. It has target-avoidance routing to enhance its physical security and survivability. When the line is not in operational use, the line check code generator originates and sends down to all of the lower echelon transmitters a special code group that is repeated at regular intervals, e.g., five seconds. Recognition circuits accept this code group as an indication that the line is functioning properly. When a ten-second period in which no code group is received occurs, a "line out" alarm is sounded and the internal logic of the logic circuit undergoes a change. This line checking is important to the functioning of the overall system, as will be seen later.

When the operator's console furnishes a switch closure to the wire encoder, the line check code generator is by-passed until the code group designated by the switch closure can be generated and sent down the wire line to the controller at the public broadcast transmitter. The wire encoder has internal logic similar to that of the programmer in that it must interpret and translate the same switch closures. The code required for the wire line will probably be different than the code required for the radio channel.

The long lines terminal equipment represents the interface of OCD equipment with the leased line and will be considered as part of the line. At the public broadcast transmitter the wire decoder interprets the wire transmission and feeds the resultant control message to the logic circuit. This could be in the form of a code group to be interpreted by the logic circuit. An alternate method would be to have the wire decoder convert a code group to the one of several switch closures that corresponds to the switch closure that was originally input to the wire encoder at the National Warning Center.

5.2.3 Logic Circuit

At the heart of the control network are the logic circuits at each of the public broadcast transmitter sites. The logic circuit is the device that receives the control signal from two different channels, checks their authenticity and decides whether to initiate the warning broadcast or sound an alarm calling for human intervention in cases where the probability is high that the received alert control message is false. The logic circuit constantly monitors both incoming channels. The 60 kHz monitor receiver is tuned to WWVB at all times and furnishes an audio input to a WWVB recognition circuit which determines whether WWVB is operating. This information is supplied to the logic circuit. The logic circuit also continuously monitors the wire line inputs. It has recognition circuitry which accepts the codes generated by the line check code generator and from the presence or absence of these codes determines whether the wire line is operable.

With this basic information on the conditions of the input channels being maintained continuously, the logic device is in a position to make certain logical decisions about the authenticity of the incoming control messages. It will implement these decisions by either automatically initiating the warning broadcast to the public or asking for a human decision to be made whether to proceed with the alert.

There are several situations with which the logic circuit could be confronted. These will be discussed individually below with the reaction of the logic circuit to these situations explained in each case.

Two Command Case

The most usual situation that could be expected would be an alert initiated with both communication channels functioning correctly. An operational minimum reliability[1] of 0.999, or better, will be specified for each communication channel independently of the other.

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1. Calculations based on data received from David Andrews, National Bureau of Standards, Boulder, Colorado, indicate an operating reliability for WWVB of 0.9755. This was calculated from system outage records compiled for the

The signals coming into the logic circuit from the two channels will be accepted as legitimate alert control signals, provided the following conditions are met:

1. The 60 kHz monitor input to the logic circuit was existing within some nominal period of time prior to receipt of the command on the radio channel (probably 10 seconds maximum).

2. The 60 kHz monitor input to the logic circuit does not exist after the 61.15 kHz command code is first detected.

3. The line check code on the wire channel was existing within some nominal period of time prior to receipt of the command on the wire channel (probably 10 seconds maximum).

4. The line check code on the wire channel does not exist after the command code is first detected.

The logic being instrumented here is that, with both channels known to be working properly immediately prior to receiption of the commands, the probability that both channels could be simultaneously seized by unauthorized persons is extremely low. The radio transmitter is located on a government reservation with, presumably, adequate physical security. Any attempt to fake the signal with another transmitter at 61.15 kHz will be detected because WWVB will still be broadcasting at 60 kHz. If the logic circuit detects WWVB simultaneously with a seemingly correct command message at 61.15 kHz it will not initiate an alert, but instead, will sound an alarm calling attention to the enomaly.

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two-month period, 19 February to 21 April, 1965. Data from this period were chosen for the calculations as they represent the latest data available, and they appear to be free of the discontinuities in failure rate and downtime which characterize earlier data. If the assumption is made that the majority of the outages were caused by failure of the transmitter and/or the primary power supply (according to Andrews the principal cause of downtime has been the failure of commercial power and the lack of an auxiliary power supply), then the possibility exists of meeting the desired reliability standard of 0.999 or better. This could be accomplished by providing 100% redundancy in transmitting equipment and primary power supply. It can be shown, for example, that with a basic single transmitter reliability of 0.9755, and with the assumptions mentioned, the reliability can be increased to a theoretical reliability of 0.9994 by providing a spare transmitter and an auxiliary power supply with automatic switchover for both in case of failure, e.g., $R = 1 - (1-0.9755)^2 = 0.9994$. On the other hand, if an appreciable percent of the downtime was caused by failure of the antenna system due to lightning strikes, high winds, ice loading or other natural phenomena, this high level of reliability may not be attainable at reasonable cost.

The wire channel will be made reasonably secure with sealed terminals and will have no appearances on any unauthorized terminals. It is, of course, possible that a disloyal employee of the common carrier furnishing the leased wire service could seize the channel and initiate a false command. He would, however, have to interrupt the line check code sequence at the time he sent down the false control message or the logic circuit would sense the presence of the two simultaneous signals and sound an alarm. This could probably be managed without too much difficulty by someone with access to the telephone company's records and facilities, but the radio channel has to be taken care of at the same time. The time interrelationship of the alert signals in the two channels could be made critical so that very precise timing would be required for a successful spoofing of both channels simultaneously. This rules out an enemy submarine or trawler being able to spoof the system. The submarine could put out a false alarm on the radio channel at 61.15 kHz, but he could not stop WWVB from broadcasting on 60 kHz without some help from a sabotage team on shore. The timing would have to be very exact because WWVB must cease broadcasting at 60 kHz and the command signal be received on 61.15 kHz within 10 seconds, or the logic circuit would sound an alarm. Even if this could be accomplished and the radio channel could be seized, there is still the wire channel and its complications in timing that must be somehow coordinated with the take-over of the radio channel. The principal advantage of the two-channel concept for security is that unauthorized take-over of the two channels requires a precision of timing that is almost impossible to achieve.

Single Command Case

There is a finite, though small, probability that one of the channels will be inoperative when an alert is being inititated. Under these circumstances the logic circuit will make use of different criteria to determine the authenticity of a command. If the logic circuit receives a proper command signal on only one channel, i.e., the check signal disappears in the proper time relationship to the reception of a legitimate command, then it checks the second channel to determine whether it is operative. If it is inoperative this will be accepted as evidence that a command signal would have been sent over this channel had it been operating and the controller will initiate the alert and warning.
If, on the other hand, the channel is operative and a matching command signal was not received, this will be taken as evidence of an attempt to spoof the system. An alarm will be sounded at the cognizant Emergency Operations Center or other civil defense installation which, being manned on a 24-hour basis, can accept responsibility for monitoring the operation of an alert and warning transmitter. The responsible official at the Emergency Operations Center will be alerted by the logic circuit via an audio-visual signaling device at his location. Upon receipt of the audio-visual signal, the official will follow prescribed operating procedures to determine if a true alert and warning was intended. Obtaining this information can include making inquiries to the proper authorities through use of NAWAS or such other communication networks

as may be prescribed or available. Under the circumstances described the probability is small that a true alert and warning was intended, so the resulting delay is considered acceptable. If the responsible official determines, however, that a true alert and warning was intended, he can initiate the alert manually by means of a push button at his location. If he is situated physically close to the transmitter site, the push button will furnish an override switch closure directly to the logic circuit. If the responsible official and the transmitter site are separated by a long distance, a digital encoder at the push button site and a decoder at the transmitter may be required to transmit the switch closure over a toll line connecting the two sites. In either case the push button cannot initiate an alert unless this input function is enabled by the logic circuit. This would occur only if one of the situations exist that are described by logic equations 4 through 12 in Table 3-1. These situations all have the common attribute that a seemingly valid command signal is received on a channel that is simultaneously operating in a non-alert mode. These situations are characteristic of spoofing, so the logic circuit must request human intervention to settle the dilemma.

5.3 MULTIPLE INPUTS

The inputs to the control network from N2WC and N3WC must be made independent of the NWC inputs and therefore redundant. This could be done by providing a low-frequency transmitter for each NWC. An alternate way would be to let N2WC and N3WC share a single low-frequency transmitter. Three wire networks would be required to provide redundancy and make each initiation point entirely independent of the other. Three different low or very low frequencies would be used to differentiate the three initiation points. One station could be WWVB as the data rate of the system is low enough to be handled by WWVL. Some compromise might be made on the wire portion of the network whereby all three input locations would be looped with all of the broadcast transmitter sites. The line check code could be generated at only one of the NWCs, or three NWC generators could be synchronized to provide the line check code in sequence with each transmission preceded by an identifier so the logic circuits at the transmitter sites could know which initiation points were on line. The logic circuits at the transmitters would have to be more complex and two more receivers and recognition circuits would be required at each location.

5.4 TIME PHASING INTERFACE

If this configuration is required to interface with subnational transmitters that must resort to sequential transmissions to eliminate interference zones, there are two ways that the phasing may be controlled. One way would be similar to that described in the AUTODIN configuration. The subnational transmitters would need time standards and the appropriate logic circuits. The control message would be tagged with a reference time at the NWC to which all

the transmitters would synchronize themselves. A nine or ten-bit time message would be required to give time to the nearest second in five-minute intervals. This would add about 1.3 seconds delay in the transmission time for the control signal (e.g., 10 bits at 7.5 band), which is well within allowable limits of time delay.

Another way of handling the sequencing would be to coordinate all stations with timing signals from WWVB. This is probably less desirable as loss of the control signal could cause a failure of the sequencing operation.

5.5 CONCLUSIONS

High system reliability is achieved in this configuration by the use of two reliable, dissimilar communication channels, i.e., radio and leased wire, to provide redundancy against system failure. This diversification of facilities also allows a high level of security to be obtained without sacrificing reliability. The fact that the two communication channels are completely different makes it difficult for an enemy to spoof the system. It also reduces the probability that any natural or inadvertant man-made phenomena that could generate a false control signal on one channel would also induce a false control signal on the other channel. A third benefit gained from this diversity of facilities is an increased probability of surviving the initial phases of an enemy nuclear attack. While both of the channels must be highly reliable, requiring considerable redundancy, they are not necessarily high cost facilities. The low data rate requirements of the system can be satisfied by a 15 Hz wire facility. The low data rate will also allow the WWVB transmissions to be coded to take maximum advantage of the available power and band width of the system. This should provide a high signal-to-noise ratio resulting in very reliable coverage of the United States with the single transmitting station at Fort Collins.

6.0 PROBLEM AREAS

Four problem areas have been identified and singled out for special consideration in this section of the document. It is not because these particular problems are the only important problems that confront the development effort or that they are necessarily the most critical. They have been singled out for special treatment at this time, however, because they are more fundamental than many strictly engineering and hardware problems.

Being of a more fundamental nature they need to be studied, critically discussed, and resolved as soon as possible. Unresolved, they stand as a bar to the orderly development of the Radio Warning System. These problems will be defined and recommended solutions will be presented in the following pages. The material is arranged and discussed under four main groupings:

1. Functions Performed by Teletype and Live-voice
2. Data Rate Considerations
3. Security and Authentication
4. Overlapping Coverage

6.1 FUNCTIONS PERFORMED BY TELETYPE AND LIVE-VOICE

Teletype requirements in the Radio Warning System are based on Operational Requirement 4.1.3[1] which specifies that the capability for hard copy be provided where required. In Section 4.1.3 of the Operational Requirements there are three reasons listed why hard copy is needed. The first is to provide the text for a live voice warning to be read into the Radio Warning System at a lower echelon. This is, of course, based on an assumption that live voice cannot be inserted into the system at the national level. The second reason given for using teletype is the need to provide authentication to an owner for the operational use by OCD of his commercial broadcast facility. This is based on the assumption that commercial broadcast facilities will be a part of the Radio Warning System. The third reason for the use of teletype is that it provides a useful tool for trouble shooting system malfunctions.

The first reason for needing teletype is invalid if the system has the capability for allowing live voice inputs into the system to be made at the initiation points. It would also be invalid if there were no requirement for the system to have a live voice capability. One principle reason for needing teletype may thus depend on whether a live voice capability is needed. This point will be discussed later.

The second reason given for requiring teletype is the need to provide authentication for assuming control of a commercial station. As pointed out in Section 4.1.3 of the Operational Requirements, the owner of a commercial facility cannot be allowed to have any discretionary control over the participation of his facility in the warning operation. If this is so, then there is no need to deliver him a teletype message. The owner is not in a position to take any action when his facility is converted to OCD use even if he does not receive hard copy notification. In order to inform station personnel that their equipment is not malfunctioning, a real-time indication of Radio Warning System operation can be provided by audible alarm and/or indicator light.

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1. Chapter Two of this Volume.

Hard copy notification thus serves no useful operational function. The stated need for hard copy notification is, therefore, only to provide a courtesy to the owner and to provide a permanent record to him of the fact that control of his commercial facility was assumed by OCD, and to record the time at which this occurred. Neither of these two reasons is adequate justification for providing hard copy through Radio Warning System channels. The type of notification called for in this section of the Operational Requirements is not time critical and could just as well be sent before-the-fact for scheduled tests or after-the-fact for real alerts. The medium used for transmission of this notification could be Western Union telegram, government or commercial teletype, or in the case of scheduled tests, U.S. registered mail. Any one of these media would provide adequate courtesy and a permanent record. In any case, the notification is required for administrative rather than operational reasons, and it could hardly be justified on a cost basis if providing the capability to deliver it through Radio Warning Systems in any way downgraded the capability of that system to perform its primary function of warning the public or if it resulted in excessive costs. It will be shown that a high price will be paid in degradation of this primary function or in actual monetary costs if teletype is made a requirement of the Radio Warning System. (See Section 6.2, Data Rate Considerations).

The third reason that the Operational Requirements give for needing teletype is that it will provide a tool for troubleshooting system malfunctions. The relative value of teletype for troubleshooting is not likely to be demonstrated until the Radio Warning System configuration is specified in considerably more detail than it is at present. This value is not currently substantiated by any evidence that it would be useful for this purpose. In any case, this reason, standing alone, without the support of the first two reasons can not be considered justification for a teletype requirement for the Radio Warning System.

Section 4.3.1 of the Operational Requirements calls for a semiautomatic mode of operation for the Radio Warning System. This is defined as the transmission of live-voice messages to some segments of the public and manual transmission of hard-copy messages within certain portions of the system control network. In justification for the semiautomatic capability requirement, Section 4.3.1 of the Operational Requirements, specifies a need to ad lib a warning message to the public. This implies, and it is so stated, that all contingencies in the warning situation cannot be planned for in advance. This is a reasonable observation, and in general, the system should be made as flexible as possible to allow the OCD operators maximum freedom to adapt to any possible contingency. It is open to question, however, whether any situation can be postulated that would require immediate response by the Radio Warning System and at the same time could not be covered by a pretaped message. The means already exist via the Emergency Broadcast System (EBS) to get live voice messages to the public.

All emergencies can be expected to fall into either one of two categories, (1) imminent nuclear attack, or (2) other emergencies. In the case of direct nuclear attack, time is of such overriding importance that it is difficult to envision the Radio Warning System operator taking the time to compose a special message. The paramount objective of a warning system in a nuclear attack situation must always be to get the public to take protective measures as soon as possible. It is counter to OCD policy to alert and warn only one section of the country when an actual nuclear attack has been detected so no special geographically limited warning message would ever need to be composed.

The other category of emergency calling for use of the Radio Warning System includes any situation that does not involve imminent nuclear attack. All such situations are less time-critical than the nuclear attack situation. If the message were so urgent that it required waking the entire population in the middle of the night then the Radio Warning System could be used in conjunction with EBS. The Radio Warning System could be used to transmit a taped voice message instructing the public to tune in on their local EBS station for an important announcement. The amount of time lost in setting up the EBS network would be relatively unimportant for any conceivable situation other than direct nuclear attack.

Thus, due to the time criticality of a tactical alert that inhibits use of live voice, and the availability of EBS for non-time-critical alerts, a live voice capability is not required for the Radio Warning System. The lack of a requirement for live voice in the Radio Warning System removes the remaining justification for teletype, i.e., hard copy to provide the text for a live voice input by someone at a lower echelon.

6.2 DATA RATE CONSIDERATIONS

If the requirement for teletype is set aside, simpler codes and lower data rates can be used with considerable advantage. For example, if there were only one response that could be elicited from the Radio Warning System, then it would be only necessary to reliably transmit a switch closure from the national initiation point to the transmitters that broadcast to the public. This is not the case, however, as the Radio Warning System will be required to perform more complex functions than a simple on-off type of operation. The Radio Warning System can fulfill its function by transmitting to the public any one of a number of pretaped messages, with certain messages preceded by an alert signal. The total amount of information that needs to be sent from one of the National Warning Centers to the transmitters that reach the public then must be only great enough to unambiguously select one tape or action sequence from among all the others. The total number of choices available determines the maximum amount of information that would need to be sent. While the exact number of different types of messages that must be sent has not been determined, it is estimated that at least the following options should be available (Operational Requirement 4.3.4, Chapter Two).

1. Tactical Alert and Warning
2. Strategic Warning Only
3. Cancel
4. Test
5. Preempt

Only three bits of information are necessary to give a choice of any of the above 5 options. Five bits of information allow for a choice of up to 32 options. Given the need to select one of a limited number of prerecorded tapes, the informational demands on the control network are quite modest. This fact can be used to good advantage since the principal advantage in having a low data rate requirement is that a typical communication channel's high information rate capacity can be traded for greatly increased signal reliability.

There are a variety of ways in which a transmission channel may be manipulated by electronic techniques to increase the signal to noise ratio of the transmission. Other methods used to decrease the probability of error in the signal employ some type of redundant coding that allows the signal to be integrated with respect to time at the receiver. Whatever the method employed, it is based upon the principal that a reduction in the data rate for a given band-width and power can be exchanged for improved signal-to-noise radio and, hence, greater reliability.

6.3 SECURITY AND AUTHENTICATION

Security[1] of the control signals and authentication[2] to the recipient of these control signals may be achieved in numerous ways and with varying degrees of effectiveness. The security objectives of the Radio Warning System are twofold. First, it is desired to decrease to a sufficiently low level the probability of an unauthorized person or combination of persons generating a false alert by sending false signals through the control system. The probability against this situation happening should be high, commensurate with the expected harm that would ensue to the country if a false alarm were propagated. The second objective is to give such a level of assurance to the rightful recipients of the warning message that they can act on a legitimate message without hesitation and without the fear that it may be a false alarm.

1. Security is defined as the relative freedom of the control network from seizure and false activation by unauthorized persons whether the act was deliberate or inadvertent.
2. Authentication is defined as a method for assuring the recipient of a message that the message is actually what it appears to be.

It has been suggested that the receipt of a hard-copy teletype message gives this assurance. This can be quite misleading because an unauthorized person who knows enough about the system to be able to seize the channel could also generate a hard copy message to provide a false authentication to the message recipients.

In a fully automatic system such as the Radio Warning System, hard copy authentication would appear to be somewhat of an anachronism. What is more appropriate in an automatic communication system is a mechanized, self-checking feature that will allow the use of relatively simple, straightforward logic devices at the broadcast transmitter sites to determine with a high degree of accuracy that a message is authentic.

6.3.1 Cryptographic Devices

If only one channel is available for transmission of the message and this channel is a one-way channel, one feasible means of achieving security and providing authentication is by the use of cryptographic equipment. The underlying principle in this is that the elaborate security precautions that are enforced to prevent compromise of the cryptographic codes insure that the probability of unauthorized persons acquiring the key to the system is extremely low. As a result, the probability is extremely high that the message is authentic.

The primary function of a cryptographic system is to deny knowledge of the informational content of messages to unauthorized recipients. The problem in the Radio Warning System is completely different. It is relatively unimportant if some unauthorized recipient of a warning message can correctly interpret it. The message would in all probability end up being broadcast to the general public before the unauthorized recipient could take any action based on this special knowledge that would be detrimental to the mission of the Radio Warning System.

6.3.2 Two-Mode Channel

There is another way that security and authentication can be provided on a single channel. The three additional requirements that will be placed on the channel are: (1) that it have two clearly identifiable modes of operation, (2) that these two modes be mutually exclusive, and (3) that it be a full period channel operating in one or the other of the modes at all times.

In the fulfillment of these requirements the National Bureau of Standards station WWVB is almost an ideal example. It normally radiates continuously (or could be made to do so) on a frequency of 60 kHz with a distinctive, identifiable signal. Presence of this signal at a monitor receiver can be used to

indicate to a logic circuit that the station is in a non-operate mode (from the point of view of the OCD warning operation). When WWVB is shifted over to the OCD alert mode of operation, it will radiate a signal at 61.15 kHz. It will, of course, cease radiating at 60 kHz coincident with the shift to the OCD mode of operation. A logic circuit driven by two receivers -- one pretuned to 60 kHz, the other to 61.15 kHz -- can be built to recognize whether WWVB is operating in the NBS or the OCD mode. If the logic circuit should at any time recognize an apparently valid alert control signal at 61.15 kHz while it is still receiving the normal WWVB signals at 60 kHz, then the conclusions must be that the signal at 61.15 kHz is a spoof, inadvertent or otherwise. This dual use of the channel makes the task of spoofing the system much more difficult. Not only does the spoofer have to create a good simulation of the legitimate control signals at 61.15 kHz and deliver it to the receiving system of the broadcast stations he is trying to spoof into false operation, he also, and coincidently, must put WWVB off the air.

The spoofing task can be made even more difficult and unprofitable by making the logic circuitry highly critical as to the timing of the termination of the WWVB 60 kHz transmission in relation to the beginning of the 61.15 kHz control transmission. For instance, if the 60 kHz transmission ceases too soon before the commencement of the 61.15 kHz transmission, leaving too long of a time gap between the two transmission, e.g., greater than 10 seconds, the 61.15 kHz transmission will be considered to be false. If the enemy used jamming to deny information on the presence of the 60 kHz transmission, the presence of this jamming coincident with the reception of the 61.15 kHz transmission would be a sufficient basis for rejection of the 61.15 kHz transmission. The invalidation of the 61.15 kHz signal by the logic circuit need not imply a failure of the system. It would be interpreted as a warning that the system was behaving abnormally. The recognition of this fact can be used to initiate standby procedures that require manual verification of the intent to alert by means of another communication channel such as NAWAS, AUTODIN, or another facility of this type. At the worst, a delay would have been introduced into the delivery of an alert message if the attempt to alert had been real.

In trying to evaluate the probability that the enemy will spoof, the cost of spoofing must be weighed against the probable gain. If successful spoofing requires drastic measures, such as rendering WWVB inoperative, and only then if it were done in some precise time sequence with the generation of a false signal on another frequency, the cost of spoofing could conceivably be too great for any expected benefit.

6.3.3 Two-Channel Security

An even better method of providing an extremely high degree of security and authentication and at the same time increasing the reliability of the system by a considerable amount, can be achieved by using two channels to transmit the

control message. It might be considered costly to provide an extra channel just for the purpose of providing good security and authentication when only one is needed to transmit the message, and it cannot be denied that two channels cost more than one. However, due to other considerations, the Radio Warning System should not be a one channel system. The need for high reliability in the system to perform a critical defense function demands at least 100% redundancy in the control network that disseminates the alert control signals to the broadcast stations that transmits the alert and warning message to the public.

It should be kept in mind that redundancy is the key work in providing high reliability. Having a standby back-up system is one way of providing redundancy, but only one way. The important thing is that the system be made highly reliable. Redundancy as a means of achieving this reliability is certainly called for in the Radio Warning System.

Another reason why the Radio Warning System should not be a single channel system is that government regulations require that government communications systems be based on use of commercial leased wire circuits, if this is technically feasible. Government dedicated radio circuits can, however, be used to provide redundancy in case of failure of the primary system.

Integrating the use of landline and radio, as proposed here, results in at least as good reliability as if the two were used in a primary and backup configuration and it makes possible a large increase in system security. This special use-of dual communication channels was described in detail in Section 5.0 and is, in fact, the basic argument justifying the configuration in which it is used.

6.4 OVERLAPPING COVERAGE

When there are not enough frequencies to provide each of the subnational transmitters with nonconflicting coverage, i.e., coverage such that no transmitter will interfere with the transmissions of any other transmitter, two problems arise. The first, and most serious, is the operational problem of interrupted warning messages to those areas whose transmitter must of necessity, interrupt its transmission because it must time share its frequency with another transmitter. The second problem revolves around the technical problems of time-phasing those transmitters that conflict.

6.4.1 Interrupted Warning

There can be little question that the best warning is a continous warning. This is based on many factors; short term population mobility being one of the most important factors to consider. During the normal working day, people will be constantly moving in and out of areas where warning can be received. With an intermittent warning being given, it will take longer to warn any given portion of the population than it would if a continuous warning was being disseminated.

During the normal sleeping hours, there exists the problem of waking people up. Here again it is intuitively obvious that a continuous warning is superior to an intermittent warning.[1] All this must be taken in the light that the first few minutes of warning are the most important as far as movement to shelter is concerned.

Another facet of interrupted warning is that the minority of the population is receiving the best warning. This is due to the fact that whenever a subnational transmitter ceases transmissions to allow reception of signals from another subnational transmitter in a zone of interference, it is essentially denying warning to the population in its primary coverage. This is not to say that the warning received in the interference zone is necessarily continuously intelligible, but at least the receivers are continuously demuted and making some kind of noise. By contrast, in the primary area of coverage of a transmitter the interruption must be at least one message length plus the demuting time. This means, of course, that the receivers in the primary areas must be demuted again each warning cycle.

Another interesting problem with interfering subnationals is in the area of periodic testing. If it is assumed that there is an optimal time of day for testing, the portion of the population living in the interference zone will get garbled messages for the first portion of the test cycle; the other alternative is double test messages - an annoyance in either case. There exists also the possibility, again assuming testing at the optimum time of day, of the interfering transmitters having an interference zone crossing time zone boundaries. Thus people in the interference zones will receive two test messages an hour apart, again an annoyance. It may be said that the portion of the population thus annoyed will have to live with it, but will they? It is also recognized that Daylight Savings Time also presents problems for optimal time of day testing, but these are beyond the scope of this discussion since they only complicate the problem of timesharing.

6.4.2 Technical Problems in Timesharing Frequencies

The problem of the time phasing of transmitters with conflicting coverage can be simply stated as the problem of synchronizing the transmissions of two or more transmitters that are not in contact with one another. The problem is rather trivial as far as the mechanics of the situation are concerned if message duration and start of warning time are known, and assuming that each transmitter site has available an accurate clock which is synchronized with, say, WWV or some other national time standard. Each transmitter issues any desired number of warning messages at the beginning of the warning period. By prior scheduling then, it alternates transmissions with its conflicting neighbor

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1. See Chapter Four, Proposed Alert Signal and Warning Messages.

until the warning period has terminated. If a nonsimultaneous start is expected, a maximum time delay is assumed for all transmitters to get on the air and this time is added before synchronized transmissions begin. In this case, however, the time of issuance of the warning in the control net is needed as the standard time to which the maximum time delay is added.

Another problem associated with timesharing frequencies is the effect of intermittent operation on the transmitters and receivers. The intermittent muting and demuting of the receivers and the intermittent application of power to the plates of the transmitters during the warning period cannot help but have a detrimental effect on the reliability of such equipment. This would, of course, not be critical during a test; but during the protracted warning period, it could be damaging.

6.4.3 Conclusions

From the above discussion, the desirability of having nonconflicting coverage for the subnational transmitters is evident. The interrupted warning effects on a mobile population and awakening people, as well as the effects of intermittent usage of equipment indicates that, both operationally and technically, it is extremely desirable to have enough frequencies to provide the subnational transmitters with nonconflicting coverage.

CHAPTER FOUR

PROPOSED ALERT SIGNAL AND WARNING MESSAGES

1.0 INTRODUCTION

1.1 BACKGROUND

This chapter contains recommendations for the alert signal and warning messages for use in the Radio Warning System that is being planned by the Office of Civil Defense (OCD).[1] The Radio Warning System is designed to disseminate an alert signal and warning messages to the general public on a nationwide basis.[2] The alert signal and warning messages are to be received indoors through special-purpose radio receivers. The primary source of the alert signal and warning messages will be prerecorded tapes containing the required intelligence.[3] These tapes will be mounted in playback equipment at selected radio stations throughout the country. Some stations will be specially designed low-frequency stations that will serve large geographical areas of the country; other stations will be specially equipped commercial broadcast stations that will generally serve urban areas in which the noise level is too high for satisfactory reception of signals from the low-frequency stations. Because of the relatively few stations to be incorporated into the Radio Warning System, the national character of alert signals and warning messages must be emphasized. The prerecorded tapes positioned at these stations must provide intelligence suitable for dissemination over a wide area of the country.[4]

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1. This chapter supercedes Proposed Radio Warning System Alert Signal and Warning Messages, which was originally published as TM-L-1960/030/00, dated 30 June 1965.

2. Additional information on the Radio Warning System appears in Chapter Two, "Interim Operational Requirements," and in Chapter Three, "Alternate System Configurations." See also Samuel Weems, Report on Radio Alerting and Warning Meeting, System Development Corporation, TM-L-1960/027/00, 16 February 1965.

3. In addition, the possibility of providing for the dissemination of live-voice inputs is being considered for incorporation into the system. (See Chapter Two, Section 4.3.11.)

4. Arguments in support of this contention are presented in Section 5.0, below.

1.2 NATURE OF PROBLEM

Prerecorded tapes must be available at Radio Warning System stations for the following types of messages:[1]

1. Warning Message Preceded by an Alert Signal. It is assumed that this combination of signal and message be reserved exclusively for tactical warning, that is for warning of an imminent attack.

2. Warning Message Without an Alert Signal. Presumably this message will serve to announce a strategic warning, such as warning of a highly probably attack.

3. Cancel Message. This message serves to cancel a previous false alarm.

4. Test Message. This type of message will serve to familiarize the public with the operation and function of the Radio Warning System and to indicate the operational status of the receivers in the system. (These uses are not necessarily compatible, and, consequently, several different messages are recommended. See Section 5.7, below.)

(In addition there may be a need for prerecorded test messages for delivery to the subnational or local broadcast stations for testing the system through either or both of these levels. Since these types of messages are not to be disseminated to the public, their content is not critical, and they will not be discussed in this paper.)

Limited information is available on alert signals suitable for use in the Radio Warning System. Much of this information is contained in a research study performed for OCD by Michigan State University (MSU), Department of Speech; this study attempted to determine an optimum alerting signal for public use.[2] Even this study, however, was not able to develop the optimum signal or signals to be used in attack warning because it was limited to evaluating the effectiveness of available alert signals.[3] MSU did, however, provide the basis for developing optimum signals by identifying the critical parameters of such physical attributes of sound as frequency, complexity, and intensity. It does not appear necessary at this time to develop an optimum

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1. See Chapter Two, Section 4.3.4.

2. Herbert J. Oyer and Edward J. Hardick, Response of Population to Optimum Warning Signal, Michigan State University, SBBLR163, September 1963. This report was completed under contract OCD-OS-62-162.

3. Ibid., p. 3.

alert signal, since MSU has identified several available signals as effective in a wide variety of laboratory and field tests. Since the Radio Warning System is completely flexible in the prerecorded signals that it can disseminate to the public, a suitable alerting signal can be recommended at this time based upon the MSU recommendations. (The only inflexibility inherent in the Radio Warning System is that caused by limitations to the audio bandwidth of the home receiver.) The alert signal selected lacks any meaning in the literal sense and depends, for its effectiveness, upon a conditioned response upon the part of the public. However, in the interval between the initial field tests and availability of receivers to the public considerable opportunity will be available for reassessing the choice of an alert signal.

If only limited information is available on alert signals suitable for the Radio Warning System, even less information is available on the format and content of the warning messages to be broadcast by the system. The messages recommended are based upon intuition and analysis of known responses of people to disaster warnings. Again, this appears adequate for the Radio Warning System at this time. The complete flexibility inherent in prerecorded messages allows the messages recommended to be changed as more experience is gained with the Radio Warning System. In comparison with the alert signal, which lacks any explicit meaning, the messages transmitted are self-explanatory and can be changed without risk of loss of previous conditioning of the public. Therefore, these messages can be changed even after the system is operational and receivers are available to the public.

1.3 CONSTRAINTS

The recommendations incorporated into this paper are derived from prior studies performed outside of SDC. Because of time and funding limitations only limited work has been done on the laboratory development of optimum alert signals or warning messages; most of this effort has been expended on n subjective listening evaluations of alert signals by System Development Corporation personnel with prior experience on OCD warning projects.

The signals and messages recommended in this paper were derived from the best available information on signaling techniques and the effects of warning in a disaster situation. As pointed out in Section 1.2, above, considerable opportunity exists for improving both signal and messages during the period of development and testing prior to availability to the public. Such testing must be carried out to verify these recommendations.

In attempting to determine the duration and loudness-level of the recommended alert signal, the approach taken was to determine these parameters for a sleeping population and to use the values developed for alerting both an awake and a sleeping population. This decision is based upon the assumption that the system should not be complicated by any attempt to program different day and night messages. (No evidence gathered during the study has invalidated this assumption.) The decision is predicated, even more practically, upon

the availability of some information upon the effectiveness of alert signals for awakening a sleeping population and the complete unavailability of any data that make feasible the selection of a time interval or loudness-level for daytime alerting. The loudness-level and interval selected for nighttime alerting, furthermore, seems intuitively adequate to alert the population during its waking hours.

Live-voice warning messages may also be disseminated to the public via the Radio Warning System.[1] Since live-voice messages are intended to cope with situations that cannot be anticipated in advance of an emergency, no attempt has been made to develop standardized message content for them; the criteria established for prerecorded messages, however, apply to any live-voice messages transmitted to the public.

Multistage shelter movement strategies have not been considered in this paper because there is neither an OCD policy on them, nor is there adequate information for evaluation of these strategies.[2]

1.4 ASSUMPTIONS

Recommendations for the signal and messages are premised upon the following three assumptions:

1. The Radio Warning System will be implemented in the post-1970 time period.

2. In that time period there will be adequate shelter space for the total population, distributed so as to provide approximately 15-minute access time in urban areas.

3. As a result of specific and intensive educational efforts--reinforced by the installation of a shelter system and the Radio Warning System--the vast majority of the public will know in the time frame of the system the purpose of both the Radio Warning System and the shelter system, the nature of attack hazards, and the proper response to an attack warning.

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1. Chapter Two, Section 4.3.11.

2. Cf., R. I. Condit and R. L. Coen, Should Movement to Shelter be One Stage or Two Stages?, Stanford Research Institute, November 1963; J. F. Devaney, Movement to Shelter, Office of Civil Defense, February 1964.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 WARNING PROCESS

The task of selecting the alert signal and of designing the various messages transmitted over the Radio Warning System is tantamount to designing the interface of that system with the total civil defense program. Signals and messages can be devised, but they are effective only if they are coordinated with the shelter program; are presented effectively to the public through training, education, and advertising; and are supported by effective civil defense at the local level. The messages must be directed to the level of protection available; this factor necessitates the shelter interface. However, neither shelters nor the Radio Warning System can be effective unless the public is conditioned to the effective use of both; this necessitates the education, training, and advertising interface. Finally, the best national programs in warning and shelters are likely to be inadequate (the national warning can, indeed, be virtually countermanded at the local level) without close support from local civil authorities; this factor necessitates the interface with local government, including the use of local broadcasting facilities for communication with the public in the preattack and transattack periods.

2.2 ALERT AND WARNING TECHNOLOGY

Only limited work has been done that is applicable to the selection of an alert signal for a system such as the Radio Warning System. No work at all has been done on the effective design of message format or content for such a system. There has been some experience with warning messages, however, in nonwartime disasters. This experience can be drawn upon, and warning message content should be in conformity with this experience. All the recommendations incorporated into this paper are to be regarded as working hypotheses to be verified by further testing in conjunction with the development of the Radio Warning System.

2.3 TYPES OF MESSAGES

The Radio Warning System requires five prerecorded messages:

1. Alert Signal and warning message (recommended for tactical warning only).

2. Warning message without an alert signal (recommended for strategic warning).

3. Cancel message (to countermand a false alarm disseminated to the public).

4. Test message without alert signal (for testing the Radio Warning System through to the home receiver).

5. Test message with modified alert signal (for testing the Radio Warning System through to the home receiver and conditioning the public to the alert signal).

2.4 ALERT SIGNAL

A synthetic alert signal having no analogue in everyday experience is recommended. This recommended signal is generated by sounding two specific horns from a foreign automobile. The lower-pitched of the two horns is sounded continuously, while the higher-pitched horn is pulsed at the rate of two pulses per second. The sound of the horns is rendered unspecific by first tape recording it and then rerecording it at twice the speed of the initial recording. This rerecording process tends to double the apparent pitch of the signal and probably accounts for the high alerting potential that was assigned to the signal by a large number of listeners of various ages, sexes, and occupations. It probably also accounts for the excellent power this signal has to penetrate high levels of ambient noise.

It is assumed that the alert signal will be used only to precede a tactical warning message, i.e., one which announces the imminence of an enemy attack. For this purpose an alert signal duration of 40 seconds is recommended.

A sound pressure level of 90 db is recommended. This sound level is justified for two reasons. First, in a daytime work environment it is necessary to penetrate the ambient noise and make the signal audible. Secondly, when the listener is asleep, this level is necessary to assure that he is awakened and ready to receive the following spoken message.

2.5 MESSAGE CONTENT

The specific messages to be disseminated via the Radio Warning System require about one minute to deliver and are designed to incorporate the following attributes to the degree appropriate to each:

1. Official. The message should represent to the recipient the official policy of the warning agency.

2. Impressive. The warning should be difficult to ignore.

3. Unequivocal. The message should be simple, clear, and direct; any instructions given should be completely consistent and noncontradictory.

4. Personal. The contents of the message should apply directly to the listener.

5. Balanced. The message must balance the danger impending with the protection afforded by taking the appropriate action.

Of the various messages only the tactical warning message is a true warning message that has all of the above attributes. The strategic warning message is, in particular, only an announcement of an unspecified emergency and of the availability of information via commercial radio and television. It is recommended that the verbal portion of the tactical warning message be broadcast at a sound pressure level of 75 db. It is also recommended that the first cycle of the strategic warning message be broadcast at a sound pressure level of 90 db in order to increase the probability of attracting attention without the necessity of using an alert signal; subsequent cycles of the strategic warning message are to be broadcast at a sound pressure level of 75 db to increase intelligibility. The cancel false alarm message is to be broadcast at 75 db. The test messages are to be presented at 65 db, with the alert signal, when used, to be presented at 60 db.

3.0 DISASTER RESPONSES

3.1 DECISION PROCESS

It appears to be characteristic of responses to emergency that most people prefer to believe that they are safe rather than in danger. There is a type of mental "inertia"--to draw a physical analogy--that motivates people to try to fit signs of danger into the normal patterns of activity. Given an opportunity to delay taking protective action, people generally seem to take that opportunity. Once the mental inertia--to extend the analogy--is overcome by acceptance of a warning or by the impact of the disaster, people tend to fit all signs into the danger pattern that characterizes the disaster.[1]

It appears almost axiomatic that, in a warning situation, the "burden of proof seems to be on the warning system...."[2] Responses to disaster warnings very frequently involve attempts to verify or authenticate the warning. This

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1. H. B. Williams, "Human Factors in Warning and Response Systems," in G. H. Grosser, et al., eds., The Threat of Impending Disaster: Contributions to the Psychology of Stress, The M.I.T. Press, Cambridge, Massachusetts, 1964, pp. 93, 94; C. E. Fritz and H. B. Williams, "The Human Being in Disaster: A Research Perspective," The Annals of the American Academy of Political and Social Science, 309, January 1957, pp. 43-44; Irving L. Janis, "Psychological Effects of Warning," in George W. Baker and Dwight W. Chapman, eds., Man and Society in Disaster, Basic Books, Incorporated, New York, 1962, pp. 70-71; Stephen B. Withey, "Reaction to Uncertain Threat," in Baker and Chapman, op. cit., p. 113.

2. Williams, op. cit., p. 94; cf., R. W. Mack and G. W. Baker, The Occasion Instant: The Structure of Social Responses to Unanticipated Air Raid Warnings, National Academy of Sciences - National Research Council, Disaster Study 15, pp. 39, 63.

process involves matching the warning against experience and current signs of danger (or lack of these signs); seeking confirmation from some other channel (comparing a radio message, for example, with information obtained from family or neighbors); or waiting for repetition (of a noncontradictory nature) to lend credence to the initial warning.[1]

The physical analogy to inertia can be developed further. In a disaster situation, danger signals are probably additive in their impact. Only when the overall force of a disaster situation exceeds an individual's tolerance level, is the mental inertia that tends to prevent protective action overcome. Thus a danger signal, a piece of information, some prior experience finally add up to a decision to act--sometimes to the decision to do nothing.[2] In such a process positive and negative factors tend to balance each other. A person's response to disaster warnings apparently are a function of his answers--conscious or unconscious--to the following types of questions:[3]

> 1. Threat. What is the threat? How likely is the threat to materialize here? How serious will be the loss to me, my family, and my friends?
>
> 2. Countermeasures. What protective action are available to me? Will they do any good against the threat?
>
> 3. Time. How long will it be before I have to decide upon a course of action? How long will it take to take effective protective action?
>
> 4. Cost. What financial loss will I suffer if I do take protective action? Will I be separated from family or friends? Will I look foolish if my protective actions are disproportionately more drastic than those of friends and neighbors, or if the disaster fails to materialize?

These questions are probably interrelated; if the threat is great enough, then the cost of protective action may play a minor role; if time is very short or protective action deemed ineffective, then no decision may be possible.

In Hurricane Audrey (1957), for example, extensive loss of life occurred in Cameron Parish, Louisiana, probably because of a precarious balance between factors tending to encourage a feeling of relative danger and those tending to encourage a feeling of relative safety. The Weather Bureau broadcast storm

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1. Williams, op. cit., pp. 94-96.

2. Ibid., pp. 93-93.

3. Withey, op. cit., pp. 109-110.

warnings beginning 36 hours before the peak of the storm advising evacuation to high ground. Lower Cameron Parish is marshland, at or below sea level, but it is traversed by ridges six to 12 feet above the surrounding marsh. Prior hurricane experience indicated that the high tides would not reach the tops of the ridges. These ridges were "high ground" to people in lower Cameron Parish.[1]

Furthermore, official warning messages relating to Cameron Parish were confused by other messages--official and unofficial--asserting no danger (in Port Arthur, Texas, 40 miles away) or danger much later than the actual disaster (in Lake Charles, Louisiana, 60 miles away).[2] Confronted with this confused picture, only 40 percent of the inhabitants of Cameron Parish evacuated; others had deferred a decision, had decided not to evacuate, or had decided to move to a nearby ridge location.[3] It is apparent, even from this brief account of Hurricane Audrey, that 60 percent of the people of Cameron Parish were not able to resolve the questions relative to their taking protective action in a manner that allowed effective action.

3.2 IMPROVING RESPONSE

If a disaster-threatened area has a plan of action that is known to and accepted by the residents of the area (especially if this knowledge is gained through training and exercising), and if the area has organized leadership accepted by the residents, the effectiveness of the warning appears to increase.[4] The need for validation is reduced. The natural tendency to interpret danger signs in a nonthreatening manner is reduced. The personal questions relative to the consequences of taking protective action are easier to resolve in a positive and timely manner. Thus, the effects of Hurricane Audrey stimulated the residents of Cameron Parish to develop an operable civil defense organization, with known plans for protection against subsequent disasters. The impact of subsequent disasters produced a far more positive response to warning than was the case with Hurricane Audrey. This improvement partly stemmed from devastating personal experiences with Audrey and partly from organizational improvements following that storm. In 1958, 75 percent of the residents of Cameron Parish evacuated their homes prior to Tropical Storm Ella, even though the Weather Bureau did not advise evacuation. In 1961, 96 percent of the residents evacuated in the face of Hurricane Carla.[5]

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1. F. L. Bates, et al., The Social and Psychological Consequences of a Natural Disaster: A Longitudinal Study of Hurricane Audrey, National Academy of Sciences - National Research Council, Disaster Study 18, pp. 7-8, 11.

2. Ibid., p. 13; cf., Williams, op. cit., pp. 81-82.

3. Williams, op. cit., p. 94.

4. Ibid., p. 98.

5. F. L. Bates, op. cit., pp. 137-148; cf., H. E. Moore, et al., Before the Wind: A Study of the Response to Hurricane Carla, National Academy of Sciences - National Research Council, Disaster Study 19, 1963.

3.3 NUCLEAR ATTACK

The problem of response to attack warning appears to be much more critical than that of disaster warning. The precise nature of a nuclear attack, its hazards, and the effectiveness of protective measures against these hazards are known to the general public only in a limited sense.[1] Warning time is extremely short compared with that of most natural disasters. After the attack radiological hazards cannot be detected by the senses until exposure has exceeded critical levels. Furthermore, the physical and psychological impact of the severest natural disaster is likely to be very limited in comparison with even a light nuclear attack.[2]

In the few cases in which it is possible to study responses to possible enemy attacks, many of the same conditions that affect responses to disaster warnings prevail. In several well documented accidental siren soundings (Oakland, California, May 1955; Washington, D. C., November 1958; and Chicago, Illinois, September 1959), the response of those exposed to the false alarms was characteristic of disaster behavior in general.[3] Many people did not even hear the false alarm (Oakland, 25 percent; Washington, 13 percent; Chicago, 17 percent).[4] The burden of proof for those who did fell upon the alerting system. Most people sought additional information (1) by observation, looking out the window, checking the papers; (2) by checking other possible warning channels (radio, TV) or attempting to create such channels (by telephone calls to possible sources of information); or (3) by turning to relatives, friends, neighbors, and supervisors (again, often by telephone).[5] Only a few people took any type of protective action. In Chicago only 2 percent took any action that could be construed as even vaguely protective. In Washington, where the alarm sounded in several federal agencies, approximately 20 percent of those exposed went to shelters. While this latter percentage is still low, it is well in excess of that in Chicago and can be attributed to the higher knowledge and training of the government employees.[6] In all cases those who thought that the world situation was tense were more likely to take the siren signals seriously.[7]

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1. For example in a recent survey only 22.9 percent of the total sample was able to recall exposure to civil defense or government-sponsored reading material on nuclear war and fallout shelters. Richard Pomeray, "Information Level," in Jiri Nehnevajsa, et al., Some Public Views on Civil Defense Programs, University of Pittsburgh, December 1964, p. 103.

2. R. J. Lifton, "Psychological Effects of the Atomic Bomb in Hiroshima: The Theme of Death," in Grosser, op. cit., pp. 152 ff.

3. Mack and Baker, op. cit., pp. 39-41; cf., Janis, op. cit., pp. 73-74.

4. Mack and Baker, op. cit., pp. 10, 18, 29.

5. Ibid., pp. 13, 20-23, 31-33, 39.

6. Ibid., pp. 40, 61-64.

7. Ibid., p. 39; Janis, op. cit., p. 73.

3.4 SYSTEMS APPROACH

It is evident that any alerting and warning function must be approached from a systematic point of view. This is important in disaster warning; it is critical for a nuclear attack warning system if only because of the potentially short warning time and the wide range of potential devastation. The systems approach must be used to accomplish the following:

1. Alert Signal. A unique signal must be selected. This signal must be meaningful to the listeners. To be effective it must have a single meaning: nuclear attack is imminent.[1] The signal should not allow for ambiguous confusion with other, less critical, signals. The signal selected should be capable of attracting the attention of people in a wide range of indoor situations; presentation should be at effective loudness levels to overcome all masking effects except those of unusually high levels of ambient noise generally encountered indoors only in special working situations. The signal should have a high potential for waking sleeping persons.

2. Warning and Other Messages. Messages must be prepared that stimulate prompt and positive protective actions. Such messages should be simple, clear, and emphatic. If designed to warn of impending attack, the message should indicate the nature of the protective action to be taken, and it should also indicate the effectiveness of taking such action. No doubt should be left in the listener's mind as to his course of action, the advantage of taking that action, or the time at which that action is to be taken.

The alert signal and warning message alone do not constitute a system. In this case we deal with the Radio Warning System, which is capable of transmitting alert and warning directly into home, place of business, transient accomodation, or other indoor location. The Radio Warning System is a national system and, therefore, must perform its functions successfully for a wide variety of locations (urban, suburban, rural), threats (target area, nontarget area), and time sequences (minutes to hours or even days). The national character of the Radio Warning System does make more difficult the creation of a warning environment that will stimulate the entire country to action; in part, the messages disseminated must overcome a multitude of regional and local variations and create a realization that right here, right now there is a need to take protective action. The problem is complicated by the need to use local commercial broadcast facilities (whether part of the Emergency Broadcast System or not) to provide strictly local information; use of these facilities raises the possibility of introducing contradictions into the warning situation that can cancel out any positive move to take protective action that the Radio Warning System may have stimulated.

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1. Chapter Two, Section 4.3.10.

All of these problems are related to an even larger context. The Radio Warning System is ultimately part of the civil defense system. If there is an accepted civil defense plan and organization effective at all levels--federal, state, and local--then possible contradictions among messages and possible negations of the warning can be eliminated. If there is an effective shelter program, then protective action will be feasible. If the plan, the shelters, and the Radio Warning System all exist, a public responsive to the exigencies of a possible nuclear attack can be developed through the combined techniques of training, education, and advertising. A responsive public, a shelter program, the Radio Warning System, effective planning at all levels--each of these appear as a necessary condition for all the others. The impact of each on the selection of warning signals and the design of warning messages will be demonstrated in detail below.

4.0 ALERT SIGNAL

4.1 PREVIOUS ALERT SIGNAL STUDIES

A number of theoretical and practical studies of the effectiveness of alert signals have been made. These have been of limited scope and are generally limited in their applicability to the problem of selecting an alert signal for transmission via the Radio Warning System. A recent study conducted by the Department of Speech, Michigan State University (MSU), however, contains much information directly relevant to the task at hand.[1]

In this study MSU researchers set out to find one or more optimum alerting signals. It is their own conclusion that they did not succeed in specifying the criteria that define the characteristics of the optimum alert signal or signals.[2] Rather, the MSU research determined the frequency, intensity and time ranges within which the developed optimum warning signals should occur. Additionally this research identified a number of signals that were highly effective for alerting. Much of the material on alert signals presented in this study is drawn from the MSU research; however, other sources, as indicated in footnotes, are used as relevant and appropriate.

The MSU researchers tape recorded 400 sounds for evaluation; these sounds consisted of warning signals currently employed, various environmental sounds (including various forms of noise, as well as human and animal sounds), and sounds produced electronically (including those produced by changing playback

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1. Oyer and Hardick, op. cit. The report summarizes most of the relevant prior literature, pp. 12-16.

2. Ibid., p. 3.

speeds of recordings of existing alert signals and environmental sounds).[1] These were reduced first to 113 signals and then to 22 signals through listener judgments of alerting effectiveness in a series of subjective rating tests. All signals were judged on the following scales: warning-nonwarning, bizarre-ordinary, unpleasant-pleasant, and startling-nonstartling.[2] Subsequent tests, also using these same rating scales, were conducted to obtain further judgments of the alerting potential of the various signals. These experiments, conducted under laboratory-controlled conditions, provided: (1) data on signal effectiveness that could be compared with physical measurements of the signals to determine whether relationships existed between the human responses and the physical characteristics of the signals, and (2) a means of reducing the number of signals to those that were most effective for further experimentation.

The 22 selected alert signals were then subjected to a series of field and laboratory studies. Field studies included presentation of the selected signals to groups of school children, housewives, professional people, and skilled workers. The subjects rated the alerting potential of the signals as well as their distinctiveness against various noise backgrounds. Laboratory studies evaluated the effects of the signals upon the reaction time of subjects as well as the effectiveness of the signals to awaken sleeping subjects. Laboratory studies also evaluated the audibility of various signals in different types of background noise. These studies measured the sound pressure level at which each alert signal had to be presented if it were to be detected in any of four noise backgrounds (factory noise, speech babble, traffic noise, and wide-band white noise).

All the signals used in these studies were subjected to spectral analysis. These analyses yielded information on the total amount of energy contained in each of the signals and the distributions of that energy throughout the audio spectrum of the signals examined. The six that proved most effective were:[3]

1. Missile Alarm
2. Yelper Siren
3. British Air Raid Siren--Speeded
4. Falcon Horn #1
5. Car Horns R1 and R2--Speeded
6. Yelper Siren--Speeded

The physical characteristics of these signals are described and frequency analyses of them are presented in Section 4.2.1. (The term speeded, appended to signals 3, 5, and 6 in the above list, indicates that these signals were played back at twice the speed at which they were originally recorded).

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1. Ibid., pp. 2, 68.
2. Ibid., pp. 51-52, 125-126.
3. Ibid., pp. 5, 100.

4.2 SELECTION OF AN EFFECTIVE ALERT SIGNAL

4.2.1 Characteristics of Signals Judged Most Effective in Michigan State University Study

The following descriptions of the six alert signals judged most effective are extracted from the MSU report:

1. Missile Alarm.[1] This signal (see Figure 4-1) is a two-tone jump signal. The lower of the tones has its greatest energy at 640 Hz; the higher, at 1600 Hz. The jump rate is 6 Hz. In addition to the two basic frequency centers, a high-frequency harmonic occurs, centered at 3200 Hz.

2. Yelper Siren and Yelper Siren--Speeded.[2] The yelper siren is an electronically generated, warbled (frequency-modulated) signal. The basic signal (see Figure 4-2) has maximal energy in the one-third octave band centered at 800 Hz. The warble rate is about 4 Hz. The amount of warble (percentage of modulation) is unknown. The signal was recorded outdoors. The speeded signal is obtained by playing back the recording of the basic signal at twice the speed at which it was recorded.[3]

3. British Air Raid Siren--Speeded.[4] This signal (see Figure 4-3) has its maximal energy in the one-third octave band centered 1000 Hz. This is a warbled signal. The basic siren, as used during World War II, has a rate of warble variable from two to six seconds per warble. The rate of warble and amount of warble of the recorded signal is not stated. Again, the speeded signal was obtained by the same method used to produce the Yelper Siren--Speeded (see 2, above).

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1. Ibid., pp. 31, 32.

2. Ibid., pp. 31, 32.

3. A less effective version of this signal was recorded indoors. Ibid., pp. 35, 40.

4. Ibid., pp. 33, 40.

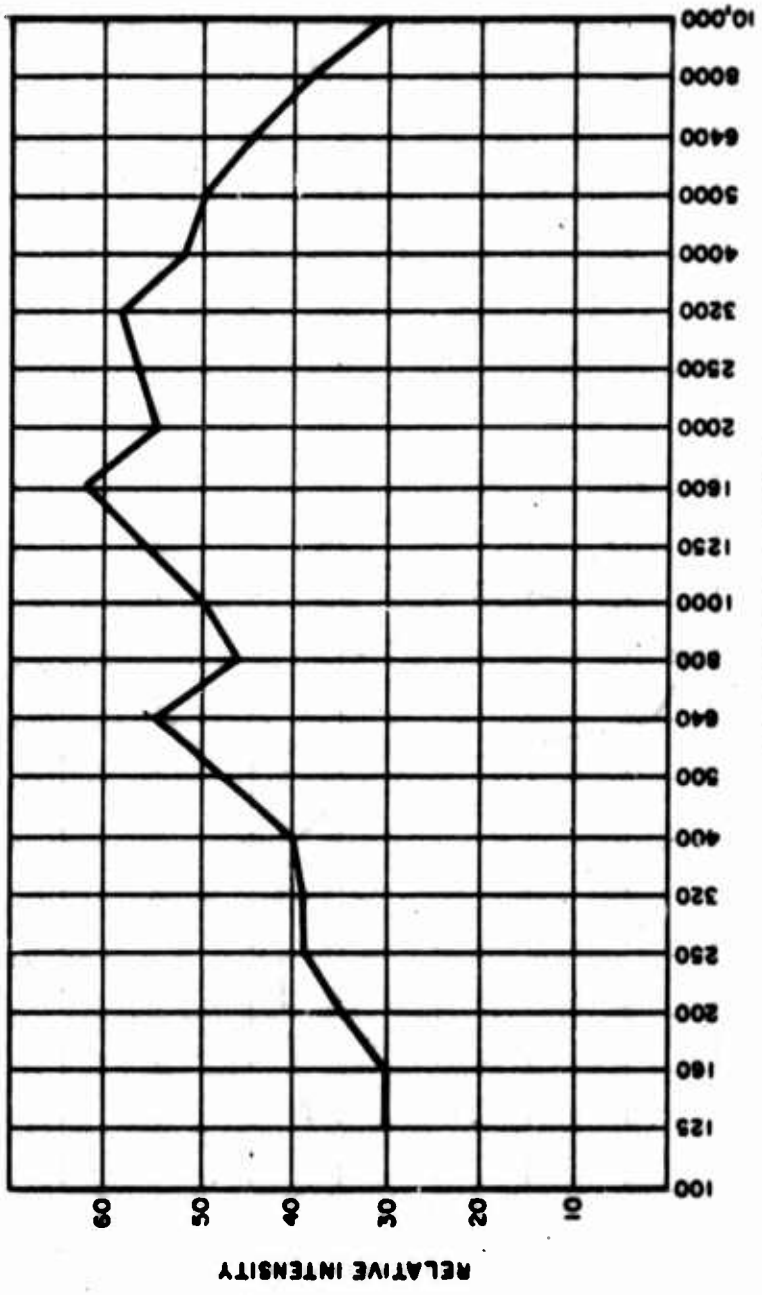


Figure 4-1. Spectral Analysis of Missile Alarm

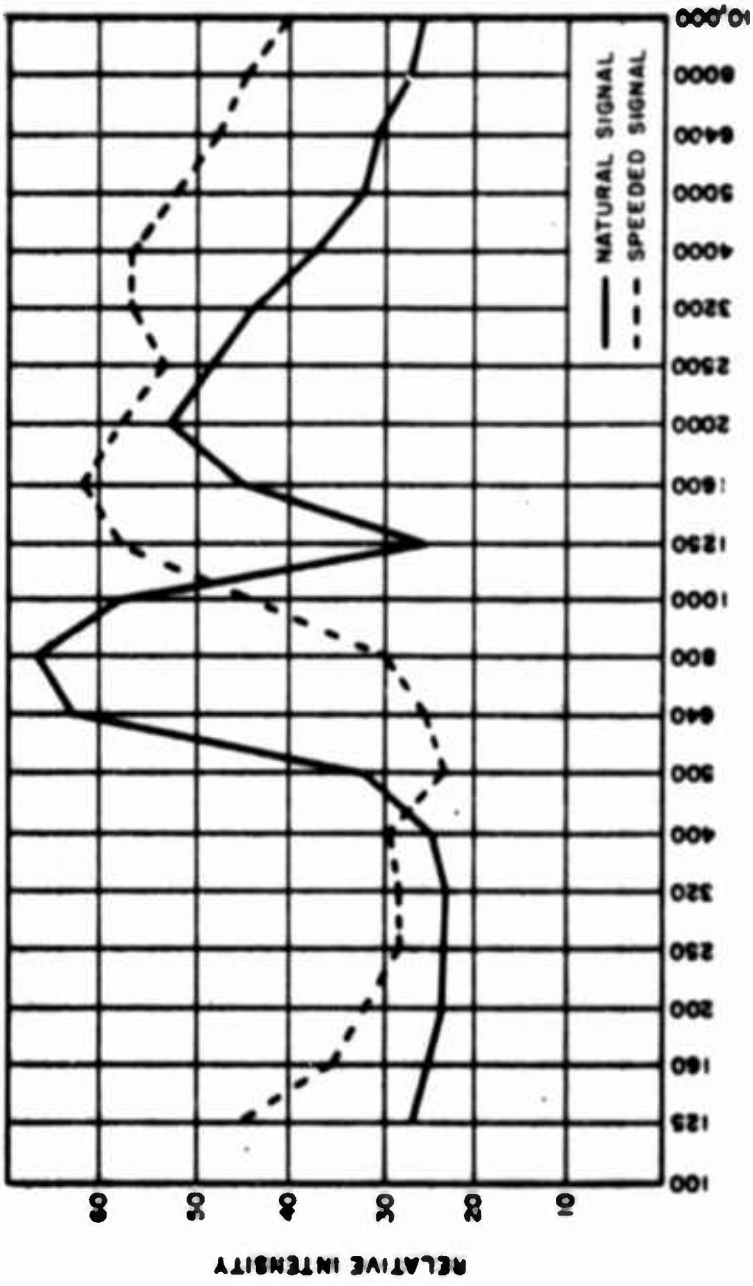


Figure 4-2. Spectral Analyses of Yelper Siren and Yelper Siren -- Speeded

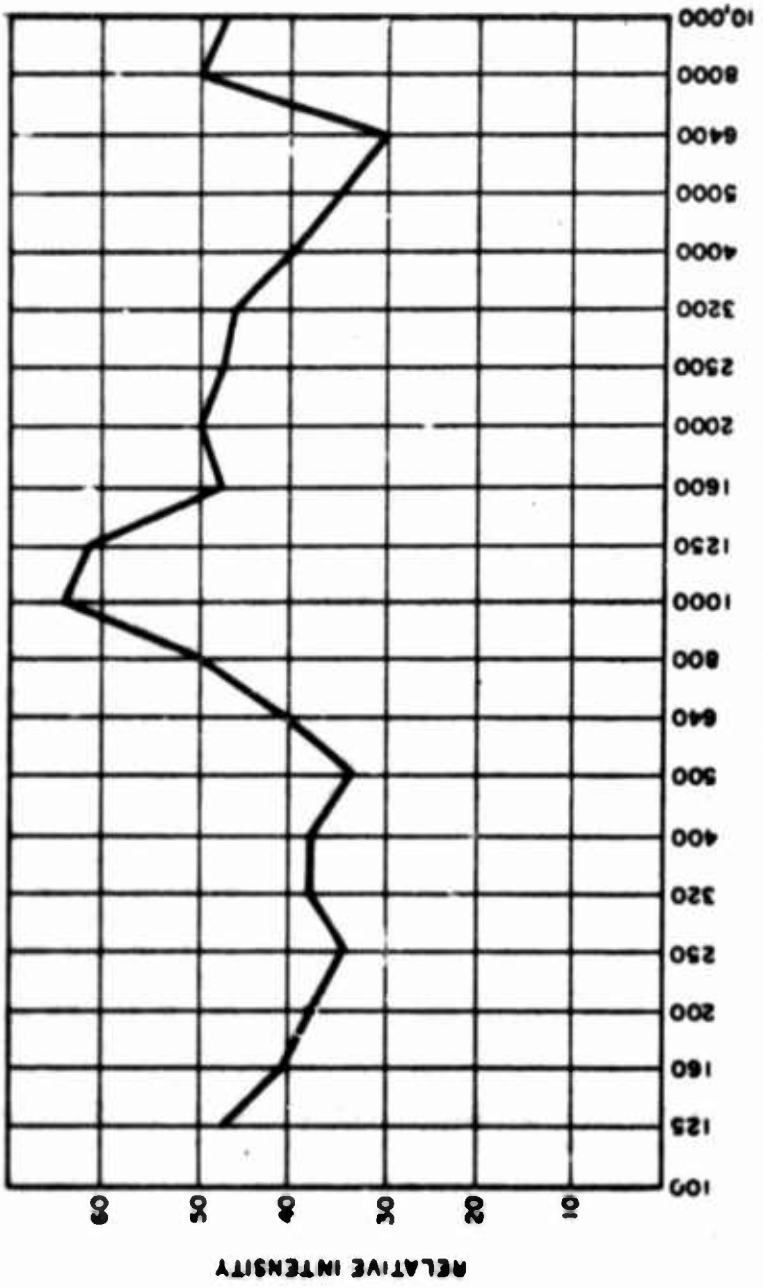


Figure 4-3. Spectral Analysis of British Air Raid Siren -- Speeded

4. Falcon Horn #1.[1] This is a signal recognizably produced by an air horn. It produces a broad-band of high-amplitude components. The recording used was made in a large, hard-surfaced room that was very live; the spectrum of the recording (see Figure 4-4), therefore, may differ from the specifications of the manufacturer.

5. Car Horn R1 and R2--Speeded.[2] The car horns used to produce this signal are from an unidentified, foreign-made automobile. Two horns are used; the one with the lower pitch is operated continuously, while pulses from the one with the higher pitch are superimposed on it. The pulsed horn is operated at a rate of two pulses per second in the initial recording; the speeded effect is obtained by the same method used to generate the Yelper Siren--Speeded (see 2, above). The peaks at 800 and 5000 Hz shown in Figure 4-5 are those of the pulsed horn. The continuous horn has primary energy in the one-third octave bands centered at 2500 and 3200 Hz; a secondary peak occurs at 400 Hz.

4.2.2 Summary of Measures of Effectiveness in Michigan State University Study Considered Significant for Radio Warning System

The MSU researchers derived a summary rank-order of all judgments of alerting potential. In this summary, which reflects the judgments of over 1200 people of various age, sex, and occupation, the six signals discussed in Section 4.2.1 ranked highest. Their rank orders were as follows:

Rank	Signal
1	Missile Alarm
2	Yelper Siren
3	British Air Raid Siren--Speeded
4	Falcon Horn #1
5	Car Horns R1 and R2--Speeded
6	Yelper Siren--Speeded

Several of the individual experiments conducted by the MSU researchers appear to be significant and to warrant further discussion.

4.2.3 Effectiveness in Noise Fields

In one of the MSU studies, 20 laborers in the age range 33 to 55 years listened to the 22 alert signals in a sound field of factory noise.[3] The audio signals

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1. Ibid., pp. 34,40.

2. Ibid., pp. 34,40.

3. Ibid., pp. 94-95.

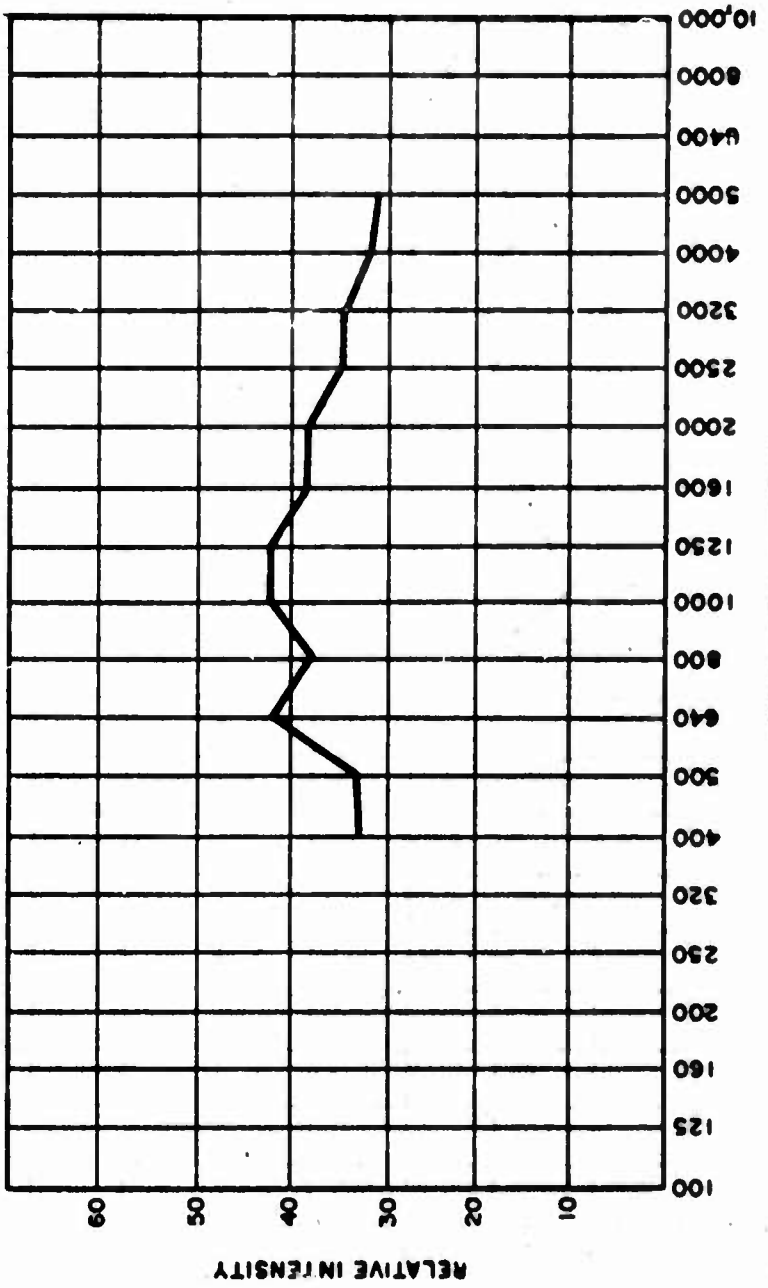


Figure 4-4. Spectral Analysis of Falcon Horn #1

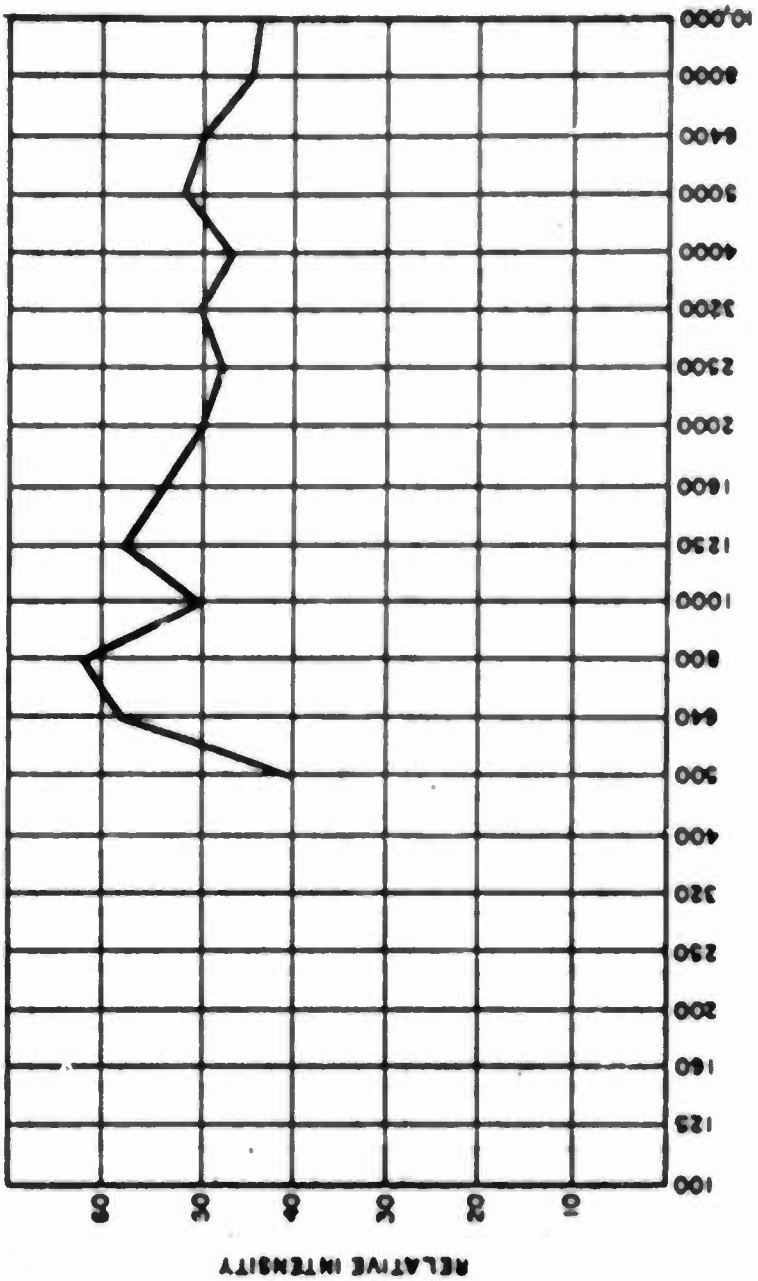


Figure 4-5. Spectral Analysis of Car Horns: R1 and R2 -- Speeded

were presented through earphones at a loudness-level of 90 phons. These signals were in a sound field of factory noise maintained at an average sound pressure level of 85 db at the earphones. The 20 subjects ranked five of the six signals under discussion as follows (total of 22 signals):

Rank	Signal
1	Missile Alarm
2.5	Car Horns R1 and R2--Speeded
4	Yelper Siren
6	Yelper Siren--Speeded
10	Falcon Horn #1

The British Air Raid Siren--Speeded ranked as either 8 or 11; because of a typographical error the term "speeded" is omitted from the appropriate listing.[1] The rank of 2.5 assigned to Car Horns R1 and R2--Speeded indicates that the signal was ranked equally effective as at least one other signal by the subjects. (Note that this was not a test of the subjects' ability to detect the signals, but a subjective judgment of effectiveness on the four scales described in Section 4.1.)

Thirty housewives served as subjects in another similar study of subjective effectiveness.[2] In this study, however, each woman judged the 22 alert signals in their own homes while engaged in routine household activities of her own choosing. The 22 signals were played at a sound pressure level equal to a loudness-level of 95 phons at six inches from the loudspeaker used as the source of the test signals. The loudspeaker was always located in the living room of the subject's home, but the subject was not restricted in her movements to that room. Ambient noise was measured for each environment as was the sound pressure level of each signal. The six signals being reviewed were ranked as follows (total of 22 signals):

Rank	Signal
2	Yelper Siren
3.5	British Air Raid Siren--Speeded
6	Missile Alarm
6	Falcon Horn #1
11.5	Car Horns R1 and R2--Speeded
14	Yelper Siren--Speeded

The average sound pressure level at the subject's ear varied from 66 db to 90 db with a mean of 80 db. The average signal-to-noise ratio was computed for each signal; the mean of these ratios varied from +8 db to +30 db with an

1. Ibid., Table XXVII, p. 95.

2. Ibid., pp. 91-93.

average signal-to-noise ratio of +21 db. The results of this particular test, while interesting, are not statistically significant, since no control was exercised over signal-to-noise ratio. Those signals that rated highest appear to be those that had a good alerting potential were presented at a high signal-to-noise ratio; and were distinctive sounds.

4.2.4 Detection in Noise Fields

In another of the MSU experiments[1] 20 young adults with normal hearing listened to all of the 113 signals that were derived from the original 400 sounds (see Section 4.1). These signals were heard in several noise fields presented at a loudness-level of 80 phons. Each subject was able to adjust an individual attenuator to control the level at which the alert signal was presented. In the experiment, a subject adjusted the level of an alert signal until he determined the threshold for that signal in a particular noise field.

The noise fields were white noise, speech babble, traffic noise, and factory noise. The white noise was a wide-band signal (100 Hz to 10 Hz) without fluctuation in intensity. The factory noise was obtained from a commercial recording, as was the traffic noise. The factory noise was a relatively narrow-band sound, containing maximum acoustical energy below 1200 Hz.[2] In traffic noise the high-amplitude energy was located in the mid-frequency bands between 300 Hz and 4800 Hz, with considerable attenuation above and below these points.[3] Both traffic noise and factory noise fluctuated considerably in intensity, with the former fluctuating up to ± 15 db. The speech babble was obtained by recording the vocal output of 25 people simultaneously reading aloud. This sound presented a somewhat wider band sound than did the factory noise; intensity fluctuations were small, not exceeding ± 5 db.[4]

The detection levels and rankings of the six signals discussed in Section 4.2.1 (against 113 signals) are shown in Table 4-1. Chi-square tests indicate that there is a positive correlation between the mean rating assigned to the 113 sounds in subjective tests of effectiveness and their detection thresholds in speech babble and factory noise; there was no correlation between effectiveness ratings and detection thresholds in white noise and traffic noise. Both white noise and traffic noise are broad-band sounds and tend to produce a random

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1. Ibid., pp. 108-113, 135-146.

2. Ibid., pp. 48, 109.

3. Ibid., pp. 48-49, 109.

4. Ibid., pp. 48-49, 109; there is a minor discrepancy between the description on p. 49 ("wider high amplitude spread") and that on p. 109 ("narrow-band sound").

Table 4-1. Signal Detection vs. Noise*

Summary Rank (Section 4.3.1)	Signal	Factory Noise		Traffic Noise		Speech Babble		White Noise	
		Detection SPL (db)	Rank	Detection SPL (db)	Rank	Detection SPL (db)	Rank	Detection SPL (db)	Rank
1	Missile Alarm	54	21.5	63	44.5	59	36.5	66	74.5
2	Yelper Siren	71	90.5	71	89.5	70	83.5	67	83.5
3	British Air Raid Siren--Speeded	64	61.5	61	33.5	**	**	61	34.5
4	Falcon Horn #1	54	21.5	59	24.5	55	27.5	71	107.5
5	Car Horns R1 and R2--Speeded	40	4.5	56	17.5	49	12.5	66	74.5
6	Yelper Siren--Speeded	62	54.5	71	89.5	67	71.5	69	98.5

Rank - Against 113 other signals in this noise field; decimal values indicate a similar ranking for two or more signals.

*Ibid., pp. 133-146.

**Ibid., pp. 141-142 fails to differentiate between the British Air Raid Siren and the British Air Raid Siren--Speeded (58 db, 32.5 rank; 65 db, 63.5 rank).

(for white noise) or almost random (for traffic noise) effect on threshold as a function of signal pitch. This finding tends to confirm the hypothesis that alerting effectiveness and detectability are both improved by using alerting signals with higher pitches, i.e., those with predominant energy above 1000 Hz at least for indoor alerting. (See Section 4.2.3.)

4.2.5 Effectiveness as an Awakening Agent

In this test 19 male college students with normal hearing served in tests to determine the effectiveness of six of the 22 signals for awakening a sleeping subject.[1] The sounds used were:

1. Missile Alarm
2. Yelper Siren Indoors--Slowed
3. British Air Raid Siren--Speeded
4. Yelper Siren--Speeded
5. Diving Alarm
6. Car Horns R1 and R2--Speeded

Note that signals 2 and 5, above, do not appear in the six discussed in Section 4.2.1; they were not among the six ranked most effective in overall evaluations (see Section 4.1). The designation "slowed" appended to signal 2 indicates that the signal was derived by playing back the original recording at half the speed at which it was originally recorded. Two signals previously discussed are missing from the above list: the Yelper Siren and the Falcon Horn #1.

The six signals were presented one at a time to the individual subjects at intervals during a single night. The order of presentation was appropriately varied from subject to subject. Each signal was presented at a loudness-level of 80 phons. The signal was sounded for a maximum of seven minutes.[2] The subjects were instructed to turn on a small light and to make a subjective judgment of the signal as soon as they were awake. The length of time between the start of the signal and the subject's turning on the light was timed. The results are presented in Table 4-2.[3]

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1. Ibid., pp. 104-107.

2. H. J. Oyer, Michigan State University, Letter to M. I. Rosenthal, System Development Corporation, Subject: Response of Population to Optimum Warning Signal, 6 June 1965.

3. Latency was measured and reported as ranging from 13.43 seconds for the British Air Raid Siren--Speeded to 16.56 seconds for Car Horns R1 and R2--Speeded, Oyer and Hardick, op. cit., p. 106. The exact meaning of these figures is not specified, but they appear to be mean response times for those who were awakened by the signals.

Table 4-2. Effectiveness of Alert Signals for Awakening Sleeping Subjects*

Ranking of Subjective Effectiveness	Signal	Percent of Time Signals Awakened Subjects
1	Missile Alarm	79%
2	Yelper Siren Indoors--Slowed	79%
3	British Air Raid Siren--Speeded	79%
4	Yelper Siren--Speeded	68%
5	Wailing Alarm	68%
6	Car Horns R1 and R2--Speeded	95%

*Ibid., p. 105.

It is interesting that the alert signal that was most effective as an awakening agent (Car Horns R1 and R2--Speeded) was ranked lowest in the effectiveness judgments of the subjects. This contradiction is evaluated in Section 4.2.7.

4.2.6 Alert Signal Recommended for Dissemination via the Radio Warning System

On the basis of the MSU studies reviewed in Sections 4.2.2 through 4.2.5, the only alert signal that can be recommended is Car Horns R1 and R2--Speeded.

This recommendation is based upon information presented in Sections 4.2.2 through 4.2.5:

1. This signal was among the best five as subjectively rated in a series of tests involving over 1200 people.

2. Car Horns R1 and R2--Speeded was among the top three signals as subjectively rated by a group of 20 laborers; this rating was of the sound in a field of factory noise.

3. The signal is highly detectable in ambient noise; it ranks highest of all six alert signals in fields of factory noise, street noise, and speech babble.

4. Car Horns R1 and R2--Speeded is the most effective awakening agent of those tested in a sample of 19 students.

The populations used in several of the experiments are rather small, but the results are derived with apparent scientific caution. These results certainly warrant recommendation of the selected signal for use in the Radio Warning System pending further testing.

The recommendation is based, however, upon more than the research cited above. It is based upon the uniqueness of the signal. The British Air Raid Siren--Speeded is sufficiently similar in overall quality to many sirens, especially those used for civil defense alerting in the United States, that is, it would be virtually indistinguishable from other sirens to most people.[1] The Falcon Horn #1 is virtually indistinguishable from many factory and emergency vehicle horns. The Yelper Siren and the Missile Alarm are known to at least a small portion of the population through occupational connections; far more serious, however, is the use of both signals as well as similar ones as sound effects on television and radio.

The Car Horns R1 and R2--Speeded is a completely novel signal.[2] Though it was derived from two commercial car horns, these horns are used in a special manner (one steady, the other pulsed); the speeding process, furthermore, completely conceals the common nature of the sound source. The signal has not been used as a sound effect. The fact that this signal was a highly effective awakening agent, but was not rated highly by those who were subjects in the awakening test (see Section 4.2.5), tends to substantiate this position. To a considerable extent the subjective rating assigned to alert signals reflect conditioning to certain types of signals. Car Horns R1 and R2--Speeded is not a signal to which the subjects were previously exposed; its effectiveness appears to derive from its high-frequency sound spectrum and from its generally-recognizable horn quality, both of which tend to connote an alerting situation to most people.

The alert signal recommended, therefore, is essentially neutral so far as specific meaning. An effective program of training and education can condition the public to the immediate recognition of a specific danger--nuclear attack. Ineffective use of the signal, however, especially through poorly designed testing programs, can deprive the signal of any effective meaning, or, even worse, can cause the alert signal to connote a meaningless alarm. The signal, itself, is excellent; the meaning given it depends not only upon the Radio Warning System, but is also a function of the entire civil defense program.

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1. Operations Research Office, The Johns Hopkins University, Knowledge and Attitudes Concerning Civil Defense among Residents of the Washington Metropolitan Area, August 1958, February 1960, p. 31.

2. The Yelper Siren--Speeded need not be considered, since it is less effective than the four alert signals discussed above or the recommended alert signal.

4.3 DURATION AND LOUDNESS OF ALERT SIGNAL

The alert signal must be delivered loudly enough for a period of time sufficiently long to attract reliably the attention of a significant segment of the public. The duration and loudness of the alert must be selected for effectiveness under two different circumstances: (1) population awake and (2) population asleep. These two situations are characterized by significantly different circumstances. When the population is awake, the alert signal must compete not only with the noise of daytime and evening activities, but also with various levels of preoccupation with those activities. When the population is asleep, the noise level drops significantly, but the sleeper has more or less isolated himself from the external world; the alert signal must be sounded long enough to bring the sleeper to a level of consciousness that will allow him to operate efficiently.

4.3.1 Problem Areas

There are some problems inherent in determining the duration and loudness of the alert signal for either of these situations. Little work has been done on the problems of using an alert signal to attract the attention of the average individual from a task in which he is involved. Given an alert signal without adequate meaningfulness, test subjects seem readily able to disregard that signal. Thus, presented with an air raid signal in an ambient noise level approximately 67 db, unalerted test subjects performing routine tasks failed to "reveal the faintest externally observable sign of having heard the wailing 'take cover' siren signal, which ran from 42 seconds to well over a minute continously...."[1] Sound pressure levels were as high as 20 db over ambient.

The alert signal selected (see Section 4.2.6), if presented at adequate volume, holds promise of effectively penetrating ambient noise. The meaningfulness of that alert signal, the duration of its presentations, and its loudness together determine the success with which the signal can compete for attention with those activities. The alert signal--as discussed in Section 4.2.6--is completely synthetic and, therefore, its future meaningfulness is entirely a function of the public conditioning developed by the civil defense program.

Some limited information is available to aid in determining the duration and loudness of the signal for awakening a sleeping population. The general problem of awakening has been given only limited attention.[2] Some of the experiments

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1. Theodore Wang, et al., Air Raid Warning in the Missile Era, Operations Research Office, The Johns Hopkins University, ORO-TR-1, July 1960, p. 28. See also pp. 89-93.

2. Nathaniel Kleitman, Sleep and Wakefulness, The University of Chicago Press, Chicago, Illinois, 1963, p. 124.

in awakening sleepers have depended upon stimuli far stronger than the simple alarm signal and voice message (or voice message only) used in the Radio Warning System.[1] Several of the experiments have depended upon stimuli that have a high level of meaningfulness different from any possible in the Radio Warning System; thus the telephone ring, which has its own inherent conditioning, has been used in several studies attempting to determine alert duration for civil defense purposes.[2] No study has been able to simulate the emotional stress of a potential attack-warning situation, but it is clear that perception of the alert by a sleeper is a function of the meaningfulness of the alert to the individuals to be tested.[3] The few studies available do, however, provide useful information upon which to make initial recommendations for alert signal duration and loudness when the objective of the alert is to awaken a sleeping population.

The approach of this discussion is to determine the duration of the alert signal that appears suitable for alerting a sleeping population and to use this time interval for alerting both an awake population and a sleeping population. This decision is predicated upon the assumptions that the system should not be complicated by any attempt to program different day and night messages. It is predicated, even more practically, upon the unavailability of any data that make feasible the selection of a time interval for daytime alerting. The interval selected for nighttime alerting, finally, seems intuitively adequate--given an adequate signal-to-noise ratio--to alert the population during its daytime and evening activities.

4.3.2 Duration Studies Using the Telephone as Awakening Agent

In one of two tests of the responses of a sleeping population to a telephone ring, researchers at the Operations Research Office (ORO) of the Johns Hopkins University called the homes of several hundred ORO employees who had volunteered for the experiment. In this experiment all ORO employees were told that they would be telephoned at some unspecified future date between midnight and 6:00 a.m. unless they specifically requested not to be called. Information was obtained on the number of telephones (including extensions) in the house; the

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1. For example, severe changes of atmospheric pressure (ibid., p. 124); high-intensity fire alarm, flashing light, and electric shock (work of H. L. Williams, A. C. Morlock, Jr., and J. V. Morlock reported in H. L. Beh and P. E. H. Barratt, "Discrimination and Conditioning during Sleep as Indicated by Electroencephalogram," Science, 19 March 1965, 147 (3664), p. 1471)

2. W. A. Hamberg, et al., Study of Tactical Movement Concepts and Procedures for Civil Defense Planning, Operations Research, Incorporated, Technical Report 210, pp. 143-161, 173; Wang, op. cit., pp. 29-33.

3. Beh and Barratt, op. cit., pp. 1470-1471.

location of the telephone nearest an occupied bedroom; and any modification of the telephone ring to give greater or less intensity than is standard.[1] Of the 500 questionnaires submitted, 292 were returned on a timely basis, 232 calls were placed approximately one week later, and 225 useable responses were obtained. The location of the nearest telephone in the 225 cases breaks down as follows: Bedroom--100; room or hall adjacent to the bedroom--102; room on a floor different from that of the bedroom--23.[2]

Table 4-3. Results of Two Experiments Using the Telephone as Awakening Agent*

	Location of Telephone				
	Bedroom	Same Floor	Another Floor	Total	Unspecified
Sample	100	102	23	225	100
Median Time	16 sec.	23 sec.	35 sec.	-	13.8 sec.
% Responses in 30 sec.	91%	75%	35%	77%	92%
% Responses in 1 min.	94%	93%	69%	90%	98%
% Not Answered	4%	6%	17%	6%	-
Maximum Time	(2 min. test limit)	(3 min. test limit)	(4 min. test limit)	-	6 min. 50.4 sec.

* All data derived from Wang, op. cit., pp. 30-31, except for column labeled "Unspecified," which was derived from Hamberg, op. cit., pp. 147, 152, 173.

1. Wang, op. cit., pp. 29-30. Unmodified telephones were determined to have a sound pressure level of 100 to 105 db at 12 inches. Sound pressure levels in the same room varied from 65 to 80 db. Sound pressure levels in adjacent rooms varied from 55 to 65 db. No figures are given for modified telephones or for telephones located on different floors.

2. Ibid., p. 30. Telephones are also divided into standard ring and softened ring, but this information has not been subject to further analysis by ORO researchers and has, therefore, been disregarded in this report.

Response time was regarded as the interval between the time of the first ring the caller heard and the time that the telephone was answered. Time was measured in six-second intervals based upon the ringing cycle (a two-second ring followed by four seconds of silence). Two minutes were allowed for answering the telephones in the bedroom; three minutes in an adjacent room; four minutes on another floor. Failures to answer within these times were recorded as unanswered calls. Table 4-3 records the results of the test.

In another test of the responses of a sleeping population to a telephone ring, researchers at Operations Research, Incorporated (ORI) selected at random 100 residential phone numbers from the Atlanta, Georgia metropolitan telephone directory. These numbers were dialed, without any prior warning, during the period from midnight to 5:00 a.m. in a single day. The response time was measured from the first ringing sound that the caller heard until the first word was spoken by the respondent. As in the ORO experiments, time was measured in six-second intervals. If no answer was received within eight minutes, it was assumed that no one was at home. Three calls fell into this category and alternate numbers were called. Because of the surprise nature of the telephone calls, no information is available on the locations of telephones. The responses obtained are also recorded in Table 4-3.

Though the ORI study includes the element of surprise that is missing in the ORO study, the ORI study lacks the statistical foundations established in the ORO study. For this paper, the assumption was made that the distribution of telephones for the random population selected from the Atlanta telephone directory was similar to the distribution of telephones throughout the homes of ORO employees. A Chi-square proportions test was made between the total ORO responses at 30 seconds and one minute and the ORI responses at the same times. This test tends to establish that the ORO and ORI populations were not statistically different.

A detailed analysis of the ORO and ORI data (excluding those ORO data for telephones on other floors because of small sample size) indicates that the general response of a sleeping population to a telephone ring conforms to a Pearson Incomplete Gamma Distribution.[1]

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1. Milton Abramowitz and I. A. Stegun, Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables, U. S. Government Printing Office, Washington, D. C., National Bureau of Standards Applied Mathematics Series 55, June 1964, pp. 930, 941.

$$P_a = 0.19559t^{0.686} e^{-\frac{t}{12.458}}$$

where:

P_a represents the probability of awakening an individual; and

t represents time in seconds.

Table 4-4 establishes accumulated percentages of a sleeping population that can be expected to respond to a telephone ring in given periods of time.

Table 4-4. Time Response of a Sleeping Population to a Telephone Ring

Awakened (Percent)	Time (Seconds)
50	21
66	30
90	42
95	53
99	75

4.3.3 Recommended Alert Duration

The telephone is an instrument that serves the majority of the population. Approximately 75 percent of all homes have telephones.[1] The telephone is a primary source of both everyday and emergency information (see Section 3.3). It appears that any experiments conducted using a telephone ring as the awakening agent are biased by the degree of positive conditioning established by general reliance upon the telephone. In fact, it appears appropriate to regard responses to a telephone ring as optimal for any general alert signal.

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1. The System Development Corporation, Civil Defense Warning Requirements Study, TM-L-900/001/01, 31 January 1963, pp. 114-115.

The selected alert signal could achieve a similar degree of effectiveness only if a program of training and education effectively conditions the population to the life-saving potential of the information presented over the Radio Warning System.

In addition, it is well known that people can be awakened, perform some simple task or answer a question, and readily fall back to sleep. The alarm clock is frequently treated in this manner. In addition, sleep and waking studies have established that performance immediately upon awakening is poorer than normal.[1]

The information presented in Table 4-4 must be used with considerable caution. There appears to exist in many people--if not in most people--a high level of conditioning for a positive response to a ringing telephone. It is, furthermore, impossible to determine how many of the subjects in the two experiments described in Section 4.3.2 were awakened to the point at which they could have effectively recognized and responded to a warning message. If, however, it is assumed that the population is conditioned to the recommended alert signal to some approximation of the degree it is conditioned to the ring of a telephone, then it appears that the optimum duration of the alert signal for awakening the population from sleep should range from approximately 20 seconds to 75 seconds. It appears desirable, furthermore, to awaken as many people as possible on the first sounding of the alert signal. Achieving as high a level of alert effectiveness as possible on the first alert cycle has the following advantages:

1. It potentially starts the greatest number of people moving to shelter at the earliest possible time.

2. It provides the confirmation of as much repetition as possible to those who are still groggy or who are skeptical.

3. It provides the greatest insurance against premature system failure or destruction.

The last of these reasons seems to be the most compelling. For the reasons given above, and particularly to minimize the impact of early system failure or damage, it is recommended that the objective of the system be to alert 90 percent or more of the population on the first presentation of the alert. The minimum time for the alert is, therefore, approximately 40 seconds.

It is impossible to determine the extent to which the warning message that follows the alert signal will augment the alert signal itself. If it is assumed that the cycle of alert signal followed by warning message is continuously effective as an awakening agent, then a one-minute alert-warning cycle (of which 40 seconds is an alert signal) could be expected to awaken as many

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1. Kleitman, op. cit., pp. 122-124.

as 95 percent of the population. If, however, the warning message is not as effective an awakening agent as the alert signal, than a 40-second alert could be expected to awaken as many as 90 percent of the population. Sounding the alert signal for more than 40 seconds appears undesirable; a longer interval, while it promises to awaken more people, also penalizes those who awakened earlier and are ready to receive the warning message.[1] Anyone not alerted on the first alert-warning cycle or not fully awakened can be alerted in subsequent cycles, assuming that the system remains operative. Because of the possible trade-offs in effectiveness of alert signal and warning message, it is recommended that the alert signal be sounded for 40 seconds each cycle.[2] This duration appears intuitively suitable for attracting the attention of the population during the day.

4.3.4 Recommended Loudness of the Alert Signal

Once again the sleeping population is easier to deal with than the population awake. Recent research into phenomena associated with perception of sound during sleep indicates that the faculties of the sleeper are operative, but that the sleeper disregards the sounds that his auditory system "detects."[3] As in the case of the alert signal duration, the critical factor seems to be meaningfulness of the signal to the auditor. It is possible, for example, for the mother to sleep soundly in a relatively high ambient noise field, but to awaken at the cry of one of her children. In the ORC test using the telephone ring as the awakening agent (see Section 4.3.2) sound levels as low as 55 to 60 db (and even lower) effectively awoke those called.

Given the higher noise levels of the daytime and evening, the signal has to be presented loudly enough to penetrate the ambient. MSU researchers discovered, in subjective tests to rate alert signals (see Section 4.1), that perceived loudness is the major determinant of judged alerting potential.[4] It is clear that the annoyance value of a sound increases as the loudness of that sound increases.[5] Finally, in noise, the more positive the signal-to-noise ratio, the more favorably test subjects judged alerting potential.[6]

The average noise level in a home that has a radio, television set, or phonograph operating is approximately 50 db. (The figure is quoted with a radio, television set, or phonograph operating, since this appears to be more typical of current noise levels in the home.) Noise in small businesses runs, on the

1. It must be emphasized that the goal of alerting at least 90 percent of the population is arbitrary, but appears to be intuitively effective.

2. It is possible that on alert cycles subsequent to the first cycle the alert signal can be reduced to 20 seconds; this approach warrants further investigation.

3. Source: Telephone call to Nathaniel Kleitman, 8 July 1965; Beh and Barratt, loc. cit.

4. Oyer and Hardick, op. cit., p. 5.

5. Ibid., p. 15.

6. Ibid., p. 54.

average, from 53.5 to 68.5 db.[1] These figures of approximately 50 to 65 db, therefore, set the minimal level of presentation for an alert signal. The limit upon the upper range of alert signal level is approximately 130 db, the point at which damage may possibly be done to a listener's hearing.[2]

The alert signal, therefore, should be presented at a level somewhere between 50 and 130 db. On the basis of overall research studies, MSU researchers conclude that the alert signal should be presented so as to provide a sound pressure level of 80 to 100 db at the listener's ear.[3]

Limited experimentation at System Development Corporation indicates that the recommended alert signal should be presented at a sound pressure level of 90 db at 10 feet. While the effort expended in this area has not been conclusive, it appears evident that the loudest alert signal has the greatest alerting potential. It is recommended, therefore, that this sound pressure level be used in presenting the Car Horns R1 and R2--Speeded so as to assure adequate loudness for that specific alert signal in a wide variety of homes.[4]

5.0 MESSAGE FORMATS AND CONTENT

5.1 PERCEPTION OF SPEECH

Once the alert signal that precedes the tactical warning message has attracted the attention of the potential listener, it is reasonable to assume that he will pay some attention to the verbal message that follows. If the alert signal is a meaningful danger signal to a listener because of prior conditioning, then his response will be purposeful; if necessary, the listener will attempt to improve the intelligibility of the message by moving closer to the receiver, turning off competing sources of sound (radio, TV, machinery), closing the window to eliminate street noises, interrupting his conversation, or some combination of similar activities.

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1. Frank Inderwiesen, Alarm Requirements for NEAR System Receivers, Midwest Research Institute, no date, p. 5.

2. Ibid., p. 12.

3. Oyer and Hardick, op. cit., p. 5. This recommendation assumes that the alert signal incorporates other necessary characteristics such as the appropriate frequency components and the appropriate level of auditory complexity. The recommended signal meets these criteria.

4. Technical problems in generating the recommended sound pressure level in a small, inexpensive warning receiver remain to be solved.

The problem of speech perception is further simplified by the nature of speech itself. A verbal communication is inherently resistant to distortion. Apparently no single characteristic of speech is, by itself, critical. The types of distortion that alter the listener's ability to respond correctly are those that significantly change the frequency-intensity-time pattern of the message. The resistance of this pattern to such distortion makes effective communications possible under difficult conditions.[1] The resistance that speech displays to distortion stems from the high redundancy inherent in verbal communications.[2]

A comparison of the sounds, syllables, or words recorded by a listener with those originally spoken results in a value--called articulation--showing the percentage of the sounds, syllables, or words interpreted correctly.[3] Intelligibility is, in turn, the measure of the ability of a listener to understand the message that he hears.[4] Tests indicate that sound articulations between approximately 66 percent and 70 percent result in an intelligibility in excess of 90 percent; sound articulations of approximately 50 percent (44-56 percent) result in an intelligibility of approximately 57 percent; and sound articulations between approximately 19 percent and 41 percent result in an intelligibility of approximately 22 percent. (The performance of a system in terms of syllable articulation remains adequate at even lower articulation percentages).[5] It is apparent that the performance of a channel (as measured by the intelligibility of messages transmitted over it) can be considerably degraded (as indicated by the articulation of messages transmitted over it) before it becomes marginal; once the marginal level has been reached, however, further decreases in performance tend to be rather rapid.[6]

In a warning system the recipient of warning may be handicapped by the emotional stress under which the danger places him. It seems reasonable to make the warning channel as good as possible in order to minimize any reduction of intelligibility--and comprehension--that may result from use of a poor or even a marginal channel. Thus, for example, the narrower the available bandwidth of the channel, the greater the loss of intelligibility. It is evident that the

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1. J. C. R. Licklider and G. A. Miller, "The Perception of Speech," in S. S. Stevens, ed., Handbook of Experimental Psychology, John Wiley and Sons, Inc., New York, 1951, pp. 1068-1070.

2. Ibid.; J. D. Griffiths, Speech Communications from an Information Theory Viewpoint, Doctoral Dissertation, Syracuse University, January 1965, pp. 17-19.

3. Harvey Fletcher, Speed and Hearing in Communication, D. Van Nostrand Company, Inc., Princeton, N. J., 1953, p. 278.

4. Ibid., pp. 299-301.

5. Ibid., pp. 294-5.

6. Ibid., p. 302.

bandpass of a simple radio receiver (which is assumed to be at least 400 to 4,000 Hz) is adequate for the reliable transmission of warning messages.[1] Reduction of bandwidth to perhaps 2,000 Hz on low-frequency channels is being considered for the Radio Warning System, but such a reduction should be avoided unless it is absolutely unavoidable from the standpoint of either economy or spectrum utilization.

The sound pressure level at which the message is presented is also relatively uncritical. There appears to be an optimum for a voice message delivered over any communications system.[2] Below this optimum level an increasing number of speech components fall below the threshold of audibility; above this optimum level the ear tends toward fatigue. Limited experimentation at the System Development Corporation indicates that the sound pressure level of a warning message should be approximately 75 db.[3] Beyond this point the distortion inherent in a loud voice message sounded through a variety of small radio speakers became very annoying, perhaps because of the fatigue factor mentioned above.

A more critical factor that must be considered in assuring the quality of the message delivered to the public is the speed of delivery. Laboratory experiments have established 120 words per minute as the optimal rate of delivery.[4] This rate of delivery is used in the time calculations associated with the proposed messages.[5]

The final factor that must be considered in preparing warning messages is highly qualitative. A verbal message carries considerable information about the speaker. Studies have indicated that listeners often agree among themselves that an unseen speaker seems to be what he is not; these studies have often resulted in attributing qualities to a speaker with a consistency significantly greater than chance,

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1. M. Y. McCormick and Kiriako Sarlanis, Intelligibility of Automatic Broadcasts vs. Live Messages, Federal Aviation Agency, National Aviation Facilities Experimental Center, RD-64-122, October 1964, p. A-2; Licklider and Miller, op. cit., pp. 1056-1057.

2. For a telephone system this is 68 db. Fletcher, op. cit., p. 325 and passim.

3. Chapter Two, Section 4.3.4.

4. Licklider and Miller, op. cit., pp. 1067-1068; McCormick and Sarlanis, op. cit., pp. A-4 through A-5.

5. This rate of delivery was checked by repeatedly reading the messages against a stopwatch in an emphatic manner suitable for a clear, impressive message.

but in the wrong direction.[1] Stereotypes are common; not all the listener's information depends upon the speaker's choice of words. The mechanisms and limits of this process are unknown, and, therefore, care must be exercised to assure that the delivery of the prerecorded message does not weaken the anticipated effect of the verbal content of the message.

5.2 GENERAL CHARACTERISTICS OF MESSAGES DISSEMINATED BY THE RADIO WARNING SYSTEM

While some experimentally valid data are available on the effectiveness of alert signals (see Section 4.0), virtually no guidelines are available for the effective design of message format or content in a system designed to warn of impending danger. This lack of information on warning message design is not limited to systems, such as the Radio Warning System, designed to warn of a nuclear attack, but also characterizes the current state of disaster warning. While experience with nuclear attack is limited to the two low-yield weapons used against Japan, first-hand experience with disaster is extensive. It is, in fact, disaster research that provides the useful clues to the problem of designing warning messages. It must be recognized, however, that these clues must be used cautiously. Disaster research is often anecdotal, and it is often possible to contradict the experiences of one disaster with those of another. Extrapolations from the most devastating disaster to a nuclear attack, furthermore, may be highly questionable.

Lacking better bases for developing messages for the Radio Warning System, guidelines have been derived from disaster studies and have been intuitively applied to the problem of attack warning. (Typical disaster experiences have described in Section 3.0.) It must be emphasized, once again, that the messages proposed are merely a starting point upon which further developmental efforts employing experimental techniques and attitude surveys, can be based. Such further development can take place continuously, if necessary, even after the Radio Warning System is operational because (1) the most critical message--that warning of an attack--will not be communicated to the public, except in a false alarm, until the system has to be used for its ultimate function, and (2) any changes in messages that do reach the public--such as test messages--will be selfexplanatory.

Of the various pretaped messages proposed in Section 2.3, the most critical is the tactical warning message. Since this alert-warning sequence will presumably be used only for warning of an imminent nuclear attack, response to it is

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1. Licklider and Miller, op. cit., pp. 1070-1071; S. E. Stuntz, Speech-Intelligibility and Talker-Recognition Tests of Air Force Voice Communication Systems, Electronic Systems Division, Air Force Systems Command, ESD-TOR-63-224, February 1963, p. 2.

extremely time critical. The recipient must be galvanized into taking effective protective action with little time available for the confirmation, evaluation, and decision processes so often associated with emergency responses.

Any warning message, to be effective, must provide the recipient with information about (1) the existence of danger, and (2) the steps that can be taken to prevent, avoid, or minimize the danger. In the case of a tactical warning delivered by the Radio Warning System, the information must clearly identify the imminence of a nuclear attack and get the recipients to shelter on a timely basis.

An effective warning message should have the following attributes:

1. Official. The message should represent to the recipient the official policy of the warning agency. In the case of tactical warning, this warning agency is the federal government.

2. Impressive. The warning should not be easily ignored. The danger inherent in the impending situation should be explicit. In part the effectiveness of the message itself can be favorably augmented by the prior presentation of a suitable alert signal. The import of the warning can also be increased by effective delivery. Repetition, even verbatim repetition, can further increase the impressiveness of the warning.

3. Unequivocal. The message should be simple, clear, and direct. It should, furthermore, allow no possibility of inconsistent interpretation; any instruction given should be completely consistent and noncontradictory.

4. Personal. The message should convince the recipient that he personally is in danger and that the protective action prescribed applies directly to him.

5. Balanced. In order to produce effective action, the message must balance the danger of attack with the protection afforded by taking the appropriate action. Failure to do this may produce ineffective, maladaptive action or may result in an apathetic rejection of any action.

The tactical warning message is a true warning message: it warns of a specific threat (nuclear attack) for which specific protection is available (fallout shelters). Additionally a tactical warning is time critical; an effective response to it must be prompt. In order to encourage an effective response, the tactical warning message must have the attributes listed above. The other messages disseminated by the system are not true warning messages; rather, they

are announcements of specific conditions warranting public attention. The tactical warning message and the other messages disseminated via the Radio Warning System are described in detail in Sections 5.4 through 5.7.

5.3 RULES FOR MESSAGE FORMATS

Certain rules have been devised for formatting messages. These rules are intuitive and have not been subjected to laboratory testing. These rules have been applied as consistently as possible to all messages.

1. Message Flags. These are one or two attention-getting words that identify the general character of each type of message. They are similar in function to a message header in communications. Each word or group of two words is repeated twice. The flags used are ATTACK--ATTACK (tactical warning message), EMERGENCY--EMERGENCY (strategic warning message), FALSE ALARM--FALSE ALARM (cancel false alarm message), and TESTING--TESTING (both types of test messages). Repetition of the flag is used to add emphasis to the message where appropriate; this is particularly true of the strategic warning message, which, if it has to waken a sleeping population, will have to do so without the aid of an alert signal.

2. Start-Stop Emphasis. Wherever possible, key words are placed at either the start of a sentence or at the end of a sentence. In all cases key words are placed at the end of a message. Thus, the final words of the test message are...THIS HAS BEEN A RADIO WARNING SYSTEM TEST. This structure is based upon the necessity of attracting the potential auditor's attention as quickly as possible (location of key words at the start of a sentence) and the suspicion that some potential listeners may not pay full attention to a warning until late in the message.

3. Redundancy. In addition to the redundancy inherent in any spoken message,[1] there are two types of redundancy built into the Radio Warning System messages: redundancy within each message and redundancy through repetition of complete messages.

   Because the listener may not be paying full attention to a warning, because of noise in the listener's environment, because of interference in the radio link to the listener, redundancy within a message is essential. Arbitrarily, double redundancy is employed as a compromise between reducing the impact of confusion and interference, on one hand, and delaying completion of the warning to

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1. Licklider and Miller, op. cit., pp. 1068-1070; J. D. Griffiths, op. cit., pp. 17-19.

those who are neither confused nor bothered by interference, on the other. Some information critical to a message may be repeated in the context of an instruction as well as within the complete repetition of the instruction. In some cases redundancy is obtained by exact repetition, while in others redundancy is achieved by repetition of the same statement in different forms, generally to achieve start-stop emphasis. Some special instructions, however, (such as those for locating an operating radio station in a strategic warning message, Section 5.5) are not repeated. Several instructions are repeated three times in order to increase the length of a short message (for example, the cancel false alarm message, Section 5.6).

In addition to redundancy within each individual message, there is further redundancy in the operation of the system: a message can be repeated endlessly as long as the system operator feels that repetition can rouse more people to take the correct protective action.[1] Each repetition has the potential of overcoming the confusion of additional people. Each repetition increases the chance of getting through any interference in the radio link to the public. Each repetition can act as a psychological reinforcement of the initial warning, persuading more and more skeptical people by the continued repetition of the message that it cannot be a false alarm.

While these rules merit further testing and evaluation, they do provide interim guidance for formatting warning messages. Use of these rules results in greater uniformity from message to message than would be possible without them.

5.4 TACTICAL ALERT AND WARNING MESSAGE

Table 4-5 contains the proposed tactical alert and warning message. It is recommended that the verbal portion of the message be presented at a sound pressure level of 75 db at 10 feet; it is recommended that the alert signal be presented at a sound pressure level of 90 db at 10 feet (see Section 4.3.4).

5.4.1 Establishing the Official Character of a Tactical Warning

The official character of the tactical alert could be indicated verbally. The message could contain the information that: THIS NUCLEAR ATTACK WARNING HAS BEEN ORDERED BY THE PRESIDENT OF THE UNITED STATES. The warning might be attributed, with greater accuracy, to the Commander-in-Chief NORAD, but he is harder for the general public to identify as a responsible authority. The delivery time for such an official "certification" of the message takes valuable time (approximately seven seconds for the one quoted above) that can be better used in taking protective action. These words, furthermore, may be lost on many recipients, who need confirmation from more localized, tangible sources.[2]

1. Chapter Two, Section 4.3.11.

2. Williams, op. cit., pp. 94-96.

Table 4-5. Proposed Tactical Alert and Warning Message

Item	Content	Word Count	Time (Sec.)
1	(Alert Signal)		40*
2	ATTACK--ATTACK	2	
3	THE UNITED STATES IS UNDER NUCLEAR ATTACK	7	
4	I REPEAT--THE UNITED STATES IS UNDER NUCLEAR ATTACK	9	10
5	GO TO SHELTER	3	
6	GO TO SHELTER IMMEDIATELY	4	
7	YOU ARE IN DANGER--YOU CAN SAVE YOUR LIFE IF YOU IMMEDIATELY GO TO SHELTER	15	11
	Total	40	61

*See Section 4.3.3.

Therefore, it appears appropriate to depend upon the system itself for the officialness of the message. This can be partially achieved through use of the appropriate identifying symbols, especially the OCD emblem, on the warning receiver. More important, however, is the actual identification, by the public, of the Radio Warning System and its messages as the source of official warning information. This can be achieved only through (1) design of effective test procedures that will prevent the system from being associated with trivial information; (2) incorporation of adequate reliability into Radio Warning System components to keep false alarm failures to an acceptably low level; and (3) training and education to encourage the identification of Radio Warning System messages as authoritative.

5.4.2 Making a Tactical Warning Impressive

The tactical warning message delivered by the Radio Warning System can be made impressive. The use of an alarm coupled with a voice message is an attention-getting combination. The voice message, furthermore, can and should be delivered in a manner that connotes the urgency of the warning.

A direct assessment of the hazard such as YOU ARE IN DANGER--YOU CAN SAVE YOUR LIFE BY IMMEDIATELY TAKING SHELTER can contribute to the impressiveness of the warning. It must be pointed out that it is impossible to determine at this time whether a more specific formulation such as YOU ARE IN DANGER FROM FALLOUT, YOU ARE IN DANGER FROM RADIOACTIVE FALLOUT, or YOU ARE IN DANGER FROM NUCLEAR FALLOUT will increase the effectiveness of the message. The most general alternative, simply, YOU ARE IN DANGER, was selected somewhat arbitrarily to protect the recipient of warning from the limitations of his knowledge. If the only source of danger is identified as fallout, a little knowledge may be dangerous, leading to postponing the move to shelter until some time at which the recipient believes fallout will arrive. The vagueness of the form used may itself lead some listeners to fearfulness about the unknown nature of the threat. However, this vagueness is probably offset by the earlier statement: THE UNITED STATES IS UNDER NUCLEAR ATTACK.

It must also be pointed out that the warning could also be made more impressive by using a formulation such as YOU AND YOUR FAMILY ARE IN DANGER. This form was not used because it seems likely to touch raw nerves and to delay taking protective action. Large numbers of families may be divided at the time of a tactical warning; a daytime alert might find a husband at work, his wife at home, their children at one or more schools. Natural disaster experience seems to indicate that families tend to take protective action together and that members of separated families often defer taking effective action by attempting to locate each other.[1]

These types of problems cannot be resolved within the Radio Warning System, but ultimately devolve upon the total civil defense system. While it is possible to adjust the content of the Radio Warning System tactical warning message endlessly, the basic problem of conditioning the public to a positive response to the possible consequences of a nuclear threat can only be accomplished through a significant training and conditioning program.

5.4.3 Providing Unequivocal Instructions

The short time available for delivery of the warning makes an unequivocal message imperative. It should, furthermore, avoid any complexity or sophistication in vocabulary, sentence structure, and verbal presentation that would confuse any listener with intelligence and schooling adequate for routine activity in the everyday world.

The national character of the Radio Warning System and its messages raises problems with the actual instructions given to the public. Three approaches have been examined. These are: (1) TURN ON YOUR RADIO FOR INSTRUCTIONS AND PREPARE TO GO TO SHELTER; (2) TURN ON YOUR RADIO FOR INSTRUCTIONS; and (3) GO TO SHELTER.

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1. Williams, op. cit., p. 95; Moore, op. cit., pp. 57-58.

1. TURN ON YOUR RADIO FOR INSTRUCTIONS AND PREPARE TO GO TO SHELTER. While this instruction does provide for those who do not know what to do (TURN ON YOUR RADIO) and for those who do (PREPARE TO GO TO SHELTER), the coupling appears undesirable. It commands two different actions, one active (preparing to go to shelter) and one passive (listening to the radio). It does not instruct those already prepared to go now, but leaves this up to their imaginations and up to the radio, once it is turned on. Other formulations (such as TURN ON YOUR RADIO AND GO TO SHELTER) are even less adequate, since the instructions are directly contradictory.

2. TURN ON YOUR RADIO FOR INSTRUCTIONS. This is a more desirable alternative than that discussed above, because it states a single instruction. This instruction directs people to a second information channel, their radio, and provides a highly desirable confirmation outside the Radio Warning System of the impending attack; it also provides them a means of rapidly detecting a false alarm before a cancel message can be transmitted. The instruction provides for extreme flexibility in controlling public responses, since the desired protective actions can be disseminated by each community having a broadcast station that interfaces with the Radio Warning System. This instruction could allow for a delayed move to shelter in areas not likely to be targets and not near likely targets. Such a delay would allow for better use of the longer shelter-access time especially for more thorough preparation of individual shelter kits; but this "advantage" is based upon the dubious assumption that the local civil defense agency has reliable information that its area is not going to be subjected to a direct attack and that it can predict reliably the time of arrival of fallout, and furthermore contradicts OCD policy that all parts of the nation are under a common threat.

   Furthermore, reference to the radio may allow for guidance about the mode of transit to be used in going to shelter. In a mixed urban, suburban, and rural area, however, shelter access may involve travel on foot, by auto, or by a combination of both; in such cases, the same time limit that is imposed upon the Radio Warning System applies to the local broadcast station.

   The instruction to turn on the radio does allow a local override in case of inclement weather so severe as to make shelter access questionable or dangerous; but this contradiction of natural hazard and nuclear hazard is likely to restrict shelter access, though it may do so at the cost of considerable mental stress.

Finally, and most significantly, the instruction to turn on the radio or TV adds an extra step to the warning process and increases the time required to secure an effective response to a tactical warning.

3. GO TO SHELTER. This instruction commands a response that may be selfinhibiting in that people may attempt to reject any instruction that promises to limit and confine their freedom of motion or their access to escape routes that might be used for evacuation.[1] This instruction, however, if responded to promptly, is exactly the one that can save the recipient's life. It is the instruction that promised the shortest response time if--and, unfortunately, only if--the recipient is trained to the extent that he knows where his shelter is, how to get there, and what to take with him.

If the high level of civil defense knowledge and the ready accessibility of shelter assumed in Section 1.4 of this document are developed concurrently with the Radio Warning System, then the instruction to GO TO SHELTER is the most desirable protective instruction to be used in the Radio Warning System tactical warning message. If those assumptions are not realized, however, as might be the case if warning receivers were marketed on a strictly commercial basis as a money-making effort by one or more radio-receiver manufacturers, then the instruction to TURN ON YOUR RADIO FOR INFORMATION would have to be recommended for the degree to which this instruction would, within obvious time constraints, allow local confirmation, reinforcement, and direction.

5.4.4 Making the Tactical Warning Message Personal

The message delivered by the Radio Warning System can be personalized only to a limited extent. The manner of presentation and the tone of voice in which the message is read (see Section 5.4.2), as well as the use of common forms of speech and simple words (see Section 5.4.3) can all contribute to a recipient's feeling of personal danger and to his need to take protective action. Perhaps the strongest personalization is in the form of direct address to each recipient: YOU ARE IN DANGER--YOU CAN SAVE YOUR LIFE....

Direct address, however, is not a substitute for the personalization that the Weather Bureau, for example, has achieved in hurricane warnings: the path of a hurricane can be predicted with precision adequate to permit a person to know

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1. Jenis, op. cit., pp. 76-77.

whether his town and, by implication, his house will be struck.[1] Unfortunately it is not possible to predict the results of a nuclear attack with any comparable level of accuracy. Even if it were possible to predict the targets in a nuclear attack, the national character of the Radio Warning System militates against providing this information to the public. It is questionable, furthermore, whether it would be desirable to provide the information to the inhabitants of a city that they were in a target area unless evacuation were possible or blast protection available; the information could be demoralizing to residents of outlying areas of targets who might otherwise be protected by use of fallout shelters.

The limited degree of personalization available from the Radio Warning System places the burden for this function on another element of the total civil defense system--the broadcasting station that provides local information to a particular locality. While the broadcasting station in the locality has no more reliable information on the fate of that locality than does the Radio Warning System, the area station can be used by local officials to authenticate and reinforce the critical nature of the alert. For example, a strong statement by the local mayor, instructing the people in his area of responsibility to take shelter immediately, can support--can personalize--the alert for the members of his community. There are, however, problems and pitfalls inherent in this interface between the Radio Warning System and the local station.

Getting people not listening to their radios or TV sets to turn them on is a significant problem. In Section 5.4.3 the problem of noncontradictory information was discussed leading to the recommendation that a single instruction be formulated: TAKE SHELTER. Ideally it is desirable for the community to respond to the Radio Warning System by doing just that, but some people will inevitably be confused. There appear to be three standard sources of information that people tend to rely upon in an emergency: (1) neighbors, friends, and family; (2) the telephone (sometimes to call other individuals, sometimes to call some official or unofficial agency); and (3) radio and TV.[2] Prompt and effective use of line-load control by the telephone common carriers, where that capability exists, can restrict access to the telephone; training must serve to minimize the use of the telephone where line-load control is not available. Commercial radio and TV remain as the key sources of reinforcing and amplifying information. This availability of broadcast media as additional channels for warning information requires that the local station respond virtually as quickly as the Radio Warning System and that its information be in close accord with that in the

1. Williams, op. cit., p. 97

2. Jiri Nehnevajsa, The NEAR System: A Study of Public Acceptance (DRAFT), University of Pittsburgh, February 1964, p. 77; Mack and Baker, op. cit., pp. 13, 21, 31-32.

prerecorded tactical warning. The Radio Warning System will be undermined if the instruction to TAKE SHELTER IMMEDIATELY is countermanded by a local message that plays down the immediacy of the threat.

The personality of the local mayor--to speculate further upon the hypothetical example developed above--can become quite critical: If the mayor is unpopular or in disfavor with his community, the attempted reinforcement of the Radio Warning System may compromise the effectiveness of the tactical alert; or if the mayor betrays signs of fear or doubt either in his words or in the delivery of his message the effectiveness of the alert may also be compromised.[1]

As in Sections 5.4.1 through 5.4.3, the problems can only be partially solved by the design of the Radio Warning System or its messages. Prompt reinforcement of the Radio Warning System by the local broadcasting station can be accomplished through the use of prerecorded messages. The content and delivery of these messages can also be controlled at least to some extent by use of prerecorded messages. The promptness of the broadcast station's response and the effectiveness of the messages it broadcasts are ultimately governed by the success of OCD in gaining local support for the Radio Warning System, the policy of immediate shelter access, and the preplanning of message content and delivery (including the use of prerecorded tapes).

5.4.5 Achieving Balance in the Tactical Warning Message

As pointed out in Section 5.2, an effective warning must demonstrate the existence of danger and indicate the protective measures available to cope with the danger. An inordinate emphasis on the danger may cause maladaptive behavior (apathy or fear). Undue emphasis upon safety and protection may cause other forms of inappropriate behavior (lack of responsiveness to the need to use available protection). The message formulated attempts to strike a balance between danger and protection in order to encourage the public to prompt use of shelters. Thus the threat THE UNITED STATES IS UNDER NUCLEAR ATTACK is balanced by the protective instruction TAKE SHELTER. Similarly, the statement YOU ARE IN DANGER is balanced by the statement YOU CAN SAVE YOUR LIFE BY IMMEDIATELY TAKING SHELTER.

The use of the expression THE UNITED STATES IS UNDER ATTACK was considered as an alternative to the expression THE UNITED STATES IS UNDER NUCLEAR ATTACK. The latter was chosen somewhat arbitrarily in the hopes of being more specific and in using whatever emotional value the term NUCLEAR carries with it. (See Section 5.4.2). The implied promise of safety in YOU CAN SAVE YOUR LIFE... may lead to emotional problems, possibly severe ones, among those who do take shelter

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1. Janis, op. cit., pp. 73-74, 77; B. B. Hudson, "Anxiety in Response to the Unfamiliar," Journal of Social Issues, July 1954, 10 (3), pp. 53-60.

and discover that all those who took shelter (either with them or in other shelters) do not survive. Any weaker formulation appears likely to be less effective in bringing people into shelter. Thus a statement YOU MAY SAVE YOUR LIFE... appears likely to introduce an element of doubt in the efficacy of the available protection. Such an element of doubt may delay the decision of people to take shelter. Until the impact of such subleties is evaluated in controlled laboratory tests, it is recommended that a strong formulation be used: YOU CAN SAVE YOUR LIFE BY IMMEDIATELY TAKING SHELTER.

5.5 STRATEGIC WARNING MESSAGE

The strategic warning message is not a true warning message: it only warns of a generalized emergency and, therefore, cannot prescribe specific protective measures (see Section 5.2). The response of the auditor generally need not be so timely as his response to a tactical warning. The strategic warning message should be official and unequivocal; but it cannot be personal, impressive, or balanced, at least as these terms have been defined in Section 5.2. Because of the lack of a specific threat, balance is impossible; consequently the message must play down the impressiveness of a warning over the warning receiver in order not to cause undue alarm and maladaptive responses.

The alert signal is not used because of the necessity to reserve it for a tactical warning which requires a time-critical response.[1] It is recommended that the first cycle of the strategic warning message be broadcast at a sound pressure level of 90 db at 10 feet in order to increase the probability of attracting attention without the necessity of using an alert signal; subsequent cycles of the strategic warning message are to be broadcast at a sound pressure level of 75 db at 10 feet to increase their intelligibility. Delivery of the message must connote immediacy, but not imminent danger. The strategic warning message is, therefore, more accurately characterized as an advisory announcement of a more specific warning to be disseminated via commercial radio and TV stations. Presumably the radio or television set, when the listener turns it on, will give him more information about a probable nuclear attack, but the strategic warning message, itself, is sufficiently general that it can be used for any purpose grave enough to warrant warning the entire nation.

Tables 4-6 and 4-7 contain the proposed strategic warning message. Two different messages are proposed, one for areas served by a special low-frequency station (Table 4-6); the other, for areas served by local AM, FM, and TV stations (Table 4-7).

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1. See Sections 1.2 and 5.5.3; Chapter Two, Section 4.3.4.

Table 4-6. Proposed Strategic Warning Message for Areas Served by a Low-Frequency Station

Item	Content	Word Count	Time (Sec.)
1	EMERGENCY--EMERGENCY	2	
2	THIS IS AN EMERGENCY	4	
3	I REPEAT--THIS IS AN EMERGENCY	6	
4	FOR INFORMATION TURN ON YOUR RADIO OR TV	8	
5	I REPEAT--TURN ON YOUR RADIO OR TV FOR INFORMATION	10	15
6-10	(Same as 1-5)	30	15
11	THE STATION YOU USUALLY LISTEN TO MAY NOT BE ON THE AIR--IN THAT CASE TUNE TO ANY RADIO OR TV STATION THAT IS ON THE AIR	27	12
12-16	(Same as 1-5)	30	15
	Total	117	57

5.5.1 Establishing the Official Character of a Strategic Warning

The strategic warning message could indicate its official character verbally, but, as was the case for the tactical warning message (see Section 5.4.1), this appears inappropriate. While the time constraints that apply to a tactical warning do not apply to a strategic warning, the specific threat contained in the tactical warning is also absent from a strategic warning. An announcement to the effect that THIS EMERGENCY ANNOUNCEMENT HAS BEEN ORDERED BY THE PRESIDENT OF THE UNITED STATES is meaningless; the strategic warning is not an emergency message per se, but, rather, an announcement of the intention to present emergency information. Therefore, it appears appropriate, as in the case of a tactical warning, to depend upon the system itself for certifying the official nature of the message. In a sense, the strategic warning message affords a

Table 4-7. Proposed Strategic Warning Message for Areas Served by an AM, FM, or TV station

Item	Content	Word Count	Time (Sec.)
1	EMERGENCY--EMERGENCY	2	
2	THIS IS AN EMERGENCY	4	
3	I REPEAT--THIS IS AN EMERGENCY	6	
4	FOR INFORMATION TUNE TO RADIO STATION WXYZ, 1250 ON YOUR RADIO	11	
	--OR--		
	FOR INFORMATION TURN ON TV STATION WXYZ-TV, CHANNEL 10	10	
5	I REPEAT--TUNE TO RADIO STATION WXYZ 1250--1250--ON YOUR RADIO DIAL FOR INFORMATION	15	Radio = 25
	--OR--		
	I REPEAT--TURN ON TELEVISION STATION WXYZ-TV, CHANNEL 10--CHANNEL 10--FOR INFORMATION	14	TV = 25
6-10	(Same as 1-5)	Radio = 38 TV = 37	Radio = 25 TV = 25
	Total	Radio = 76 TV = 73	Radio = 50 TV = 50

more critical challenge to the system than does a tactical warning. The very generality of the strategic warning message may make its use attractive in situations less grave than one of potential nuclear attack. Careless use of the strategic warning message can degrade the entire system. The availability of this message opens the possibility of undermining any official status that the public assigns to messages from the Radio Warning System. Too many marginal "strategic warnings"--like too many false alarms--may undermine the official status of a tactical warning, if such a warning is ever disseminated. In addition to reserving the strategic warning message for suitably grave emergencies, the message can be given further official sanction by such factors as effective testing, reliable operation, and public education (see Section 5.4.1).

5.5.2 Providing Unequivocal Instructions

As in the case of the tactical warning (see Section 5.4.3), the strategic warning should be unequivocal. The time constraints upon the individual listener's responses are not as severe as for tactical warning, but it is, nevertheless, undesirable to introduce any ambiguity or undue sophistication or complexity into the strategic warning message.

There are a vast variety of circumstances that can cause the dissemination of a strategic warning. These can range from a sudden surprise attack upon an ally to the slow, inexorable escalation of a crisis to the point at which armed conflict appears inevitable. Similarly, there are a range of countermeasures that can be taken by the various levels of government and the public from preparing shelter kits to participation in expedient actions to improve the defensive posture of the country. The anticipated time span for taking protective actions may range from hours to days. No prerecorded message can encompass this vast variety of threats, protective actions, and time spans. Therefore, only one instruction is feasible: FOR INFORMATION TURN ON YOUR RADIO OR TV. (note that the formulation is FOR INFORMATION..., not FOR MORE INFORMATION .. As has been pointed out in Section 5.2, the strategic warning message itself provides no information; rather it announces a more specific warning to be disseminated via the broadcast media.)

The simple instruction .. TURN ON YOUR RADIO OR TV may give rise to some problems. If the Emergency Broadcast System exists and operates as it does currently, some local stations will be off the air. In an emergency this inavailability of information from normal channels may prove confusing. Therefore, the message broadcast to a specific area by a commercial AM, FM, or TV station participating in the Radio Warning System includes the identity of the specific radio or TV station that is to provide local information. (See Table 4-7, items 4 and 5.) In contrast no such specificity is possible for areas served by low-frequency stations; therefore, the messages broadcast by these transmitters only give general information to turn on a familiar station or any one that is on the air. (See Table 4-6, item 11.) It is necessary, then, that each operating commercial station periodically indicate the specific local area that it is covering and how to locate the one serving some other local area.

5.5.3 Other Aspects of the Strategic Warning Message

The strategic warning message lacks specificity. For this reason it is even harder to personalize than is the tactical warning message. There is no specific danger that the listener can identify as a threat to himself nor are there any countermeasures that he can prepare to take. This information must come from the subsequent broadcast via the commercial media. In fact the only means of personalization is the use of direct address: TURN ON YOUR RADIO OR TV or TUNE TO RADIO STATION WXYZ, 1250 ON YOUR RADIO.

The strategic warning, furthermore, cannot be balanced; as presented by the Radio Warning System the message does not identify a specific threat and the appropriate protective measures. Because of this limitation--because of the very lack of specificity in the message--it is imperative that the strategic warning message not be an impressive message in the action-stimulating sense that characterizes a tactical warning. In this respect delivery is as important as verbal content: There is no attention-getting alarm; the tone of voice used in the prerecorded message must be emphatic and calm, underplaying the tone of urgency that appears appropriate for a tactical warning. (It is uncertain whether the strategic warning, lacking as it does any alert signal, can penetrate ambient noise adequately to attract attention during the hours of daily activity or whether it is intense or meaningful enough to awake a sleeping population at night. This is a topic that warrants further experimental study.)

Similarly, the messages in Table 4-6 and 4-7 lack intensive personalization and cannot be either impressive or balanced. All the characteristics of a tactical warning message (and most emphatically personalization, impressiveness, and balance) must be carefully built into any detailed strategic warning that is disseminated via the broadcast media; the Radio Warning System may gain an audience for strategic information, but it remains the task of the civil defense system, using the broadcast media, to secure a positive, prompt response from the public.

5.6 CANCEL FALSE ALARM MESSAGE

This type of message is not a warning message: it cancels a prior false alarm that reached the public. It may be time critical. If the false alarm was an apparent tactical warning, and the public has been trained to take shelter promptly, as has been assumed, then a timely cancel message will minimize the inconvenience and confusion by countermanding shelter-movement instructions. If, however, the false alarm was an apparent strategic warning, then the dissemination of a cancel message is less time critical because no shelter movement is involved. The message should be official and unequivocal, as defined in Section 5.2, but it cannot be impressive, balanced, or personal. Someone or something associated with the Radio Warning System delivered an "official" warning; the cancel message must overcome the apparent official nature of the prior message. It must leave the auditor completely certain that the "official" warning was, indeed, a false alarm. There is no possibility of personalizing such

a message; there is no danger for the listener to identify as a threat to himself. The lack of threat, and the consequent cancellation of instructions to take protective action, invalidate the possibility of preparing an impressive or a balanced message. The message itself is critical because it aids in minimizing potential compromise of the Radio Warning System and of the entire civil defense system that may result from a large-scale false alarm.

Table 4-8 contains the text of the proposed cancel false alarm message. It is recommended that the cancel false alarm message be presented at a sound pressure level of 75 db at 10 feet.

5.6.1 Establishing the Official Character of a Cancel False Alarm Message

This type of message is highly problematic; the more successfully the Office of Civil Defense establishes the Radio Warning System as the official source of valid warning information (see Sections 5.4.1 and 5.5.1), the more difficult it will be to cancel a false alarm without undue confusion. Ideally the level of reliability and security built into the Radio Warning System should make this message unnecessary; but, since any system works at less than the ideal level, the message must be provided as insurance against a system-wide false-alarm failure. Furthermore, since each broadcast facility in the system is equipped with prerecorded tapes, it can accidentally false alarm the area it serves. Each of these facilities should, therefore, also be capable of disseminating a cancel false alarm message to countermand any warning message that is accidentally disseminated by a failure at the local station. It is not possible to include any unique information that the public will immediately recognize as a positive, unconfusing cancellation of a prior warning message. The cancel false alarm message can gain its effectiveness only by being last in the transmission sequence, only by following the message that it cancels.

As was pointed out in Section 5.4.3, people who are confused tend to seek clarification from direct contact with nearby people, through the use of the telephone, and from radio and television broadcasts. In a false alarm situation it is natural to expect people to turn to these three sources of information for guidance. Most important is the availability of the commercial broadcast media. The nation's radio and TV stations, however, cannot simply broadcast their normal programming as an indication that the alert was a false alarm; they must quickly broadcast positive messages similar to that in Table 4-8, followed later by explanation of the cause of the false alarm and of the steps being taken to prevent future false alarms.

When the false alarm was a tactical warning message disseminated for a period of time long enough for people to start to shelter, then it is also necessary that shelter managers, police, and other authorities, prepared for the possibility of a false alarm, are available to explain the situation to people who actually attempt to reach shelter.

Thus capabilities outside the Radio Warning System must be used to give the cancel false alarm message official status.

Table 4-8. Proposed Cancel False Alarm Message

Item	Content	Word Count	Time (Sec.)
1	FALSE ALARM--FALSE ALARM	4	
2	THE ALERT SIGNAL OR EMERGENCY MESSAGE YOU JUST HEARD WAS A FALSE ALARM	13	
3	I REPEAT--A FALSE ALARM WAS JUST SENT OUT OVER THE RADIO WARNING SYSTEM	14	
4	DISREGARD ANY ALERT SIGNAL OR EMERGENCY MESSAGE YOU JUST RECEIVED FROM YOUR WARNING RECEIVER	14	
5	I REPEAT--DO NOT CARRY OUT ANY EMERGENCY INSTRUCTIONS YOU MAY HAVE RECEIVED FROM YOUR WARNING RECEIVER	17	
6-7	(Same as 2 and 3)	27	44
8	IN ORDER NOT TO INCONVENIENCE YOU FURTHER, WE ARE NOW ENDING THIS FALSE ALARM MESSAGE	15	
9	WE HOPE YOU HAVE NOT BEEN BADLY INCONVENIENCED BY THIS FALSE ALARM	12	13
	Total	116	57

5.6.2 Providing Unequivocal Instructions

In an inherently equivocal situation the need for absolute verbal clarity is critical. The explanation given in the cancel message, however must be very limited. The cause of the false alarm can range from spoofing or sabotage to human error or an equipment malfunction. The cancel false alarm message must be transmitted as soon as possible after the false alarm is detected. Any attempt to "explain" the false alarm appears likely to be inaccurate, inadequate, or both. Therefore, formulations such as THE EMERGENCY MESSAGE YOU JUST HEARD WAS AN ACCIDENTAL FALSE ALARM or THE EMERGENCY MESSAGE YOU JUST HEARD WAS BROADCAST THROUGH AN ERROR have been excluded from the message. Furthermore, people have been inconvenienced, perhaps awakened in the middle of the night, possibly frightened; it appears appropriate to make the cancel message as short and direct as possible. Once the warning receiver is quiet the listener can attempt to resume normal activities or to determine the cause of the false alarm sequence to which he was just subjected.

5.6.3 Providing a Timely Cancel False Alarm Message

It is not anticipated that the message in Table 4-8 will be repeated indefinitely as is the case with the tactical and strategic warning messages. Rather it is recommended that a single repetition, as proposed in Table 4-8, be used. Since it can be assumed that the original false alarm attracted peoples' attention, the cancel message need only announce the false alarm and turn off the Radio Warning System.

If it is deemed necessary to transmit the body of the cancel false alarm message (items 1 through 7) more than once, one of two techniques has to be employed. If the Radio Warning System does not have to time share the operation of two low-frequency transmitters having overlapping coverage on the same frequencies, then it is possible to prerecord items 1 through 7 as many times as is determined to be adequate. These repetitions of items 1 through 7 would be followed by a single broadcast of items 8 and 9, which would end the transmission of the usual message. If, however, the Radio Warning System does have to time share low-frequency transmitters with overlapping coverage on the same frequencies, then the message cannot be extended by simple prerecorded repetition of items 1 through 7; each such repetition would delay by approximately 44 seconds receipt of the cancellation by people living in areas of overlapping low-frequency coverage. Therefore, in a system using time shared frequencies and repetition of items 1 through 7, these items would have to be a separate message to be repeated as required in the appropriate time-sharing sequence. Items 8 and 9 could also be a separate message to be transmitted once at the end of the cancellation notifications; or these two items could be dropped from the message. Once again the recommendation must be reiterated that a single transmission of the cancel false alarm message, as proposed in Table 4-8, supported by timely commercial radio and TV announcements and by the use of trained shelter managers, police, and other authorities, if required, seems to be the most effective way of restoring order as quickly as possible.

5.6.4 Countermanding False Alarms that Result in the Dissemination of Ambiguous Messages

The cancel false alarm message in Table 4-8 is designed to counteract a variety of false alarm conditions that are essentially ambiguous. The operators of the Radio Warning System may recognize a false alarm that seems to be any of the legitimate messages, in various stages of delivery:

1. Tactical Warning

   a. Alert signal, first cycle (no voice information has been disseminated)

   b. Warning information, first cycle (a complete voice message has not been disseminated)

   c. Second and subsequent cycles (at least one complete alert and warning message has been disseminated)

2. Strategic Warning

   a. First cycle (condition similar to 1.b)

   b. Second and subsequent cycles (condition similar to 1.c)

3. Test (with or without modified alert signal)

   a. Incomplete message

   b. Completed message

The message proposed makes no provision for countermanding a test message disseminated at an unscheduled and unexpected time as a result of a system failure. It appears that acknowledging such a failure as a false alarm is inappropriate; this situation might better be treated as an unannounced test of the system with the appropriate test-oriented follow-up in the press and on radio and TV. The proposed message is general enough to allow system operators to countermand a false tactical or strategic warning in any of the stages described in 1 and 2, above. The proposed cancel false alarm message achieves its generality by recognizing several possible conditions (...ALERT SIGNAL OR WARNING MESSAGE...), by using general terms (...A FALSE ALARM WAS JUST SENT OUT...), and by providing general instructions (...DO NOT CARRY OUT ANY EMERGENCY INSTRUCTIONS YOU MAY HAVE RECEIVED...).

The generality inherent in the proposed message is a source of possible confusion. The only alternative, however, is to record separate cancel false alarm messages for each of the conditions listed above and to allow the timing and logic mechanisms that control the operation of the system to select the

appropriate recording. The use of multiple cancel false alarm messages appears to be overly sophisticated and is not recommended; if the high level of reliability specified for the Radio Warning System[1] is achieved, the general message presented in Table 4-8 is adequate to cover the remote contingency of a false alarm.

5.7 TEST MESSAGES

Test Messages are routine messages to which the public will be exposed with some frequency. The public response to these messages can be highly significant: the messages can help to (1) familiarize the public with the operation of the system, (2) locate failed or failing receivers, and (3) identify the system as a source of meaningful, potentially lifesaving information. These messages are time critical in a special sense; they should always occur at a time selected to reach the largest number of people. They should also have the characteristics of the tactical warning message itself, though to an extent limited by the fact that they are being used in tests. The test messages can be used to condition the public to the possibility of hearing a warning message over the Radio Warning System and to the need for each listener to take the protective action specified. Thus, while a test message is not, by itself, a critical message, an ineffectively designed or used test message can vastly degrade response to an attack warning when it is ultimately disseminated, while an effectively designed and used test message can enhance the response to an attack warning.

Tables 4-9 and 4-10 contain proposed test messages. The message in Table 4-9 is designed primarily to familiarize the public with the operation of the Radio Warning System and to help locate failing receivers. The message in Table 4-10, in contrast, is primarily designed to help condition the public to recognize and respond to the alert signal used in the tactical warning message. It is recommended that the texts of both test messages be presented at sound pressure levels of 65 db at 10 feet, and that the alert signal, when used, be presented at a sound pressure level of 60 db at 10 feet.

5.7.1 Establishing the Official Character of the Test Messages

As is the case with all the messages previously described, test messages gain their official status from the Radio Warning System itself. Warning messages can only have the sanction conferred by officialdom if the public considers the Radio Warning System as the official--and, by implication, the effective--source of warning information. Test messages, in contrast, need not depend upon the fact that they are received on a warning receiver to confer official

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1. Chapter Two, Section 4.5.1.

Table 4-9. Proposed Test Message without Alert Signal

Item	Content	Word Count	Time (Sec.)
1	TESTING--TESTING	2	
2	THIS IS A TEST OF THE RADIO WARNING SYSTEM	9	
3	I REPEAT--THIS IS ONLY A TEST	7	9
4	ATTENTION TO THIS TEST MESSAGE COULD SAVE YOUR LIFE	9	
5	WE ARE TESTING YOUR WARNING RECEIVER	6	
6	IF YOUR RECEIVER DOES NOT SOUND RIGHT, PLEASE TAKE IT TO YOUR NEAREST FIRE HOUSE FOR TESTING OR REPLACEMENT AT NO COST TO YOU*	24	19
7	IN AN EMERGENCY, A MESSAGE ON YOUR WARNING RECEIVER WOULD TELL YOU WHAT TO DO	15	
8	PROMPT RESPONSE TO A WARNING COULD SAVE YOUR LIFE	9	12
9	THIS CONCLUDES A TEST OF THE RADIO WARNING SYSTEM	9	
10	I REPEAT--THIS HAS BEEN A RADIO WARNING SYSTEM TEST	10	9
	Total	100	49

* For illustrative purposes only; see Section 5.7.3.

Table 4-10. Proposed Test Message with Modified Alert Signal

Item	Content	Word Count	Time (Sec.)
1	TESTING --TESTING	2	
2	THIS IS A TEST OF THE RADIO WARNING SYSTEM	9	
3	I REPEAT--THIS IS ONLY A TEST	7	9
4	ATTENTION TO THIS TEST MESSAGE COULD SAVE YOUR LIFE	9	
5	IN CASE OF A NUCLEAR ATTACK ON THE UNITED STATES, THE FOLLOWING SIGNAL WOULD BE SOUNDED LOUDLY:	17	13
6	(Alert Signal at low volume)		10
7	THIS IS ONLY A TEST	5	
8	I REPEAT--THIS IS ONLY A TEST	7	
9	IN A NUCLEAR ATTACK THE ALERT SIGNAL YOU JUST HEARD WOULD BE FOLLOWED BY THE INSTRUCTION TO TAKE SHELTER IMMEDIATELY	20	
10	PROMPT RESPONSE TO THE ALERT SIGNAL AND THE INSTRUCTION TO TAKE SHELTER COULD SAVE YOUR LIFE	16	24
11	THIS CONCLUDES A TEST OF THE RADIO WARNING SYSTEM	9	
12	I REPEAT--THIS HAS BEEN A RADIO WARNING SYSTEM TEST	10	9
	Total	111	65

status upon them. The only effective use of test messages directed to the public requires that listeners be in the vicinity of receivers in order to validate the performance of these receivers.[1]

There are three methods of assuring the maximum number of listeners at the time of any test: (1) scheduling tests for a time likely to find a maximum number of people in the vicinity of their warning receivers; (2) always holding tests at the same time; and (3) giving each test the appropriate publicity in the press, on radio and TV, and through other media. All of these techniques give emphasis to the official character of the system and its messages, both warning and test messages.

5.7.2 Making Test Messages Impressive

The test messages can be made impressive only in a limited sense. There is no immediate source of danger; there may not be even a vaguely recognizable threat at the time of any particular test message. The test messages proposed, if used in a rigorously controlled program of testing, can serve as a source of important conditioning stimuli to the public. Unless these test-message stimuli are appropriately impressive, however, the test messages will probably have no significant impact upon the public. (Obviously the stimuli in the test messages must be supported by a general education and training effort in support of the Radio Warning System as an element of the total civil defense system.)

The stimuli built into the test messages are particularly suitable to the task of conditioning the public because they emanate from the warning receiver itself. They help keep the receiver operative. They familiarize the public with the alert signal. They provide a direct reminder that a prompt, positive response to the tactical warning message, if it were ever disseminated, could save the listener's life.

Two separate messages are proposed. It is anticipated that the test message described in Table 4-9 (i.e., without an alert signal) will be used for most of the testing; the test message in Table 4-10 (i.e., with an alert signal) will be used on a limited basis so as not to overcondition the public to the alert signal. It is not possible at this time to determine the exact mix of the two messages that should be used for testing, but as a working hypothesis it is suggested that the test message with alert signal be used once in four tests. (The time intervals between test messages is discussed further in Section 5.7.4.)

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1. Test lights and similar devices can signal the receipt of a test message. This type of signal can even retain the information that a test message was received until the condition is recognized and acknowledged. Such devices, however, do not test the ability of the receiver to produce intelligible sounds; therefore, the only fully effective way to test a receiver is for a listener to determine that the receiver actually sounded and that the message was intelligible.

The verbal content of both test messages is designed to be impressive: ATTENTION TO THIS TEST MESSAGE COULD SAVE YOUR LIFE; PROMPT RESPONSE TO A WARNING COULD SAVE YOUR LIFE; and PROMPT RESPONSE TO THE ALERT SIGNAL AND THE INSTRUCTION TO TAKE SHELTER COULD SAVE YOUR LIFE. These statements--coupled with others designed to support the overall civil defense program and communicated via other media--can help to build the personal sense of danger necessary to achieving prompt, effective responses to a tactical warning.

5.7.3 Providing Unequivocal Instructions

The test messages provide several types of instructions. Of initial importance is the information that THIS IS A TEST OF THE RADIO WARNING SYSTEM. The information that the system is being tested has negative value. It is repeated throughout both test messages to prevent listeners from mistaking a test message for a valid warning. The positive information in the message relates to receiver maintenance and to a future threat and suitable protection.

It is impossible to use the Radio Warning System to tell a person with a failed receiver that he should turn it in for repairs or replacement. The newspapers and commercial radio and TV must do so before and after each test. The Radio Warning System can remind a person that if his receiver does not sound right to him that he can have it tested and, if necessary, repaired or replaced. (The message in Table 4-9 is based upon the assumption that test facilities will be available in local fire houses and that receivers will be replaced without charge to the owner. Both of these assumptions have no necessary validity, but were selected to provide illustrative content for the message.)

The test message with an alert signal (Table 4-10) is quite explicit in identifying the threat as nuclear attack and the available protection as taking shelter. The alert signal is presented for only 10 seconds, which appears just long enough to provoke a minor irritation reaction from the listener; the signal is also presented at reduced volume to preserve its full impact for the tactical warning situation. A level of 60 db at 10 feet is suggested. The test message without alert signal (Table 4-9) is general in its information because it is designed to cover both tactical and strategic warnings. Both of these messages have to be supported by detailed instructions in other media aimed at getting each individual to his own shelter in a timely manner.

5.7.4 Timing of Test Messages

Since these messages do not require an immediate response, message time is of relatively little significance. It is desirable to make test messages as short as possible so as to minimize their intrusion into activities in the home. A far more critical timing factor has to do with the regularity with which messages are presented. Past experience indicates that the best test strategy is testing at a standard time.[1] The use of a verbal message as part

1. Mack and Baker, op. cit., pp. 11, 29.

of the test minimizes possible confusion between a test and a valid warning. However, only if a person is conditioned to expect a test at a fixed time is there any hope of creating in him a reliable awareness of a missed test and a failed receiver.[1]

Since most receivers will be in homes, it appears desirable to test when the most people are at home. This appears to be during the early supper hour from approximately 6:00 to 7:00 p.m. The most likely day to test appears to be Monday or Tuesday. (These dates are based upon limited evidence derived from such sources as the days restaurants tend to close and must be confirmed before they can be used for planning.) Ideally each test should occur at a common time (say 6:30 p.m.) in each time zone; but this appears impractical, since there is no conformity between transmitter coverage and time zones. Therefore, testing should be as close to a common time for as many people as possible in each time zone, with everyone aware of the actual time that his receiver is tested. Daylight saving time raises some problems because the time may vary an hour in some areas depending upon whether the system and/or the area goes onto daylight saving time.

The situation is further complicated by the possibility of timesharing a single frequency between two low-frequency transmitters with overlapping coverage. If timesharing is used, the strategy of testing as close to a common time as possible cannot be used because some areas of overlapping coverage are served by transmitters in two time zones; residents of such areas would receive two test messages. In a system using timeshared frequencies the strategy of testing all the receivers in the country at some common time such as 9:00 p.m. Eastern Standard Time appears most suitable. Again each person must know the local time at which his receiver is to be tested.

5.7.5 Making Test Messages Personal and Balanced

Again there is no present danger to personalize in the test messages. Only potential future danger can be personalized: PROMPT RESPONSE TO A WARNING COULD SAVE YOUR LIFE or ATTENTION TO THIS TEST MESSAGE COULD SAVE YOUR LIFE. Similarly, since there is no specific threat, there are also no specific countermeasures. Only the countermeasures available for future use can be used for balance: the danger of a nuclear attack is paired with the information that prompt movement to shelter could save the listener's life. Yet personalization is critical; only if the individual listener identifies the potential danger with himself can he be expected to act effectively when and if that danger becomes actual. Similarly the balance of danger and protection is the

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1. The only exception to this logic results from a system failure that presents a test message as a false alarm at some unscheduled or unexpected time. See Section 5.6.4.

only factor likely to keep the listener from shutting the whole problem of a nuclear attack out of his mind through the defensive response that it could not happen to him.

6.0 MESSAGE CHARACTERISTICS AND SYSTEM DESIGN

Careful design of the messages transmitted over the Radio Warning System can effectively provide most of the attributes discussed in Sections 4.0 and 5.0. Additional data gathered from Radio Warning Systems tests, research projects, or disaster analyses can be used to make future improvements to the effectiveness of these messages. Some problems, however, cannot be designed out of the Radio Warning System, but are problems of the entire civil defense system. The most serious of these civil defense system problems relate to the national character of the Radio Warning System and its messages, to the limited time in which the tactical warning message has to be delivered, and necessary use of other, more-or-less local, sources of information to augment the Radio Warning System. These problems have been discussed in conjunction with the detailed discussions of the various messages; the problems act as limitations upon the Radio Warning System and must be resolved before the Radio Warning System can operate with complete effectiveness.

CHAPTER FIVE

REVIEW AND EVALUATION OF NIAC SIGNALING METHODS

1.0 INTRODUCTION

The material presented in this chapter reviews and evaluates the activities to date of the Federal Communication Commission (FCC) in the development of broadcast radio signaling techniques related to civil defense alerting and warning.[1] The FCC effort was undertaken through a special working group of the National Industry Advisory Committee (NIAC) and was started early in 1963.

The review and evaluation presented below considers the approach and techniques employed by NIAC without considering in detail the actual techniques and equipment under development by NIAC members. (A summary of techniques and equipment appears in Table 5-1; other technical details are included in the Annex to this chapter.)

2.0 CONCLUSIONS

Examination indicates that the lack of clearly defined requirements caused each of the NIAC proponents to establish his own set of requirements (some explicitly defined, others implicitly suggested). Even though some of the requirements set forth are presented by several proponents, these common requirements are often assigned different weights by the various manufacturers; in some cases, one proponent's requirement is another's undesirable feature. This lack of standardized requirements makes it impossible to select one system as superior to any other; in fact, it invalidates much of the work performed by NIAC. NIAC attempted to establish a severe environment in which to test receivers for false alarm and no alarm failures. This environment was established through a combination of bench testing and field testing. The bench testing appears to have been rigorously planned and standardized, but without the establishment of precise test duration. The field tests were also carefully designed, but operated for so short a time as to make impossible any guarantee that the test environment exhaustively represents the full range of environments in which operational receivers would have to function.

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1. The material in this chapter was largely derived from a briefing presented to the Working Group for Radio Warning, Office of Civil Defense, Washington, D. C., 29 September 1964. This chapter replaces Review and Evaluation of NIAC Signaling Methods, which was originally published as TM-L-1960/022/00, dated 25 November 1964.

While the NIAC effort provides some useful information, the lack of standardized requirements and of exhaustive testing make selection of alerting and warning signaling techniques and an associated receiver premature. This is true even if the receiver is used only for initiating Emergency Broadcast System (EBS) operations in the participating radio stations. Acceptance of one of the proposed techniques, even if it is only for controlling EBS, will tend to preempt signaling techniques used for home alerting and warning. It is likely that the implementation of one of the NIAC signaling techniques for EBS control will make the broadcasters reluctant to implement a second technique for home alerting and warning. If a technique is selected for EBS control before a technique is selected for public alerting and warning, it is possible that the optimum public alerting technique may be incompatible with the EBS control technique.

3.0 REVIEW

NIAC undertook the development of alerting and warning techniques suitable for use by commercial radio and TV broadcast stations early in 1963. Initially, NIAC attempted to devise techniques applicable to indoor public alerting and warning for use in individual homes, transient accommodations, and places of business. In March 1964, however, the NIAC effort was redirected toward development of signaling techniques suitable for initiating EBS operations.

As a result of a public notice in February 1963, thirteen proposals for alerting and warning techniques were submitted to NIAC. These proposals were reviewed by NIAC. Those proposals not supported by technical detail adequate to establish their feasibility were rejected. Some attempt was made to eliminate proposals that did not contribute to the variety of approaches to the problem. Some proposals were eliminated because they did not conform to certain ground rules based largely upon commercial broadcast practices.

From those proposals submitted, four were selected for further development and testing. The selected proposals were originated by:

1. Columbia Broadcasting System (CBS)
2. Philco Corporation (Philco)
3. General Electric Company (GE)
4. Zenith Radio Corporation (Zenith)

Experimental prototype equipment was constructed. Bench and field tests were completed in January 1964. Final reports were submitted to FCC in April and May 1964.[1] These reports were prepared by the four NIAC members who had submitted equipment for evaluation and by the representatives of two commercial radio stations (WHAS, Louisville, Kentucky, and WMT, Cedar Rapids, Iowa). As of the date (25 November 1964) on which the material in this chapter was prepared, NIAC had not yet recommended one of the four proposals. The requirement for such a recommendation was temporarily lifted by FCC in April 1964, when the possible conflict between OCD plans for public alerting and warning and revised FCC plans for the EBS became apparent to members of NIAC. (At a later date, however, NIAC reduced the field of competitors from four to two: Philco and Zenith. See Chapter Nine, below.)

4.0 NIAC OPERATIONS AND PHILOSOPHY

The mode of operation used by NIAC is typical of its handling of other problems. NIAC played a key role, for example, in the selection of a color TV broadcasting system and of an FM stereo broadcasting system. In both the color TV and FM stereo efforts, NIAC methods were similar to those used in selecting alerting and warning techniques.

NIAC capitalizes upon the potential commercial profit that a successful proponent stands to gain from his effort. Several of the proponents urged that a subsidiary-service capability be built into any alerting and warning system; this capability would allow receivers to be selectively activated for the dissemination of news or weather. All of the proponents designed such subsidiary-service capabilities into their receivers.

Perhaps the most significant criticism of the NIAC approach is its inherent lack of comprehensiveness. NIAC responds only to proposals. It does not designate certain techniques as requiring further study, and, therefore, it can only select the most promising of those proposals submitted to it.

The NIAC effort on alerting and warning techniques suffers, unfortunately, from failings of incompleteness that transcend the limitations of its proposal procedure. It is seriously limited by the fact that normal commercial goals are largely inapplicable to the development of an alerting and warning system. An alerting and warning system must be designed and implemented with a rigorousness

1. Federal Communications Commission, National Industry Advisory Committee (Field Test Ad Hoc Committee), Report of Field Tests of Emergency Alerting Systems for Use With Standard, FM and Television Broadcast Stations, Washington, D.C., 3 April 1964; Federal Communications Commission, National Industry Advisory Committee (Systems Analysis Ad Hoc Committee), Chairman's Report of Comparative Analysis of Emergency Alerting Systems for Use With Standard, FM and Television Broadcast Stations, Washington, D.C., 15 May 1964.

of approach equal to or exceeding that applied to the development of most military communications systems; the lives of millions of people as well as the effective utilization of shelters and other civil defense facilities and plans may well depend upon the successful operation of a public alerting and warning system. Yet, NIAC never received adequate guidance as to the requirements that such a system would have to meet. Instead, each of the four proponents proceeded to the task of devising, testing, and evaluating hardware to meet performance requirements that he devised on his own.

5.0 POSITIONS TAKEN BY PROPONENTS

In accord with the normal method of NIAC operation, each proponent prepared a final report that evaluated his effort in comparison to those of the other proponents. (This material appeared in the final report of the Systems Analysis Ad Hoc Committee, which was cited above.) A brief review of these final reports indicates the variety of approaches taken by the proponents. This variety reflects the honest attempts of the proponents to get their jobs done in the absence of firm guidance. Table 5-1 is a summary of proponents' signaling techniques.

5.1 CBS REPORT

The CBS report includes a limited characterization of requirements; it does, however, try to put down in one place performance requirements for receiver design, transmitter design, and general system operations. Security from false alarms is a basic requirement. The receiver must be reliable in the presence of signal fade and noise. The same system ought to apply to any broadcast medium (AM, FM, TV). The system ought to achieve wide public acceptance and, therefore, the system ought to have subsidiary uses. The alert signal, however, should not be associated with subsidiary uses. There are additional CBS requirements (see Annex to this chapter), but regardless of their merits, they are completely the proponent's own creation. CBS maintains in its brief treatment that the field tests were inadequate to judge one receiver against another and concludes with a general recommendation that the CBS Homealert receiver is best on the basis of the limited requirements that CBS has itself established. There is no analysis of the CBS system, as such, from either a mathematical or an engineering standpoint. There is no comparison of features of the CBS system versus the other systems. The CBS analysis is generally an argument to a special point, namely, the CBS product is best.

5.2 PHILCO REPORT

Philco, in contrast to CBS, does nothing to categorize requirements. This is not to say that it does not list or imply requirements, but these are never drawn together and made explicit. Philco instead places its emphasis upon a lengthy, intuitive engineering analysis. There is a detailed analysis of the false alarm problem and a rather elementary assigning of weighting factors based on the number of elements employed in the radio signal; on this basis the Philco

SYSTEM	FREQUENCY (Hz)	MODULATION PERCENT	MODULATION TYPE	WAVE SHAPE	DURATION (SECONDS)	TYPE OF LATCHING	USE	REMARKS
CBS	51 41	20	AM	Sine	Continuous	Non-Latching	Unmute Subsidiary	AM, FM, TV (Alert signal can be first part of warning message)
PHILCO	806 & 762 806 & 679 761 & 679	45 Ea.	AM	Sine	20	Controlled	Alert Subsidiary Remote	AM, FM, TV Tested
	f_1 (Subaudible) f_2,f_3 (Audible) f_4 (Subaudible) f_2 (Audible)	20 40 Ea. 20 80	AM	Sine Square Sine Sine	Continuous 20 Continuous 20	Non-Latching	Unmute Alert Unmute Subsidiary	Recommended, but neither built nor tested
GE	41	20	FM	Sine	Continuous	Non-Latching	Unmute	AM, FM, TV (Alert Signal can be first part of warning message)
ZENITH	1010 & 925	50 Ea.	AM	Square	20	Permanent or Temporary	Alert	AM
	570 & 635 510 & 635 510 & 570	50 Ea.	AM	Square	20	Permanent or Temporary	Alert Subsidiary Subsidiary	FM & TV

Table 5-1. Summary of NIAC Signaling Techniques

and Zenith systems are rated at a false alarm factor of five, GE at three, CBS at two -- the higher the number, the better. (Zenith disagreed, even though Zenith rated with Philco; CBS, rated lower, also disagreed. There is obviously little agreement on this particular analysis.)

Philco also makes a comparison of the four proposals on the basis of features, feature for feature. It lists certain features and considers and ranks them as desirable or undesirable. This ranking is hardly an adequate basis for defense of one system over another, since there is no standardization on either the factors to be considered or the relative weight to be assigned each.

Philco concludes, however, that of the four systems tested, not one was optimum. Philco proposes four alternate systems, and goes through its entire analysis of false alarms and another comparison of system features. The Philco report recommends that the "best" of these four alternates be the subject of all future NIAC activities. Despite the recommendation, Philco neither built nor tested any of the alternate systems.

5.3 GE REPORT

The GE report contains no discussion of requirements. Its analysis is based entirely upon a fairly detailed, quasimathematical analysis of false alarms. It concludes that the GE system is more secure against false alarming than the Philco system by a factor of six, the Zenith system by a factor of ten, the CBS system by a factor of seventeen million. These figures are a function of the number of days that a receiver can be expected to operate without false alarming. The GE advantage is not quite so conclusive as it appears at first glance. GE has to qualify its seventeen-million-to-one advantage over CBS by stating that if the receiver or signal is detuned, the falsing probability increases. In fact, detuning the receiver makes the GE and the CBS receivers very similar in performance. The analysis is further marred by a mathematical error that leads to faulty conclusions. (This error is documented in Chapter Six, below.)

GE makes a comparison of systems, again, on the basis of features it considers desirable and features it considers undesirable. (The GE comparison of system features was, furthermore, added as an obvious afterthought, and the page is not clearly identifiable as a GE contribution.) This comparison lacks standardization because of the lack of requirements. GE set their own, and they differ from those established by the other proponents. The end conclusion is that the GE system is best because it is most secure against false alarms.

5.4 ZENITH REPORT

The Zenith report also makes no attempt to pull together requirements or state them explicitly in one place. Zenith again is one of the proponents that maintains that the field tests were inadequate. It also disagrees with Philco's analysis and challenges the necessity of an alternate system. Zenith makes a tabular comparison of systems, again with no better basis for the comparison

than any of the others. It also concludes that Zenith's system is best because it has the best features.

5.5 SUMMARY TABLES

It is possible to collect from each proponent's report information that can be considered as the proponent's assessment of system requirements. In some cases, it is necessary to infer requirements from a proponent's discussion of his technique or from his comparison of that technique with those of the other proponents. Tables 5-2 through 5-5 summarize some of the key requirements. (The Annex to this chapter contains a more complete listing of these requirements.) It is important to reiterate that these requirements, explicit or implicit, are very frequently sharply in disagreement. One proponent's requirement is another proponent's undesirable feature. Tables 5-2 through 5-5 cannot even begin to suggest the different weights assigned each requirement; these tables only suggest the scattergun effect of establishing system requirements on a do-it-yourself basis.

6.0 NIAC TESTING TECHNIQUES

The NIAC tests of the proposed signaling techniques were divided into bench tests and field tests. Emphasis was upon determining immunity from false alarms caused by noise or broadcast material during normal situations, and immunity to no alarm failures in the presence of a legitimate alarm signal.

The bench tests were oriented toward three things:

1. Determining the operating range of the alert receiver with field strength variations.

2. Establishing the immunity of the receiver to false alarms resulting from complex modulation effects or signal interference.

3. Measuring the ability of the alert receiver to operate in the presence of noise.

These bench tests were rigorously designed, but with no great amount of control over the extent of the bench testing. The success or failure of the bench test has to be accepted more or less on the say-so of the proponent, who did his own bench testing.

The field tests for AM stations were conducted in Florida (9-21 November 1963), and in Philadelphia for FM and TV stations (23-25 January 1964). The tests included false alarm tests and operational tests. The false alarm tests were made by tuning the alert receiver to various commercial broadcast stations and monitoring the output of the alerting circuitry for evidence of activation during normal broadcast use. The operational tests were made during the

Table 5-2. General Requirements

REQUIREMENT	CBS	PHILCO	GE	ZENITH	WHAS	WMT
Same system for AM, FM, TV	Y	Y	Y	Y	Y	Y
No false alarms	Y	Y	Y	Y	-	-
Distinctive alert signal	-	Y	N	Y	Y	Y
Subsidiary uses	Y	Y	-	Y	Y	-
No BRECOM interference	-	Y	Y	-	Y	-

Table 5-3. Alert Signal Requirements

REQUIREMENT	CBS	PHILCO	GE	ZENITH	WHAS	WMT
Alert signals pretaped	-	-	Y	N	Y	Y
Alert signal for subsidiary use	Y	Y	-	-	Y	-
Alert signal for natural disaster	-	-	-	N	-	Y
Square wave modulation	-	Y	-	Y	Y	-

Key: Y/Yes; N/No; -/No Opinion.

Table 5-4. Receiver Requirements

REQUIREMENT	CBS	PHILCO	GE	ZENITH	WHAS	WMT
Receiver should be simple	Y	Y	Y	-	-	-
Receiver should be inexpensive	Y	Y	-	-	-	-
Receiver should be reliable	-	Y	-	-	-	-
Latching type unmuting	N	N	N	Y	-	-
Controlled remuting	-	Y	-	N	N	-
Manual remuting	-	N	-	Y	Y	-
Automatic remuting	-	-	-	N	N	-

Table 5-5. Transmitter Requirements

REQUIREMENT	CBS	PHILCO	GE	ZENITH	WHAS	WMT
Alert signal injection at studio	-	Y	Y	Y	Y	Y
Minimum transmitter modifications	Y	Y	Y	Y	Y	Y
Notch filter can be used	Y	N	-	-	N	-

nonfunctioning hours of the participating stations and were an attempt to determine that when an actual alarm condition prevails the system does disseminate an alert. The tests were conducted for AM with groundwave and skywave, strong and weak signals, and so forth. FM and TV receivers were tested in a high field strength location and a fringe-area location.

While it has been demonstrated in Section 5.0, above, that the system requirements effort was so scattered as to be nonexistent, it can be maintained equally strongly that the test results developed by NIAC, while they are informative, are unconvincing because they do not establish the fact that they were dealing with the total radio environment. Two of the proponents (CBS and Zenith) took this position formally.

All four systems operated satisfactorily under test conditions; such failures as were encountered were due to failures in the receiver and not failures in the alert-signal-detection circuitry. The bench tests indicated that the proposed techniques would all operate under extremely strong impulse noise, such as that produced by lightning and spherics.

All systems would produce false alarms if program material contained signals equivalent to those used for the control function. However, no normal programming material was found that would do this, and only an off-beat organ record with a sustained pedal note produced false alarms in the CBS receiver. Some overmodulation conditions produced false alarms in the GE receiver.

7.0 SIGNALING COMPATIBILITY

Perhaps the most interesting lesson to be learned from the NIAC tests is that signaling techniques devised without adequate coordination may be incompatible. For example, most of the proponents decided that Broadcast Emergency Communications and the signaling technique used for alerting and warning should not interfere with each other. GE took this position, and yet its signaling technique did interfere with BRECOM. The lesson is well taken: any decision on a signaling technique for EBS may invalidate other techniques suitable for public, indoor alerting.

ANNEX TO CHAPTER FIVE

SYSTEM REQUIREMENTS AS EXPRESSED IN THE FOUR REPORTS OF THE PROPONENT MANUFACTURERS AND TWO RADIO STATIONS (WHAS AND WMT)

These requirements were gleaned from the reports of the proponents to the Ad Hoc Committee on Systems Analysis and are not arranged in any particular order or grouped by subject.

The requirements were either listed explicitly by the reports as requirements or were assumed from the comparative rating charts contained in the various reports. If a particular feature of the system was listed as advantageous, a requirement for the feature was assumed and listed.

After each requirement is listed the number of the page on which that requirement was expressed or from which it was inferred.

A.1 CBS REQUIREMENTS

1. The system must be reliable in the presence of signal fade and noise (p. 67).

2. Security from false alarm is a basic requirement (pp. 68, 76).

3. Receivers should not require critical tuning (p. 67).

4. Notch filters can be used at low frequencies (p. 68).

5. Latching is an undesirable feature (p. 69).

6. Receivers should not require unnecessarily critical components (p. 69).

7. The same system should be used for AM, FM, and TV (p. 69).

8. It is necessary to achieve wide public acceptance of the system (p. 69).

9. Receivers should be inexpensive (p. 69).

10. Transmitter modifications should be minimal (p. 70).

11. The convenience of broadcasters is not as important as the convenience of the public (p. 70).

12. The system should have subsidiary uses (p. 71).

13. No subsidiary use should be made of the alert signal (p. 71).

14. The duration of the alert signal required to unmute receivers should be 1 to 2 seconds (p. 71).

15. The ability to transmit an unmuting signal and a warning message simultaneously is a desirable feature (p. 71).

16. Subsidiary use can provide needed testing of the system (p. 71).

A.2 PHILCO REQUIREMENTS

1. It is desirable that the system have subsidiary uses (pp. 73, 76, 77).

2. Public acceptance of the system is desirable (p. 73).

3. Receivers should be simple (p. 74).

4. Receivers should be reliable (pp. 74, 76).

5. The system should provide a minimum of complexity for broadcast station operating personnel (p. 76).

6. No subsidiary use should be made of the alert signal (pp. 79, 83).

7. Transmitter modifications should be minimal (p. 83).

8. Notch filters should not be used at any frequency (p. 83).

9. Security from false alarms is a basic requirement (p. 83).

10. Signal insertion at transmitters is not desirable (p. 83).

11. The same system should be used for AM, FM, and TV (p. 83).

12. An audible alert tone is desirable (p. 84).

13. Latching is undesirable (p. 84).

14. Full modulation for the alert signal and warning message is desirable (p. 84).

15. Interference with BRECOM is undesirable (p. 85).

16. Frequency modulation (FM) is undesirable (p. 85).

17. Susceptibility to jamming is undesirable (p. 86).

18. Square-wave modulation is desirable for the alert signal (p. 87).

19. Manual remuting is undesirable (p. 87).

20. Two alert signals are desirable, one for emergency and one for subsidiary use (p. 88).

21. A continuous subaudible frequency is desirable for unmuting (p. 88).

22. The audible alert signal should last a minimum of 15 seconds (p. 88).

23. The alert tone should be between 40 and 1,000 Hz (p. 88).

A.3 GE REQUIREMENTS

1. Security from false alarm is a basic requirement (p. 14).

2. A subaudible unmuting signal is desirable (p. 14).

3. Controlled or automatic remuting is desirable (p. 14).

4. The same system should be used for AM, FM, and TV (p. 14).

5. A nonlatching system is desirable (p. 14).

6. Alert signal activation equipment should be located at broadcast studios (p. 14).

7. Alerts should be pretaped (p. 14).

8. Raucous tones are undesirable for alerting (p. 14).

9. Transmitter modifications should be minimal (p. 14).

10. The system should not interfere with BRECOM (p. 14).

11. The receiver should be simple (p. 14).

12. A continuous latching signal is desirable (p. 14).

13. Modulation levels of the alert signal should not be critical (p. 14).

14. Alert signal frequency tolerances should not be critical (p. 14).

A.4 ZENITH REQUIREMENTS

1. Single tone systems do not have inherently adequate security against false alarm (p. 27).

2. The same system should be used for AM, FM, and TV (p. 27).

3. Frequency modulation (FM) for standard broadcast stations (AM) is not desirable (p. 27).

4. Controlled or automatic unlatching is an undesirable feature (pp. 29-30).

5. A system using only AM stations is desirable (p. 33).

6. Receivers should be transistorized (pp. 34-35).

7. Security against false alarms is a basic requirement (p. 37).

8. The duration of the alert signal required to unmute receivers should be between 2 and 3 seconds (p. 39).

9. A latching system is desirable (p. 41).

10. Different alert tones should be used for nuclear attack and natural disaster (pp. 43, 45).

11. Pretaped alert signals are not desirable (p. 44).

12. The alerting tone should be between 500 and 1,000 Hz (p. 44).

13. Square-wave modulation should be used for the alert signal (p. 44).

14. Alert signal insertion should be at broadcast studios (p. 27).

A.5 WHAS REQUIREMENTS

1. The system should be used and maintained daily to insure readiness for alert (p. 17).

2. The system should be tested weekly (p. 17).

3. No subsidiary use should be made of the alert signal (p. 17).

4. Two tones should be used to increase reliability -- one for unmuting, a second for the alert (p. 17).

5. Square-wave modulation should be used (p. 18).

6. Automatic remuting or remuting from the transmitter are undesirable (p. 18).

7. The same system should be used for AM, FM, and TV (p. 18).

8. Frequency modulation (FM) of standard broadcast modulated transmitters (AM) is not feasible (p. 18).

9. A subaudible unmuting signal is undesirable (p. 18).

10. Notch filters should not be used at any frequency because they degrade normal transmission (p. 19).

11. All alerts should be pretaped to minimize the complexity of action by broadcast station operating personnel (p. 19).

12. An audible alert tone is desirable (p. 19).

A.6 WMT REQUIREMENTS

1. The system should not require modification of transmitters (p. 21).

2. The same system should be used for AM, FM, and TV (p. 21).

3. The alert signal activation equipment should be located at broadcast studios (pp. 21-22).

4. The alert signal should be distinctive (p. 22).

5. The alert signal should be subject to transmission over any audio communications link (p. 22).

6. The alert signal frequency should be between 200 and 2,500 Hz (p. 22).

7. The same alert signal should be used for nuclear attack and natural disaster (p. 22).

8. All alerts should be pretaped to minimize the complexity of action by broadcast station operating personnel (p. 23).

CHAPTER SIX

PROBLEMS OF PREDICTING RECEIVER RELIABILITY

1.0 INTRODUCTION

This chapter contains a discussion of the use (and misuse) of probabilistic models for predicting the false-alarm reliability of receivers for the Radio Warning System.[1] The need for a discussion of this subject has been shown as a result of an examination of two such probabilistic models derived by corporate members of the National Industry Advisory Committee (NIAC) Systems Analysis Ad Hoc Subcommittee.[2] One of the models was devised by the Radio Receiver Department of General Electric Company and the other by Philco Corporation.

2.0 CONCLUSIONS AND RECOMMENDATIONS

The General Electric model contains several critical errors of mathematical detail. More important, however, both the General Electric and the Philco models may be in error on more basic grounds. The aim of the discussion is twofold: first, to point out previous analytical errors in order that they will hopefully not be made in the future; second, to show some of the complexities inherent in the problem of predicting the likelihood of false alarms caused by program material in the absence of empirical data upon which to base such prediction. It is recommended that either such empirical data be obtained or that attempts at such prediction through mathematical modeling be avoided in the future.

3.0 MATHEMATICAL MODELS AND FALSE ALARMS

The current desire for rational planning within government and industry has led to great importance being placed on the use of mathematical techniques for establishing a basis for decision-making. If mathematical methods are to be used in this way, the mathematician who lays the decision-making groundwork must not betray the mathematically unskilled decision-maker by making

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1. This chapter replaces Some Thoughts on Predicting Receiver Reliability, which was originally published as TM-L-1960/023/00, dated 3 December 1964.

2. Federal Communications Commission, National Industry Advisory Committee (Systems Analysis Ad Hoc Committee), Chairman's Report of Comparative Analysis of Emergency Alerting Systems for Use With Standard, FM and Television Broadcast Stations, Washington, D. C., 15 May 1964.

faulty assumptions or by allowing errors to mar his work. A mathematical model of a real process is only as valid as the assumptions upon which it is based, and the assumptions are valid only to the extent that they reflect the process they are attempting to model. Often it is valid to make relatively simple assumptions in order to make the manipulation of the model easy because no one will suggest that extremely complex processes must be reflected in greater detail than is necessary to determine the behavior of the critical parameters which are being examined; before such simplifying assumptions can be made, however, one must have an appreciation of the complex interrelationships that really exist, but which are being ignored in the model. In the problem at hand, that of predicting the likelihood of receiver false alarm, two broad areas of interrelationships between parameters are not known fully. First, the relative impact of such characteristics of broadcast program material as frequency, amplitude, and duration on the likelihood of false alarms is not clear; therefore, it is not possible to assign weighting factors to these parameters with any degree of assurance. Second, the degree to which the characteristics mentioned above are mutually related in the likelihood of their assuming certain values is not known. One thing appears clear, there are dangers present in treating program material as a random process. Music and speech consist of organized patterns of sound, and more analysis remains to be done before the effect of this organization on receiver performance can be understood.

With these difficulties to be faced, what courses are open to OCD in determining the receiver to be used in the Radio Warning System? There appear to be two, and they are mutually exclusive. The first is to explore the unknown areas mentioned above in order to provide sufficient empirical knowledge of the basic parameters involved to enable a valid reliability model to be devised. The second is to forego any appeal to such mathematical justification for the reliability of one receiver over the other and instead base such decisions on an appeal to common sense. No claim is made here for the relative merits of either course of action. Rather it is urged that one or the other be adopted in order to avoid a situation where lip service is paid to the fact that reliability models are really oversimplified and not to be trusted, while, at the same time, such models are used because they seem to fortify a position which is being taken for other reasons.

4.0 ANALYSIS OF THE GENERAL ELECTRIC MODEL FOR FALSE ALARM RELIABILITY

As part of its activity for the Systems Analysis Ad Hoc Subcommittee of NIAC, General Electric prepared a mathematical analysis of the probability of a false alarm as a function of broadcast program material. This mathematical analysis, or model, has been found to contain several errors. Two of them involve mistaken analytical assumptions, one an error in the manipulation of certain terms which has a critical effect on the result of the analysis. Because of one of the analytical errors, the assumption that the three parameters used are statistically independent, it is believed that the entire

model is invalid. Nevertheless, in order to show the effect on the results of such an analysis of mathematical errors of detail, an attempt has been made to "correct" the model and recalculate the results originally obtained by General Electric.

The error of manipulation mentioned above is found in the derivation of the probability that a given tone will be sustained longer than the time constant of the time delay circuit in the receiver. The frequency function used to find this probability is given as

$$f(t) = \begin{cases} 0 & \text{for } t < 0 \\ 4ht & \text{for } 0 < t < \frac{1}{4} \\ \frac{h}{16t^2} & \text{for } t > \frac{1}{4} \end{cases}$$

In going from the frequency function above to the probability distribution function that gives the probability that a tone will last longer than t = T seconds, it is necessary to integrate the frequency function and evaluate the constant h.

$$1 = \int_{-\infty}^{\infty} f(t)dt = \int_{0}^{\frac{1}{4}} 4ht\, dt + \int_{\frac{1}{4}}^{\infty} \frac{h dt}{16t^2}$$

$$= \frac{3h}{8}$$

$$h = 2.67$$

and $$P[t > T] = \frac{2.67}{16T} \quad \text{for } T > \frac{1}{4}$$

In his derivation of this last probability, the GE analyst arrived at the answer

$$P\ [t > T] = \frac{0.685}{48T^3}$$

which is clearly in error as an evaluation of the integral will show.

$$\int \frac{dt}{t^2} = -\frac{1}{t} + c$$

That the correction of this error results in a faulty conclusion in evaluating the performance of a receiver is now evident. As used by General Electric, the probability derived above is multiplied by the factor $\frac{T}{0.3}$ to obtain P_T, the probability that a tone or tones will last longer than the on time constant of the receiver. The constant 0.3 is used because it is the assumed average time for the appearance of a new tone. Therefore, for a receiver with time constant T, there will be $\frac{T}{0.3}$ trials during the period T which can cause the time delay circuit to charge up. The result, in the General Electric analysis is as follows:

$$P_T = \frac{T}{0.3} \cdot \frac{0.685}{48T^3} = \frac{.045}{T^2}$$

On the other hand the value of P_T obtained with the "corrected" version derived above is

$$\frac{T}{0.3} \cdot \frac{2.67}{16T} = .556$$

Note that the result is a constant. Since P_T purports to measure the probability that a tone will last longer than the time constant of the receiver, and, since P_T is independent of that time constant, then one of two situations must be present; either time delay is unnecessary in the receiver or the analysis is in error. Since the former conclusion is not reasonable on the grounds of logic, the latter must be the case.

It is apparent from the expression for P_T reached in the General Electric analysis, that the probability of a tone lasting longer than the time constant of the receiver is much smaller than a proper evaluation of the frequency distribution based upon the underlying assumptions would indicate. It is apparent that a second error was also made in the derivation of P_T. This error involves the multiplication of the quantity derived from the frequency function by $\frac{T}{0.3}$. The General Electric analysis states that this multiplication is necessary since, in the time T, tones will enter the receiver at the rate of one every 0.3 seconds and, therefore, will have to be tested by the detection circuitry to determine if they are in fact control tones transmitted to activate the receiver. This reasoning is false. P_T represents the probability that any given tone will be sustained longer than the value $t = T$. In a like manner, P_M and P_F are the probabilities that a given tone will have the proper modulation level and will lie in the proper frequency band. Therefore, the joint probability of the three occurrences, determined again erroneously by General Electric to be the product of the three separate probabilities, gives the probability that a given tone will last longer than the critical time T, will have the proper modulation level, and will lie in the proper frequency band. Once this quantity is obtained, one can worry about how many tones will enter the receiver. This process is carried out, this time correctly by General Electric, in the expression for the duration of expected false-alarm-free operation for the receiver:

$$D = \frac{0.3}{P}$$

It has been argued that even though the numerical results of the General Electric analysis are in error, the ranking of the tested receivers will remain the same after the formulas are corrected. This, however, is not the case. In the erroneous expression for P_T, given by General Electric, P_T varies inversely as the square of the time constant. (It varies with the square only because of the second error in the analyses. If that error had not been made, it would have varied inversely with the cube of the time

constant.) It should vary inversely as the first power of the time constant. This has an effect on the relative ranking of the Philco and Zenith receivers. In the General Electric ranking, the Philco receiver had the second longest expected duration of false-alarm-free operation; Zenith, the third. It is apparent that the reason for this ranking was the short time constant of the Zenith receiver, the effect of which far outweighed in the analysis the wider bandwidth used to filter out the control tones in the Philco receiver. To demonstrate that this change in ranking does occur, two sets of results were recalculated using modified forms of the General Electric model. In the first recalculation, the only change was to substitute the correct form of the integral for P_T into the expression for P. As mentioned above, if this substitution is carried out, the value of P_T remains constant ($P_T = .556$). In the second calculation, the factor $\frac{0.3}{T}$ was removed from the expression for P_T in order to "correct" the second error made by General Electric. If this is done, P_T becomes a function of the reciprocal of T.

$$P_T = \frac{.167}{T}$$

Table 6-1 shows the results of these recalculations.

Table 6-1. A Comparison of Results Obtained with the Uncorrected and "Corrected" General Electric False Alarm Analysis

Receiver	Expected Duration of False-Alarm-Free Operation		
	$P_T = .048/T^2$ Original GE	$P_T = .556$ First Modification	$P_T = .167/T$ Second Modification
CBS	12 hours	15 minutes	15 minutes
Philco *	1,300,000 days	12 hours	786 days
Zenith *	990,000 days	271 days	2,710 days
GE	8,500,000 days	488 days	140,000 days

* Order reversed between first analysis and other analyses.

5.0 CRITIQUE OF ASSUMPTIONS

The results shown above indicate more than that an error can yield faulty results. They show the critical nature of weighting factors in a mathematical expression such as was used in this analysis. In the original General Electric model, the time constant of the receiver was implicitly weighted more heavily because of the squared quantity in the denominator. This increased weighting factor was sufficiently important to result in a receiver with filters of very large bandwidth being rated better than one with filters of a much narrower bandwidth. Now, it may be true that the length of time over which the signal is integrated is more important than the bandwidth of the filters in determining the false alarm probability of a given signaling technique. but if it is, it is not because a mathematical formula says so. Rather, the reverse is true. The mathematical formula must reflect what has been determined to be true after an empirical analysis has been made of the noise and program material to which the receiver will be subjected. The analysis made by Philco for the NIAC Systems Analysis Ad Hoc Committee also involves weighting factors, but in their attempt to be fair, Philco assigns all weighting factors a value of one. The question arises as to whether this is more valid. The answer remains that one cannot be sure without proper empirical evidence upon which to base a decision.

It was mentioned above that the General Electric analysis erroneously states that the probability of the occurrence of a tone which has the proper time duration, modulation level, and frequency equals the product of the probabilities that a tone will have these three characteristics separately. To see that this is an erroneous conclusion, we must discuss the concepts of statistical dependence and independence. The statement that the probability of the joint occurrence of A and B equals the product of the probability of the occurrence of A and the probability of the occurrence of B is true if and only if A and B are independent events. In other words, the occurrence of A must not be affected in any way by the occurrence of B and vice versa. The question as to whether the time, amplitude and frequency of a given tone are independent naturally arises. The answer must be that we do not know, but that it is not likely that they are independent. As mentioned previously, music and speech are organized patterns of sound. An examination of music, for instance, indicates that in the more serious types of compositions, low frequency notes have a greater probability of being sustained for a longer time than do higher frequencies. The same may be true for other types of music as well. In the upper frequency ranges, there is a tendency for transient tones to appear not only as overtones, but as components of impulse sounds. This leads to a strong suspicion that the probability of a tone being sustained beyond a given length of time is dependent upon frequency. It also leads to a question of whether, as claimed by its authors, the General Electric analysis really established a worst case environment for the receivers which are controlled by low frequency tones. As long as the three parameters are treated independently, an assumption that all frequencies are apt to occur with equal probability is in fact, immaterial since the correlation between the parameters is not considered at all.

One can also derive intuitively a suspicion that the modulation level is dependent upon frequency, but such suspicions are only based on intuition. They cannot be incorporated into a mathematical expression for reliability until the exact nature, if any, of the independence is known. This will require extensive analysis of all types of program material found in broadcasting.

CHAPTER SEVEN

A TECHNIQUE FOR PREVENTING PROGRAM MATERIAL FROM FALSELY ACTIVATING HOME RECEIVERS

1.0 INTRODUCTION

It is the purpose of this chapter to present a method for preventing a broadcast station from ever transmitting demuting signals to radio warning receivers tuned to it during normal broadcast operations, while at the same time this proposed method removes the objections that station owners would have to use devices that would degrade their transmissions.[1]

2.0 CONCLUSIONS AND RECOMMENDATIONS

The technique, described below, uses notch filters to remove the demuting tones from broadcast material. The technique overcomes the objections of broadcasters by inserting the notch filters dynamically into the station programming line only when the demuting tones appear for a long enough period of time to threaten a false alarm. If a valid warning is required, the notch filters would be removed from the programming line, again dynamically, before the demuting tones were transmitted. Thus, the notch filters would be in the programming line only so long as they were needed to prevent a false alarm and would not degrade the quality of normal program material. It is recommended, therefore, that all future planning for the Radio Warning System include the dynamically controlled filtering technique described below.

3.0 DYNAMICALLY CONTROLLED NOTCH FILTER

One of the more difficult problems of the Radio Warning System to be solved is the design of a secure unmuting circuit for a warning receiver which operates in the commercial broadcast band. This circuit must be made impervious to the high-level audio modulation of relatively unknown spectral content that exists in program material. A practical solution to this problem was suggested by some members of the National Industry Advisory Committee (NIAC). This was to use notch filters at the commercial broadcast transmitter to prevent the

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1. This chapter replaces A Suggestion for Preventing Program Material from Falsely Activating Radio Warning Home Receivers, which was originally published as TM-L-1960/024/00, dated 4 February 1965.

unmuting signal from ever being transmitted to the home receiver.[1] This solution is basically sound as it attacks the problem at its source and makes unnecessary an involved analysis to select frequencies that have a low probability of being present in program material. There is a basic drawback of this solution, as was pointed out by one member of the committee, O. W. Towner, Director of Engineering for station WHAS, Louisville, Kentucky. This is the objection that the use of notch filters degrades the quality of the broadcast material and that "most stations would seriously object to the degradation they create."[2] Whether or not the degradation is substantial can be argued pro and con, but it is doubtful if station owners could ever be convinced that any degradation is not serious. In any program requiring voluntary participation in a Radio Warning System this would be a serious hurdle to overcome. It would seem that the use of notch filters to prevent false activation of home receivers might create more problems than it solves, especially since proof is lacking that program material does contain the combination of tones to unmute the receivers.

In order to increase signaling security, use is made of the signal integration feature of the home receiver. In order to prevent activation on noise bursts and short-duration sequences of program material that contain the unmuting tones, the home receivers will delay activation until the tones persist for some nominal period of time. Ten seconds has been mentioned as a reasonable delay period. The same unmuting circuit that is used in the home receiver could be installed at the broadcast station to monitor the program line. The delay time of this monitor circuit could be made somewhat shorter than the delay time of the home receivers so that it will operate before the home receivers have had time to unmute. When the time delay of the monitor has been overcome, it will activate not an unmuting gate, but a switch to insert a notch filter in the program line and remove the activating signals from the program material being broadcast. The discharge time of the monitor circuit could be made long enough to retain the filter in the program line until the home receiver delay circuits have been completely discharged. This method would effectively prevent any combination of tones that might contain the activating signals from being broadcast for a sufficient length of time to activate the home receivers. As the notch filter will only be switched in when the program material contains tones that could cause false alarms, station owners could hardly take the position that their legitimate program material was being degraded. To argue otherwise would place them in the untenable position of maintaining their right to initiate false alarms. As reasonable precautions will already

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1. Federal Communications Commission, National Industry Advisory Committee (Systems Analysis Ad Hoc Committee), Chairman's Report of Comparative Analysis of Emergency Alerting Systems for Use With Standard, FM and Television Broadcast Stations, 15 May 1965, p. 68.

2. Ibid., p. 19.

have been taken to devise unmuting tone sequences that have an extremely low probability of existing in normal program material, activation of the monitor-operated filter switch should be infrequent. To insure that the filter will not be switched into the program line when a real alert is being broadcast, the switch that connects the OCD warning equipment to the transmitter should be inserted in the program line on the transmitter side of the program monitor.

The cost of this device should be relatively low as the sensing circuitry is almost identical to the demuting circuitry of the home receiver. Undoubtedly the most expensive components would be the notch filters. This device could be installed at all broadcast stations used in the Radio Warning System regardless of the type of receiver finally chosen and would eliminate one potential source of false activation signals. It would have no effect, unfortunately, on interfering signals from other sources or from remote noise sources, but this is believed to be a lesser problem than that presented by program material.

An advantage of using this method is that it is completely independent of the characteristics of the home receiver that will ultimately be chosen for implementation, except that the notch filters must be designed to suppress the particular tones used for activation. It will improve the reliability against false alarm of any type of receiver and will do so at a reasonable cost.

CHAPTER EIGHT

COHERENT RECEIVER DEVELOPMENT

1.0 INTRODUCTION

This chapter contains a review and summary of work performed in developing secure signaling methods for demuting home warning receivers.[1] This effort evolved from an investigation of receivers developed by the National Industry Advisory Committee (NIAC).[2] During this investigation a deficiency noted in the NIAC evaluations was the attempt to enhance several of the reports with mathematical analyses based on unsupported assumptions about the noise and program material environments of the proposed receivers. A thorough discussion of the risks that beset the use of this approach are presented in another chapter[3] and will not be further elaborated here. It is sufficient to say that the attempts to derive quantitative figures of merit for the NIAC receivers by a rigorous analysis of the circuit parameters have been thwarted by lack of adequate information on the distribution of noise in the broadcast-frequency band. Also lacking was any information on the time, duration, and frequency of tones that exist in commercial broadcast program material. It is believed that such data are nonexistent in the form needed for a proper analysis of the effects of program material on receiver demuting circuitry and, furthermore, that any effort to collect adequate data would be time consuming, costly, and inconclusive. The presumption was that any attempt to evaluate receiver susceptibility to false alarm would inevitably be based upon an intuitive judgement of the effects that signals from these extraneous sources would have on the receiver circuitry. Rather than attempting to apply intuitive judgement to constructing a model of the noise environment which could not be justified by correlation with empirical data, it was decided to study the possibility of developing demuting circuitry which would respond only to unique signals that would not normally be produced by either natural or man-made sources.

2.0 CONCLUSIONS AND RECOMMENDATIONS

While only part of the circuit described below has been breadboarded and tested, it is believed that its principle is sound and offers the real possibility of improving the false alarm characteristics of the radio warning receiver. As comparative costing figures are still not available, it is not possible to place a

1. This chapter replaces Coherent Receiver Development, which was originally published as TM-L-1960/025/00, dated 11 February 1965.

2. Chapter Five, "Review and Analysis of NIAC Signaling Methods."

3. Chapter Six, "Problems of Predicting Receiver Reliability."

dollar value on the costs of this design; however, the number and types of components used are comparable to those used in the conventional two-tone demuting circuit currently under development for OCD, and it is believed that the costs should be in the same range. More development work needs to be done to prove out the operation of this circuit, but it is believed that such an effort would be worthwhile to the Radio Warning Program. It is recommended, therefore, that such developmental work be undertaken.

3.0 RECEIVER SUSCEPTIBILITY TO FALSE ALARM

The demuting circuitry used in a warning receiver may be compared to a locked box, which may be opened when the correct key is used. If the key consists of tones which may exist in the noise or program environment in which the receiver must operate, then there is a finite probability that the box will unintentionally be unlocked at some time. This situation is not necessarily bad as the probability of the "key" tones being present in the right form and for a sufficient length of time may be extremely low. If this is so, the cost advantage offered by simple demuting circuitry may outweigh the advantages of devising a more secure lock. The difficulty arises in attempting to prove that the above probability is actually low. Even if adequate data were available and demonstrated that selected demuting tones have a low probability of appearing, the dynamic nature of the noise environment and the rapid change in music forms and recorded program material would create doubt that past samplings of the environment are truly representative. In addition, the purposeful production of the demuting by unscrupulous persons seeking publicity would always pose a problem if no great effort is required by them to produce the demuting tones. These considerations point to the uncertainty that will always confront the analyst in his attempt to derive a quantitative measure of the susceptibility of the home receiver.

On the other hand, if a demuting signal could be devised that is not normally produced by natural or man-made noise sources, and cannot exist in program material, the receiver would be secure. If, furthermore, it takes special equipment to produce the demuting signal, then the purposeful production of the tones by unauthorized persons will be inhibited. Of course, any key can be duplicated where the details of the lock are a matter of public knowledge, but the use of such a key would imply a malicious intent. A legal defense based on lack of intent to produce a false alarm would be difficult to prove. This makes the policing of the improper usage of the key by unauthorized persons much easier.

4.0 EVOLUTION OF THE COHERENCY CONCEPT

Several configurations involving special usage of single or dual transmitters with particular receiver designs were investigated. Elementary breadboard models were constructed in some instances to validate the concepts. The three most noteworthy of these early designs are discussed below in the evolutionary

order in which they were conceived. These various configurations are considered to be technically feasible, but were rejected for possible application in the Radio Warning System because of excessive costs.

4.1 TWO-TRANSMITTER CONCEPT

A suggestion was made to utilize two cooperating radio transmitters. One transmitter could be a commercial broadcast station. The second transmitter would be tuned to a frequency differing from the first station's frequency by the intermediate frequency (i.f.). The local oscillator in the receiver would be replaced by a radio frequency (r.f.) stage tuned to the second station.

Without a local oscillator, the receiver would be muted. When the second station came on the air, it would provide the frequency normally provided by the local oscillator and would unmute the receiver. Additional security could be provided by a single resonant reed relay and the transmission of a demuting tone.

While this technique has some merit from the standpoint of receiver simplicity and a fair degree of security from false alarms, it is cumbersome and expensive at the transmitter end. It suffers from the high probability of signals being present at the second transmitter frequency during the nighttime hours.

4.2 TWO-STATION COHERENT SIGNAL CONCEPT

To avoid special transmitter requirements, it appeared to be practical to use any two radio stations located in a given city to transmit a coherent control signal. The stations would be linked by telephone line. The control code would consist of a single low-frequency tone transmitted by the first station, and the same tone phase inverted and transmitted by the second station. The receiver would require two front ends up to the first audio stage. At that point, the receiver would invert the phase of one signal and add the two signals. All in-phase transmission from the two stations or from noise would cancel, while out-of-phase signals would add. This technique results in a more expensive receiver, since it represents almost two complete receivers.

4.3 SINGLE STATION COHERENT SIGNAL CONCEPT

The audio spectrum above and below the voice frequency range could be used for transmission of the receiver unmuting code. If two frequencies such as 5 kHz and 8 kHz were selected to act as carriers of a low-frequency modulation tone, such as 90 Hertz, it should be possible to transmit the same low frequency over these two carriers, but with the phase of one modulation inverted with respect to the other.

If modulation of the higher frequencies were to occur naturally or accidentally by a lower frequency, both carrier tones would be modulated in phase. There would be no probability of modulating the 8 kHz tone by 90 Hertz while simultaneously modulating the 5 kHz tone by the same 90 Hertz phase shifted 180°. In

an attempt to breadboard and test this concept, it was realized from the initial circuit diagram that its cost would be prohibitive due to the number of high-Q filters needed.

In an attempt to reduce cost, a circuit design was attempted using only one carrier tone to carry the 90 Hertz modulation. A phase-shifted 90 Hertz tone could be transmitted directly without the aid of a carrier. This modification preserved the two-path coherent signal concept and reduced by one-half the number of filters required. It was apparent, however, that the design was still more complex and more expensive than the simple scheme of two low-frequency resonant reed relays operating an AND gate.

5.0 LOW-COST COHERENT RECEIVER

As costing figures were not available to SDC to enable comparison of SDC receiver circuitry costs with those of the OCD receiver, relative costs were estimated on the basis of the number of extra components that use of the coherency principle entailed. The previously discussed designs all were considerably more complex than the OCD receiver and, therefore, considered to be more costly. One fact became evident; the excellent narrow band mechanical filter characteristics of reed relays could not be duplicated at comparable costs with passive or active electronic components. It was decided to investigate the possibility of applying the coherency principle to reed relays as a means of bringing costs down to an acceptable level.

During preliminary experimentation with resonant reed relays, an important property of the reed was noticed. The mechanical motion of the resonant reed phase locks to the electrical phase of the deriving frequency. This relationship is maintained with high stability throughout the frequency bandpass of the relay. At one end of the reed motion, momentary contact is made to complete an electrical circuit once each cycle The duration of the contact closure is a function of the placement and resiliency of the member supporting the fixed contact. Closure time can be made from less than 1 percent of the cycle to over 10 percent of the cycle. Figure 8-1 illustrates the reed contact timing with respect to the electrical phase for two frequencies within the bandpass of the relay. The reed vibrates at the frequency of the driving signal and maintains a fixed phase relationship to the phase of the driving signal. Polarity reversal of the leads to the relay driving coil results in contact closures on the negative peaks.

While the normal practice is to avoid harmonic relationships between two resonant reed relays in a given application, the technique described here makes use of the harmonic relationship in a special way.

Two resonant reed relays were obtained having frequencies $f_1 = 151.4$ and $f_2 = 303$ Hertz. The f_1 frequency relay was manufactured by Branco Controls Company and had about a 10 percent contact closure time. The f_2 relay was obtained

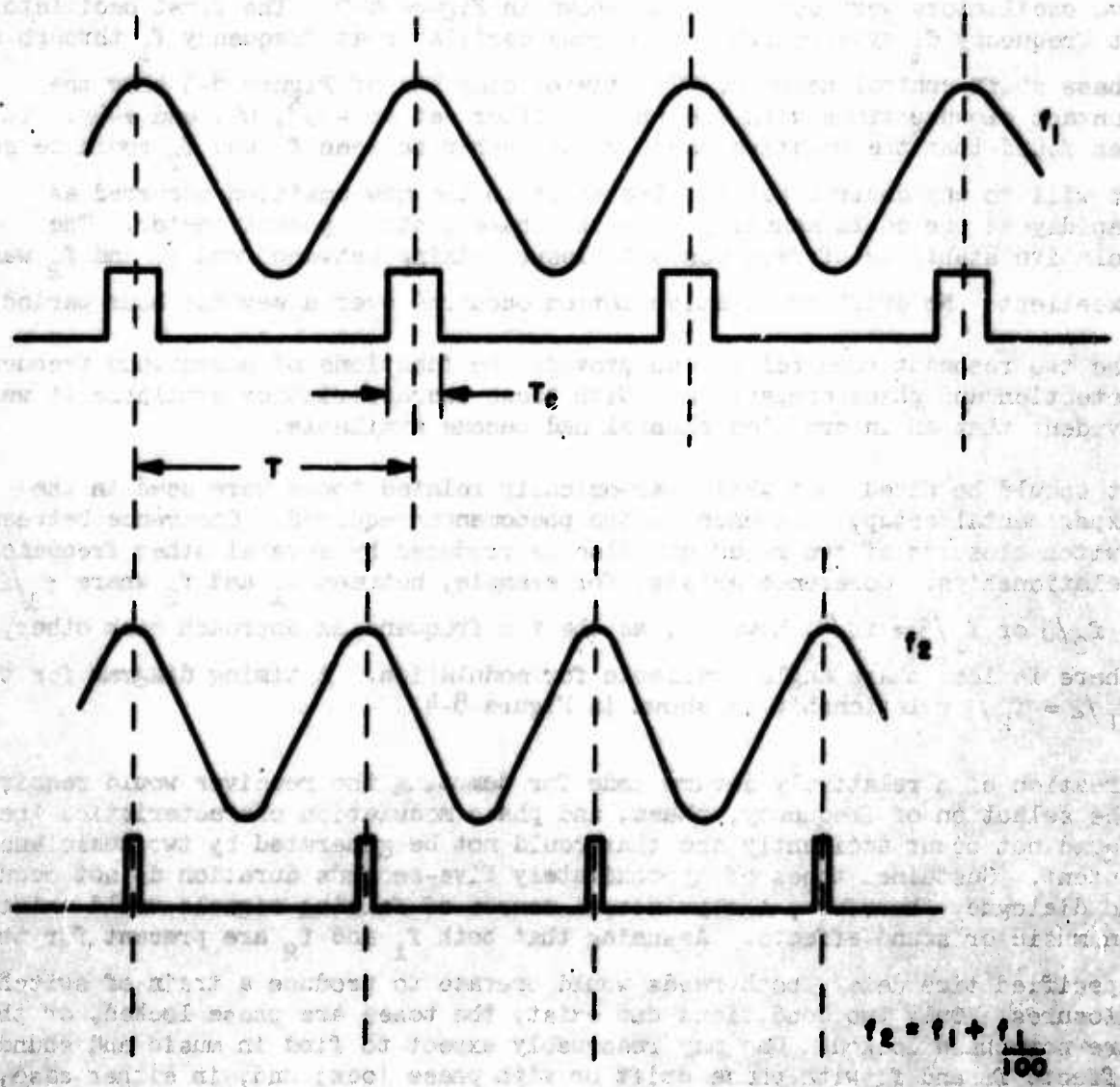


Figure 8-1. Reed Switch Closure Coincidence with Peak of Driving Frequency

from the W. S. Dean Company, whose product is used primarily for model airplane flight control. It had a fixed contact resulting in contact closure time of about 1 percent. The reed plate in the Dean relay had provisions for eight reeds, but only one reed was used.

Two oscillators were connected as shown in Figure 8-2. The first oscillator at frequency f_2 synchronized the second oscillator at frequency f_1 through a phase shift control network. The timing diagrams of Figure 8-3 show the contact closure times with the phase shifter set at -45°, 0°, and $+45^{\circ}$. It was found that the relative phase relationship between f_1 and f_2 could be set at will to any desired point. The shift to the new position occurred as rapidly as one could manually turn the phase control potentiometer. The relative stability of reed contact closure timing between reed f_1 and f_2 was excellent. No drift or relative motion occurred over a several hour period.

The two resonant reed relays can provide the functions of narrowband frequency detection and phase comparison. With these characteristics available, it was evident that an information channel had become available.

It should be noted that while harmonically related tones were used in the experimental setup, coherence is the phenomenon required. Coherence between switch closures of two reeds can also be produced by several other frequency relationships. Coherence exists, for example, between f_1 and f_2 where $f_1/2 = f_2/3$ or $f_1/3 = f_2/4$; however, as the two frequencies approach each other, there is less phase angle available for modulation. A timing diagram for the $f_1/2 = f_2/3$ relationship is shown in Figure 8-4.

Creation of a relatively secure code for demuting the receiver would require the selection of frequency, phase, and phase modulation characteristics that could not occur accidently and that could not be generated by two musicians by intent. Sustained tones of approximately five-seconds duration do not occur in dialogue, therefore, the principal source of falsing signals would exist in music or sound effects. Assuming that both f_1 and f_2 are present for the specified time delay, both reeds would operate to produce a train of switch closures. Only two conditions can exist; the tones are phase locked, or they are not phase locked. One may reasonably expect to find in music and sound effects f_1 and f_2 with phase drift or with phase lock; and, in either case, they may be amplitude or frequency modulated. Frequency modulation, when caused by wow or flutter in a tape drive, will be in phase for both tones. Relative phase modulation of f_1 with respect to f_2 could occur between two individual musical instruments. In this instance, however, drift is also present and the phase modulation will not persist between two fixed phase points. A secure code would, therefore, require: (1) no phase drift at any

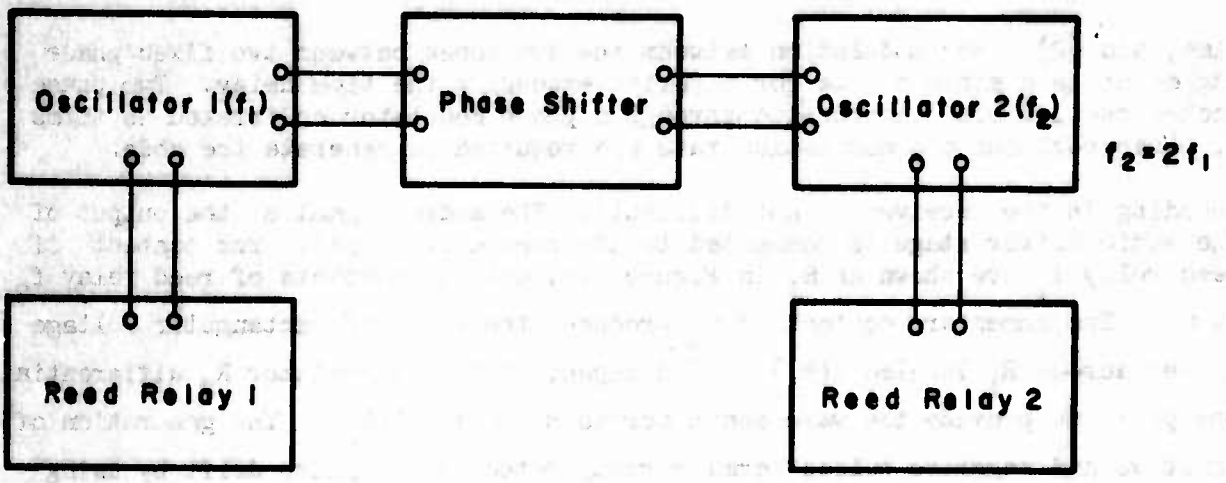


Figure 8-2. Connection of Oscillators to Produce Relative Phase Shift

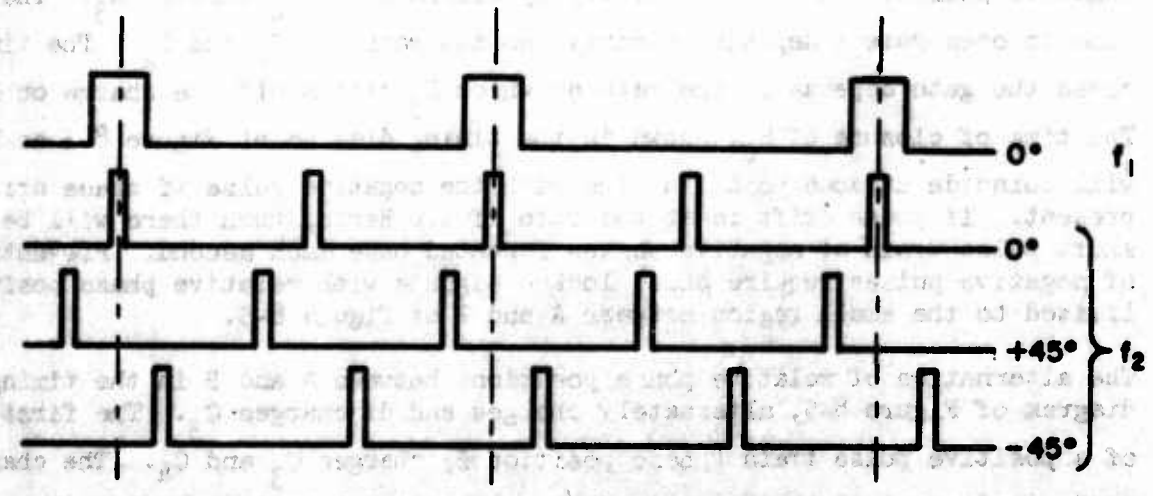


Figure 8-3. Phase-Shift Timing Diagram

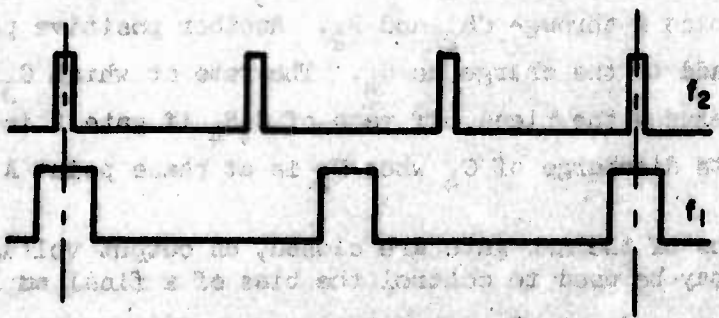


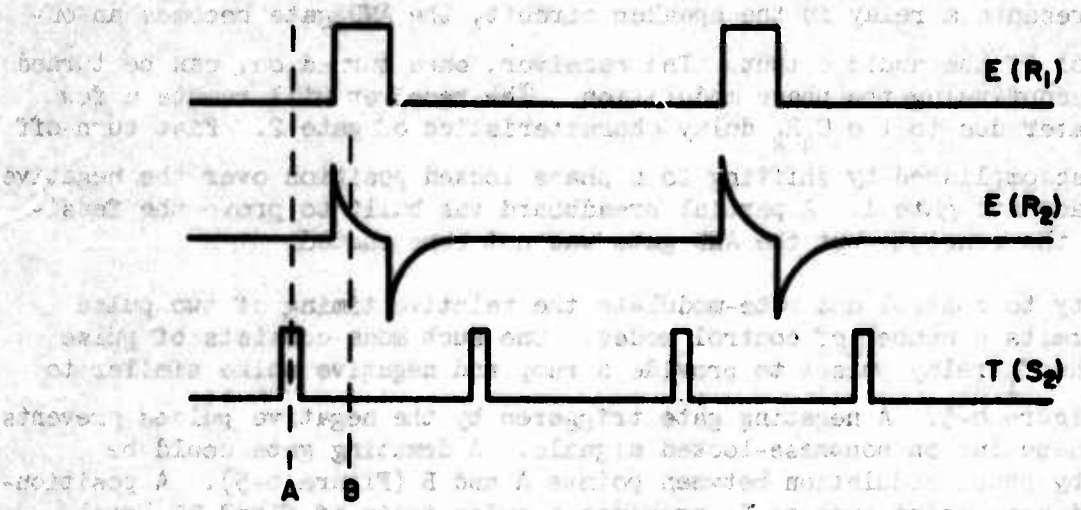
Figure 8-4. Phase Relation $\frac{f_1}{2} = \frac{f_2}{3}$

time, and (2) phase modulation between the two tones between two fixed phase angles above a minimum rate for a period exceeding the time delay. Two phase locked oscillators synchronized through a phase modulator calibrated in terms of phase position and modulation rate are required to generate the code.

Decoding in the receiver is not difficult. The audio signal at the output of the audio driver stage is connected to the reed driver coil. The contacts of reed relay f_1 are shown as S_1 in Figure 8-5; and the contacts of reed relay f_2 as S_2. The momentary contact of S_1 produces the train of rectangular voltage pulses across R_1 labeled $E(R_1)$. The capacitor C_1 and resistor R_2 differentiate the pulse to provide the wave shape across R_2 marked $E(R_2)$. The generation of positive and negative pulses permits ready detection of phase drift by using the negating section of the AND gate (gate 1, Figure 8-5). Network R_3 and C_2 provide a fast-charge, slow-discharge time delay limited to acceptance of only negative pulses. It recloses slowly by discharge of C_2 through R_3. The time to open gate 1 depends primarily on the ratio of C_1 and C_2. The time to close the gate depends on the rate at which R_3 bleeds off the charge on C_2. The time of closure of S_2, shown in the timing diagram of Figure 8-5 as $T(S_2)$, will coincide at some point in time with the negative pulse if phase drift is present. If phase drift is at the rate of 1.0 Hertz, then there will be a short pulse train of negative pulses repeated once each second. Prevention of negative pulses require phase locked signals with relative phase positions limited to the small region between A and B of Figure 8-5.

The alternation of relative phase positions between A and B in the timing diagram of Figure 8-5, alternately charges and discharges C_3. The first pulse of a positive pulse train (phase position B) charges C_3 and C_4. The charge on C_4 is determined by the ratio C_3/C_4. Additional positive pulses have no effect, since C_3 and C_4 are fully charged. C_3 is discharged when the phase relation is at point A through CR_2 and R_2. Another positive pulse will recharge C_3 and add to the charge on C_4. The rate at which C_3 is charged and discharged must exceed the bleed off rate of C_4R_4 if gate 2 is to be closed. Diode CR_3 prevents discharge of C_4 when S_2 is at phase point A.

When both sections of the AND gate are closed, an output voltage is developed across R_L, which may be used to control the bias of a final amplifier stage. The bias on the base of gate 2 transistor is a function of the phase modulation rate. Modulation rate could, therefore, be used to control the gain or audio level in the receiver.



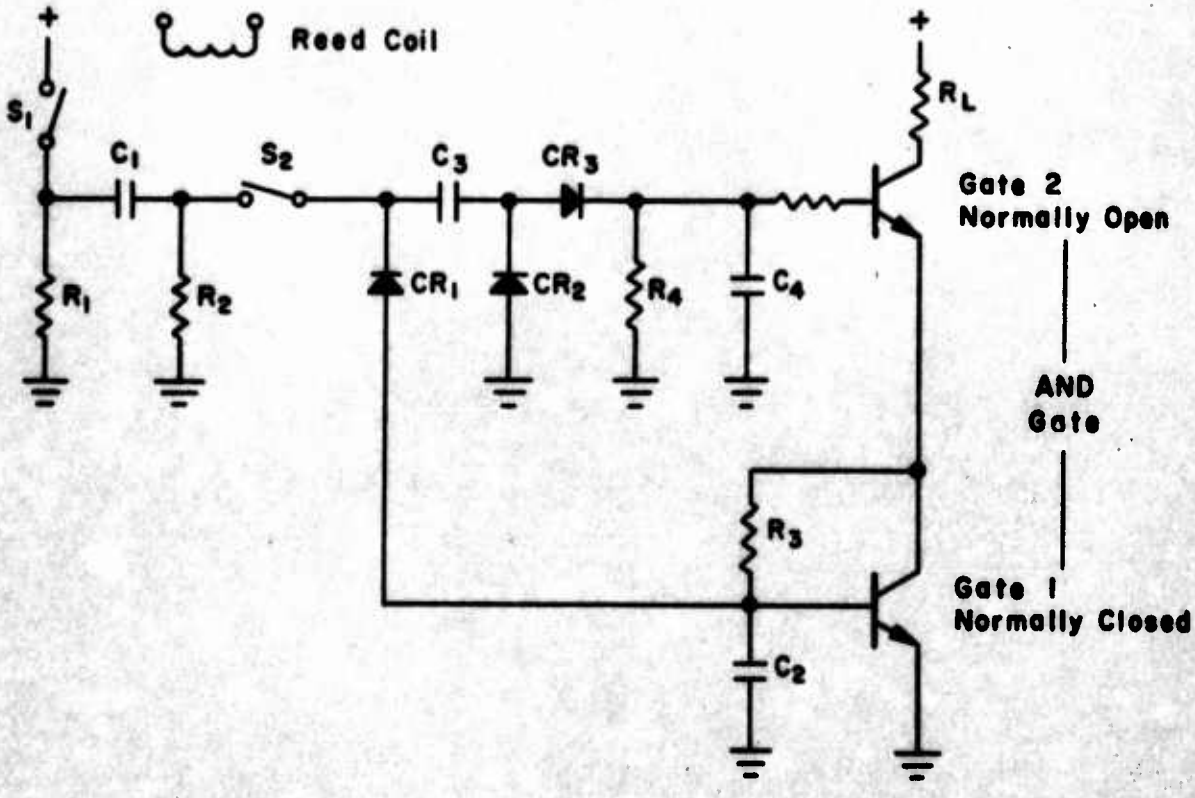
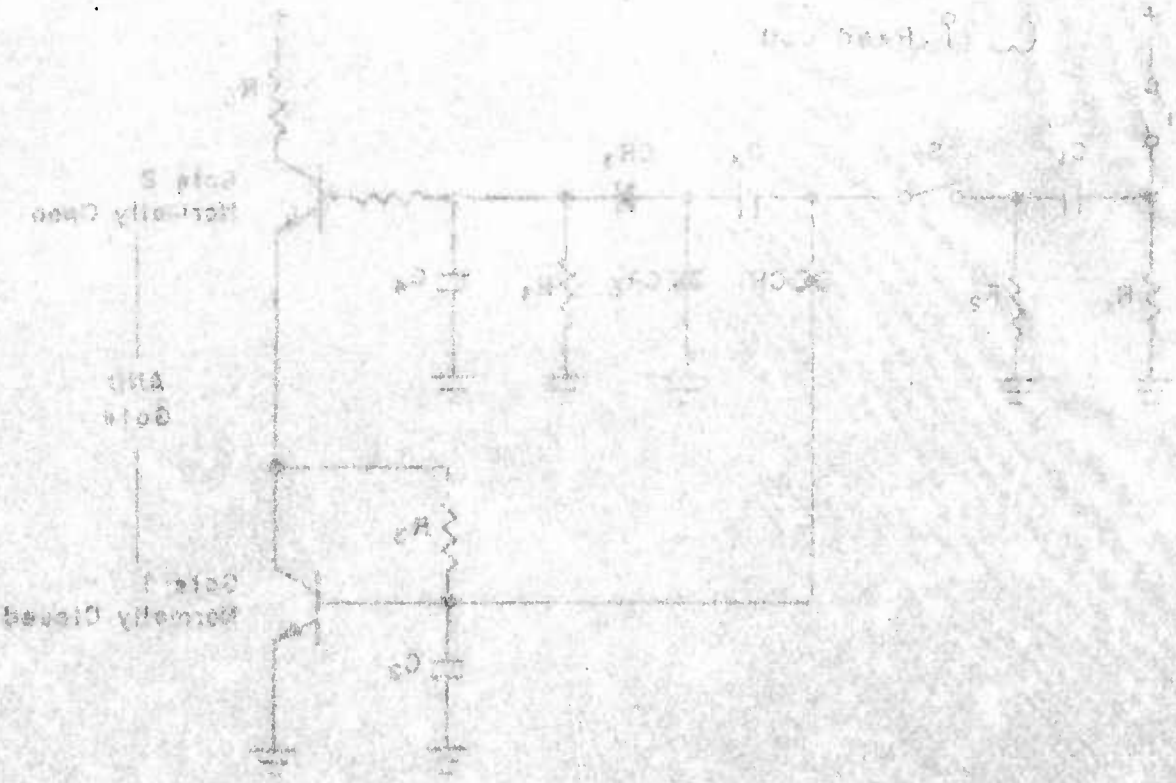


Figure 8-5. Demuting Circuit and S_1-S_2 Time-Phase Plot

If R_L represents a relay in the speaker circuit, the AND gate becomes an on-off control of the audio output. The receiver, once turned on, can be turned off by discontinuing the phase modulation. The receiver will remute a few seconds later due to the C_4R_4 delay characteristics of gate 2. Fast turn-off would be accomplished by shifting to a phase locked position over the negative pulse to actuate gate 1. A partial breadboard was built to prove the feasibility of the concept, but the AND gate was not constructed.

The ability to control and rate-modulate the relative timing of two pulse trains permits a number of control modes. One such mode consists of pulse shaping the f_1 relay pulses to provide a ramp and negative spike similar to that of Figure 8-5. A negating gate triggered by the negative pulses prevents receiver demuting on nonphase-locked signals. A demuting gate could be operated by phase modulation between points A and B (Figure 8-5). A positional hold at some point such as B, provides a pulse train of fixed DC level. Receiver volume could be controlled simply by sliding point B up or down the ramp.



CHAPTER NINE

A COMPARISON OF NIAC AND OCD RECEIVERS

1.0 INTRODUCTION

The material in this chapter compares three radio warning home receivers: those receivers proposed by Philco Corporation and Zenith Radio Corporation to the National Industry Advisory Group (NIAC) of the Federal Communications Commission; and that receiver under development for the Office of Civil Defense (OCD).[1]

In order to compare logically these receivers, one with another, some standard criteria must be established as a basis for the comparison. So far, the only authoritative document which has been widely disseminated and generally accepted within OCD is that which defines the operational requirements for the Radio Warning System.[2] This document contains a few requirements which refer specifically to the radio receiver component of the system. There are other receiver requirements which derive from these operational requirements and from practical considerations. These requirements have been generally accepted by those who have been associated with the development of an OCD receiver.

2.0 CONCLUSIONS

The development of a set of operational requirements generally acceptable within OCD provides a yardstick against which various receiver designs can be measured. Using these requirements as such a yardstick, it is evident that, of the three receivers compared, only the OCD-proposed receiver is compatible with the mission of a civil defense public warning system.

3.0 OCD RADIO RECEIVER OPERATIONAL REQUIREMENTS

The following list is a compilation of those requirements pertinent to the home receiver. The source or justification of the requirement is found as indicated.

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1. This chapter replaces A Comparison of NIAC-2, NIAC-6, and OCD-4 Receivers, which was originally published as TM-L-1960/028/00, dated 31 March 1965. NIAC-2 and NIAC-6 are the Philco and Zenith receivers, respectively; OCD-4 is the OCD-proposed receiver.

2. See Chapter One, "Interim Operational Requirements."

1. Receivers shall be muted when not in operation (Section 4.3.7[1]).

2. Receivers shall be under positive control of operator (Section 4.3.8). Automatic, timed selfremuting cannot be used in the receiver. The warning message length is subject to the discretion of the system operators and should not be compromised by arbitrary technical limitations on the length of time the receiver will stay unmuted.

3. The alert signal generator shall not be located in the home receiver (Section 4.3.9).

4. Unmuting tones or signals shall be distinct from the tones used to signal an alert. This requirement is implied by the operational requirement that, "The Radio Warning System shall be capable of transmitting messages to the public with or without the accompanying alert signal." (Section 4.3.10). This, of course, cannot be accomplished if the unmuting tones are audible each time the system is used to transmit messages and if the same audible tones serve the double function of unmuting and alerting.

5. Unmuting tones shall be nonraucous and not easily mistaken for alerting tones. This requirement derives from the operational requirement to transmit a message to the public without an alert signal (Section 4.3.10). If the unmuting tone is in the audible frequency band passed by the receiver audio circuitry and is actually audible through the receiver loudspeaker during the unmuting process then this rule applies. If the unmuting signal is not audible through the speaker, its particular waveform is unimportant.

6. A two-tone unmuting signal shall be used. Intuitive evaluations of program material and noise environment indicate that the probability of a single tone occurring is sufficiently high to render infeasible the use of a single tone for unmuting.

7. Signaling techniques shall be compatible for all modes of use, i.e., AM, FM, TV, low-frequency. Unnecessary costs would be incurred if different signal generators would be required for the different types of transmitters that may be used in the system.[2]

8. Recovery from a false alert shall be automatic. Receivers must have the capability to remute automatically after the spurious signals which caused the unmuting have ceased. This requirement is

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1. Section numbers refer to Chapter Two.

2. Gautney and Jones Communications, Inc., Report on Choice of Method of Home Receiver Activation for OCD Alert/Warning System, 16 November 1964.

for the purpose of preventing a potential source of public annoyance from unattended receivers which continue to blast out program material at high volume after the falsing signals have disappeared. If this receiver were in a locked apartment, it would require a forcible, and perhaps illegal, entry in order to abate this public nuisance.

9. Susceptibility to false alert shall be minimized. Within cost limitations, the most important single requirement for the receiver is that it have minimum susceptibility from false activation by noise, program material, or malfunction.

10. Receiver cost shall be as low as practicable within the constraints of the forgoing requirements. Due to the extremely large number of receiver units that will be required for the system even small differential costs between competing receivers can total to large amounts of money. If performances of competing receivers are about equal, costs will be the controlling factor in choosing one receiver over another.

4.0 EVALUATION

Table 9-1 lists the significant operational parameters of the Philco, Zenith, and OCD receivers. It can be seen that the frequencies of the unmuting tones employed by both NIAC receivers place them clearly in the audible range. In contrast, the OCD receiver employs only one audible tone, and that tone disappears before the receiver unmutes. The audible tones used by the NIAC receivers must also be made to disappear if any useful message is to be transmitted over the audio channel. The only way that these tones can be made to disappear is to use a latching circuit to hold the receiver in an unmuted condition when the tones are discontinued. This lessens the control that the operator has over the unmuting function as well as creating a potential source of public annoyance and thus violates OCD's receiver Requirements 2[1] and 8. Use of narrow-band rejection filters in the receivers to remove the unmuting tones would add substantially to the receiver costs and make the NIAC receivers noncompetitive on the basis of Requirement 10, which specifies minimum receiver costs. One other method that might be employed to overcome the handicap from which the NIAC receivers suffer in regard to Requirement 8 would be to require the transmitter to periodically transmit a remuting tone, e.g., every five minutes, to remute any receivers which might have been unmuted by false signals. This places a requirement on the transmitters which cannot be justified on other grounds and would be intolerable if imposed on a commercial broadcast station. Except for testing or circuit checking the transmitters should not be required to transmit except in an operational situation.

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1. Cf., Chapter 10, p. 10-4, par. 2.

Table 9-1. Comparison of Signaling Techniques

System	Unmuting Frequencies (Hertz)	Modulation Percent	Modulation Type	Wave Shape	Duration (Seconds)	Type of Latching	Use	Remarks
Philco	806 & 761 806 & 679 761 & 679	45 ea.	AM	Sine	20	Controlled	Alert Subsidiary Remote	AM, FM, TV
Zenith	1010 & 925	50 ea.	AM	Square	20	Permanent or Temporary	Alert	AM
	570 & 635 510 & 635 510 & 570	50 ea.	AM	Square	20	Permanent or Temporary	Alert Subsidiary Subsidiary	FM, TV
OCD	512.8 105.9 105.9	85 85 20	AM AM AM	Sine Sine Sine	6 5 -	Non-latching	Demuting Demuting Hold-on	AM, FM, TV

Table 9-2 lists in tabular form the previously discussed receiver requirements with an indication as to whether the receivers meet each requirement. The Philco receiver does not meet Requirement 4 and 8. The Zenith receiver does not meet these requirements and, in addition, does not meet Requirements 5 and 7.

The similiarities between the NIAC and OCD receivers are more than superficial. The RF sections of the receivers can be made to meet the same specifications without difficulty. The only real differences in the receivers lies in the logic of the decoding circuitry and the philosophy of operation. The OCD receiver design was the result of a careful consideration of the operational requirements as propounded and refined by numerous discussions and working group meetings with OCD technical and operational personnel. The NIAC receivers, on the other hand, were derived independently by individual manufacturers each working from his own definition of the operational requirements.[1] The work of the NIAC committee was hampered, and the results are inconclusive due to the lack of a standard definition of the operational requirements. Now that these requirements have been produced, the only reasonable approach is to use them as a basis for evaluation of all component parts of the Radio Warning System, including the radio warning receiver.

1. See Chapter Five, "Review and Evaluation of NIAC Signaling Methods."

Table 9-2. Capabilities of Receivers to Meet OCD Requirements

Requirement	Philco	Zenith	OCD
1. Muted when Not Operated	Y	Y	Y
2. Positive Control (Remuting Not Timed)	Y	Y	Y
3. Alert Generator Not in Receiver	Y	Y	Y
4. Distinct Unmuting Tones	N	N	Y
5. Nonraucous Unmuting Tones	Y	N	Y
6. Two-Tone Unmuting Signal	Y	Y	Y
7. Compatible Signaling Methods	Y	N	Y
8. Automatic False Alert Recovery	N	N	Y
9. Low Susceptibility to False Alert	Y	Y	Y
10. Low Receiver Cost	Y	Y	Y

Key: Y - Meets OCD requirements

N - Does not meet OCD requirements

CHAPTER TEN

DETERMINATION OF CONTROL FREQUENCIES FOR THE RADIO WARNING SYSTEM

1.0 INTRODUCTION

This chapter[1] contains some extensions of ideas presented previously in Chapter Six.[2] The previous chapter expressed a great deal of skepticism about the value of several mathematical models which purported to describe the program material environment in which the Radio Warning System receivers would operate. The conclusions reached then were that further attempts at using such mathematical models for quantitative evaluation of receiver design be foregone until further studies could be carried out. These studies would provide sufficient empirical data to enable the derivation of a model that would satisfactorily relate the key parameters to each other rather than assume that they were statistically independent. The focus of the present chapter is on a slightly different, though related, problem: Is it possible to arrive analytically at an optimum signaling technique, using conventional methods, that will minimize the probability of receiver false alarms caused inadvertently by normal broadcast program material?

The approach taken in solving this problem may appear to violate the conclusions previously presented in Chapter Six because mathematical models are derived and used. However, the models are qualitative, not quantitative, and the conclusions drawn from them are based on empirical knowledge of the type of program material that the models describe. The result is a recommended signaling technique for controlling the public receiver components of the Radio Warning System. Within the critical constraint that the signals used must not require unusual receiving techniques, such as coherent signals do, the recommended technique is one that will minimize receiver false alarms. Work continues on the possibility of using more sophisticated signals, which cannot be inadvertently duplicated in normal broadcasting.[3] If these more sophisticated techniques can be shown feasible on a cost basis, then a revised recommendation will have to be made, since the effectiveness of such a technique in minimizing false alarms is patently clear.

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1. This chapter replaces The Determination of Control Frequencies for the Radio Warning Receiver, which was originally published as TM-L-1960/029/00, dated 18 May 1965.

2. "Problems of Predicting Receiver Reliability."

3. Chapter Eight, "Coherent Receiver Development."

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 AUTOMATIC RECOVERY FROM FALSE ALARMS

Whatever signaling technique is used to activate the public receiver, it must be such that a receiver, accidently activated by noise in the radio environment that duplicates the effect of the transmitted control tones, automatically turns off in the absence of such noise.

2.2 "SUBAUDIBLE" CONTROL TONES

The control tones used to activate the public receiver must be inaudible at the receiver output, lying either above or below that portion of the audio spectrum used by the human voice. Since "superaudible" frequencies are reproduced in practically all combinations in the course of musical programming, the "subaudible" spectrum appears to have greater potential for false-alarm-free control. This potential can be enhanced by the proper selection of control tones.

2.3 PARALLEL OPERATION

It can be demonstrated that a control signaling technique which uses n tones transmitted simultaneously is inherently more reliable than a technique which uses n tones transmitted in sequence.

2.4 CONTINUOUS SPECTRUM OF "MUSICAL" TONES

The musical scale must be considered as a continuous spectrum as far as analyzing the programming environment to which the public receiver will be exposed. In other words there are no frequencies that cannot appear as musical tones, not even in the "subaudible" range.

2.5 CHARACTERISTICS OF DEMUTING SIGNALS

It is recommended that the signaling technique used to activate the public receiver in the Radio Warning System have the following characteristics:

1. Two Tone Simultaneous. The system should use two simultaneous tones to activate receivers.

2. Percent Difference. The higher tone should have a frequency 22 percent greater than the lower tone.

3. Octave Band of 50-100 Hz The two tones should both lie in the octave band between 50 and 100 Hz, which is in the octave band approximately between A^3 and A^2.

4. Ten-Second Time Delay. The two tones should be transmitted for at least 10 seconds. The time delay of the receiver should also be at least 10 seconds.

It is suggested that two suitable tones for use in receiver control be 87.31 Hz and 106.52 Hz.

3.0 "SUBAUDIBILITY" REVISITED

The operational requirements for the Radio Warning System specify that the public receiver shall be designed to operate under the positive control of the system operator. This means that the public receiver will be turned on and off automatically as part of the system's operation. Of the several methods which have been proposed for controlling the public receiver, this requirement rules out those using clock mechanisms to turn the receiver off after a certain time period, and those requiring that the owner turn off his receiver by means of a switch after he has received the message. The first type must be ruled out because no time period can be established that will encompass all possible situations in which the receiver will be used. A solution to this problem has been proposed in which the receiver is designed to demute for a short period upon receipt of the control signal. The control signal must then be repeated periodically during the course of the voice message, either during pauses in the course of the message or in the form of an inaudible signal superimposed on the message. This method has not, however, been shown to be cost competitive with other equally satisfactory methods. The second type, that requiring the owner to turn his receiver off, must be ruled out because it also enables the receiver owner to disable his receiver at a time when it might be needed for other messages. This method also suffers from the inconvenience to neighbors caused by an unattended receiver continuing to operate after it has been activated during a test. The two principal methods remaining, which meet the positive control requirement, are the use of separate signals to turn the receiver on and off, and the use of a continuous signal to hold the receiver on once it has been turned on. The first of these two is called a "latching" receiver method since the receiver is locked into the on condition by the first signal and stays on until a second signal is transmitted to turn the receiver off. From an operational standpoint, this type of receiver is not satisfactory despite its meeting the positive control requirements. This is because it does not adequately meet the problem of minimizing the false alarm potential of normal programming material and random noise that may appear in the transmissions of a radio station. If the turn-on signal is inadvertently transmitted, receivers will be activated and locked into the on condition to remain there until a turn-off signal is received. Unless the transmissions of the radio station are continuously

monitored by station operators to detect such inadvertent turn-on signals, there will be no way of knowing when receivers have been accidently activated. There will be added cost in such a configuration due to the need for installation of such monitoring equipment at each transmitter. Even with the monitoring gear installed, there remains the problem of random generation of the turn-on signals by noise in the radio environment. The threat here is that receivers in a locale may be activated and the owners will have no means available to turn them off except to call the radio station and request that the turn-off signal be transmitted. An operationally satisfactory receiver must have the ability to recover automatically from accidental false alarms of all kinds.

The latching receiver suffers several other weaknesses as well. It is subject to the possibility of accidental turn-off during the course of a message delivery. This is because there is always a finite probability that the turn-off signal will be inadvertently generated. Furthermore, such an accidental turn-off may effect only a portion of the receivers under the control of a particular transmitter if the false alarm is generated by noise and not as part of the transmitted broadcast signal. Another disadvantage would be the added circuitry required to recognize the turn-off signal. If two tones were used to turn the receiver on, which is the minimum number recommended to minimize false alarm potential, and a third tone were used for turn-off, there would be the added expense for recognizing the third tone by means of a reed relay or some comparable device. If one of the turn-on tones were also used for turn-off, there would be the added circuitry needed to enable the dual-purpose tone to carry out two functions. It is for these reasons, primarily the inability to recover automatically from a false alarm that the latching receiver is unsatisfactory.

A receiver that remains in the on condition as long as the proper signal is transmitted and goes off, if this signal is terminated, provides the solution to the problem of automatic recovery from accidental false alarm. If the proper combination of tones to turn on the receiver accidently appears in some program material, the receiver will be activated only during the time that the combination persists. Once the tones change or disappear, the receiver will automatically turn off. This is the mode of operation of the receiver currently being procured by OCD. Two control tones are transmitted to turn the receiver on, then one tone cuts out, leaving the other to hold the receiver on.

Because the receiver will be used to send voice messages, the holding tone must be "inaudible," that is, it must lie in a portion of the audio spectrum which is outside the bandpass either of the human ear, or, more practically, of the audio reproduction portion of the receiver. The bandpass of the loudspeaker in the receiver can be kept relatively narrow because the receiver will only be required to reproduce voice messages, not music. It can be said, therefore, that from the standpoint of the OCD operational requirements, any signal below 150 Hz and above 3,000 Hz is "inaudible."

Now the question arises whether to use control tones in the low range of inaudibility or the high range. Much of the basis of the arguments presented in this chapter is derived from the structure of music.
Music will present the type of program material that is richest in potential false alarm signals, both from the standpoint of audio content and amount of programming time devoted to it in normal commercial broadcasting. There are few rules which can be stated with authority as far as musical composition and performance are concerned. In examining the problem of whether to use subaudible or superaudible control tones, however, there are certain rules that can be used to advantage. The analysis of this problem is carried out in greater detail in Section 4.0, below. In brief, the argument rests on the fact that certain combinations of sustained musical tones in the frequency range below approximately 100 Hz are avoided by composers and arrangers because they have an unpleasant sound. This characteristic is true on a probabilistic basis only; there is no absolute guarantee that such combinations will never be used in particular compositions. Nevertheless, enough probabilistic "maybes" will result in an "almost-never" if designed properly into the system. Because the rules about sustained tones apply almost entirely to the lower frequencies, it is recommended that the control tones for the OCD receiver be in the subaudible range.

4.0 SEQUENTIAL OR PARALLEL TONES

Having recommended that the signaling technique for controlling the Radio Warning System receiver use subaudible tones, it remains to determine the manner in which the tones should be transmitted. In the course of the analysis necessary to determine the manner of transmission, the recommendation for subaudible tones will be justified as well. In order to specify whether the control tones should be transmitted simultaneously or sequentially, the probability that n tones will appear in musical program material either simultaneously or sequentially must be determined. Music is used as a worst case because of the range of frequencies which occur in it and the amount of programming time devoted to it.

Previous operational analyses have attempted to determine the probabilities of various tones appearing in program material. In particular, two of these, the first by General Electric and the second by Philco Corporation, were carried out as a part of the NIAC alert receiver development program.[1] These

1. Federal Communications Commission, National Industry Advisory Committee (Systems Analysis Ad Hoc Committee), Chairman's Report of Comparative Analysis of Emergency Alerting Systems for Use With Standard, FM, and Television Broadcast Stations, Washington, D. C., 15 May 1964.

analyses have both been subjected to criticism in a previous chapter.[1] Their intent was to provide a mathematical model that could be used to evaluate quantitatively the reliability of the several alert receiver designs submitted to the FCC by NIAC. The general criticism of both analyses was that they failed to consider the functional interrelationships among the variables whose behavior they were attempting to describe. As a result, the mathematical models derived do not even give a good general description of the process involved, let alone provide a tool that can be used to make accurate quantitative ratings on the reliabilities of alert receivers.

In order to discuss the relative security present in sequential and parallel signalling schemes, it is necessary to examine the general form of a mathematical expression measuring the probabilities associated with the appearance of musical tones in program material. The model derived here differs from the models previously derived in two respects:

1. The previously ignored correlation of parameters is included.

2. It is a qualitative model, rather than quantitative.

While the model cannot be used to make accurate predictions of program material behavior, it does provide an insight into the processes involved and enables one to make some useful decisions about signaling methods.

The heart of the model is a probability density function. This is a mathematical expression that relates any realizeable combination of values for a set of variables to the probability of that combination being realized.[2] In the model constructed, the probability density function provides the probability that a tone of a given frequency will appear in the course of a radio program at a given level of energy and for a given length of time. There are three variables involved: frequency, energy level, and duration (time). Since there is an associated probability with each combination of values the three variables can assume, there are four quantities involved in the function. The geometric representation of the function is, therefore, a four-dimensional surface. The shape of this surface is presently unknown, but it would seem to be an extremely complicated one. Without trying to visualize its shape, however, we can find the general mathematical expression for the surface. This expression can be written as:

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1. See Chapter Six.

2. For example, the probability density function used to describe the probabilities associated with the rolling of two fair dice would be a function which associated the value 1/36 with the number 12, the value 1/6 with the number 7, etc.

$$p = f(F,E,T)$$

where F is the frequency of the tone,
E is the energy level or amplitude of the tone,
T is the length of time over which the tone persists,
p is the probability that a tone of frequency F will appear in program material with amplitude E and for time T, and f represents the presently unknown functional relationship between the variables involved and the probability of their taking on specific values jointly.

In the problem at hand, it must be determined whether there is a difference in the probabilities that two tones will appear simultaneously on the one hand and sequentially on the other. This requires the examination of the probabilities associated with the occurrence of two tones:

$$P_1 = f(F_1,E_1,T_1)$$

and

$$P_2 = f(F_2,E_2,T_2)$$

Let the probability of the simultaneous occurrence of the two tones be denoted by P_s, and the probability of the sequential occurrence by P_f. Then the following functional relationships hold:

$$P_s = p_1p_2\ (1+ \rho_{12}^{s} \frac{q_1q_2}{p_1p_2})$$

$$P_f = p_1p_2\ (1+ \rho_{12}^{f} \frac{q_1q_2}{p_1p_2})$$

where ρ_{12}^{s} and ρ_{12}^{f} are correlation coefficients which provide an indication of the likelihood that tone 1 and tone 2 will appear simultaneously and following each other respectively, and $q_i = (1 - p_i)$, i.e., the probability that tone i will not occur.

The correlation coefficients ρ_{12}^{s} and ρ_{12}^{f} can assume values from minus one to plus one. They take on specific values for each combination (p_1p_2) of frequencies, amplitudes, and durations. In other words, the correlation coefficients are also functions of the same variables as p_1 and p_2, only they are functions of the two sets of variables considered jointly. One cannot,

at this time, state precisely the value which ρ_{12}^{f} and ρ_{12}^{s} will take on for any set of variables, (F_1,E_1,T_1) and (F_2,E_2,T_2). Nevertheless, one can say with a great deal of certainty that for harmonically unrelated tones in certain octave bands ρ_{12}^{s} is less than ρ_{12}^{f}. In other words, for certain groups of musically discordant tones, the probability of their occurring simultaneously is less than that of their following each other sequentially. This conclusion is based on the difference between the "rules" governing the harmonic structure of music and those governing the melodic structure. In general, the rules of harmony place more severe restrictions on the composer or arranger than do the rules of melody. These differences provide a means by which the system designer can use the nonrandomness of music to his advantage. The assumption here is that the correlation coefficients are derived from the entire range of musical program material a station might choose to transmit, from the latest popular dance music to the most esoteric contemporary symphonic music, with all other ranges of musical styles included. It is necessary to include this caveat because it is intuitively clear that the correlation coefficients will take on different values for different musical styles. What was harmonically unthinkable in the eighteenth century is commonplace today. Furthermore, the average values of the correlation coefficients which we are discussing must weigh the correlation coefficients of the various styles of music in proportion to the amount of performance time they enjoy on the radio stations that will be included in a radio warning system. The likelihood of certain combinations of tones appearing on a "hillbilly" station in Tennessee is far different from their appearing on an avant-garde FM station in San Francisco or New York.

The octave bands in which the correlation coefficients can be used to advantage are those below approximately 100 Hz. In this range common musical practice requires generally that sustained tones be separated by at least a fifth (a frequency ratio in the equally-tempered scale of 1.498:1.000) and more probably by an octave (2:1). The lower in the musical scale one descends, the greater the separation. While it is true that these restrictions may be violated in certain cases, on the whole they will be observed because their violation results in an unpleasant, "muddy" sound. In the octave bands above 100 Hz, restrictions are not as severe. In fact, one of the key developments in musical style over the past several centuries has involved the breaking down of the rules governing the closeness with which tones can be sounded simultaneously or "harmonically" in these regions of the audio spectrum. Today, one can find compositions in which tones more closely spaced than a half-step, the minimum frequency difference (ratio of 1.049:1.000) available on the piano, are sustained harmonically. While these works are few, they may indicate a trend. Nevertheless, even in such exotic music, there remains the tendency to keep the deep bass tones more widely separated.

The results of this analysis indicate that advantage can be taken of certain nonrandom characteristics of music to decrease the probability of accidental triggering of system receivers by program material. The use of two or more simultaneous tones that are harmonically unrelated appears to be one method by which this minimizing process can be accomplished.

5.0 DISAPPEARING DISCRETENESS OF THE MUSICAL SCALE

It has been suggested that, since our musical scales are based upon a system of discrete frequencies, a signaling technique using one or more tones not included in that system would be relatively free from false alarms. This proposal assumes that there are so-called musical frequencies that can be anticipated in system planning. While it is true that in any given musical performance, there will be a certain set of discrete frequencies that will generally be adhered to within certain limits, it is fairly easy to demonstrate that the basis for each set of frequencies will vary sufficiently that it is impossible to consider the audio spectrum used in music as being anything other than continuous. Therefore, even if the two or more harmonically unrelated signaling frequencies are chosen based on the analysis presented in Section 4.0 above, one cannot guarantee that one or more of them will not occur in a given musical performance.

The critical factors in this portion of the analysis are the bandwidths of the sensing elements of the receivers, and the tuning systems used in music. It is intuitively obvious that a receiver that employs broadband detectors, which can be triggered by tones lying in a broad portion of the audio spectrum, will be more prone to false alarm than a receiver employing narrow-band detectors, which are more critically tuned to signalling frequencies. This is true simply because the receiver with the broader bandwidth detectors will be sensitive to more tones capable of triggering it. It has been suggested that reed relays provide the tuning accuracy necessary in a satisfactory receiver. Without any consideration of the reliability and longevity of reed relays, it would certainly appear that they do provide a sufficiently narrow bandwidth within the severe cost constraints that the system designer faces. Nevertheless, a reed relay or its equivalent, still has a certain bandwidth over which it will respond to signals. Generally, the response of a reed relay will be about 6 db down at ± 1 percent of its fundamental frequency. Therefore, there will be variation in receiver response introduced by the bandwidth of its detectors.

There are two physical standards for tuning prevalent in the musical world. In the United States, the standard is 440 Hz for A above middle C. In Europe, the standard is 435 Hz for the same tone. Figure 10-1 shows the standard frequencies for the "musical" tones between G^3, two octaves and a fourth below middle C, and middle C.

Figure 10-1. Musical Frequencies Between 50 Hz and 200 Hz (Upper number based on A = 440 Hz; lower number based on A = 435 Hz.)

It can be seen that the minimum frequency separation between two discrete tones of different nominal pitch varies in the two systems from 2.33 Hz at the low end to 11.71 Hz at the high end of the range. This difference represents approximately 5 percent of the lower tone's frequency, or a bandwidth of about ± 2.5 percent into which a control signal can be inserted.

This bandwidth assumes, of course, precise tuning to the established standard. This is seldom accomplished in actual practice. A study by Shower and Biddulph[1] showed that the smallest discernible frequency change in pure tones was about 2 or 3 Hz in the range 200 Hz. This result would show that it would be fortunate if all of the instruments in an orchestra were tuned to an accuracy of ± 1 percent. As a result, the bandwidth available for the control signal is narrowed to a maximum of ± 1.5 per cent of the frequency chosen. Remembering that the bandwidth of the reed relay will be approximately ± 1.0 percent of the chosen frequency, there remains but ± 0.5 percent as a "guard" band.

The "guard" band disappears when the standards of sound recording and reproduction established by the National Association of Broadcasters (NAB) and the International Consultative Committee on Radio (CCIR) are considered.[2] The NAB standards established a tolerance of ± 0.3 percent for speed variation in recording and reproducing turntables.[3]

The CCIR standards allow a speed variation of ± 0.5 percent in both disk and magnetic recording. The CCIR standards will apply to records imported into the United States. Therefore, in a worst-case situation, a recording made at the limit of the CCIR standard for speed variation and reproduced in the United States at the limit of the NAB standard, there will be a variance of ± 0.8 percent and the "guard" band of ± 0.5 percent will no longer exist. As a result, it must be concluded that the portion of the audio spectrum in the range that is being considered for control signals has to be treated as a continuous spectrum of musical frequencies. There are no "musical" frequencies as such. On the other hand, however, one cannot assume that all frequencies have equal probability of being used musically. While one cannot state precisely the probability that a given frequency will appear in a

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1. E. G. Shower and R. Biddulph, "Differential Pitch Sensitivity of the Ear," in Journal of the Accoustical Society of America, (3, 275), pp. 153-155.

2. A. P. Walker, Ed., NAB Engineering Handbook, McGraw-Hill Book Company, Inc., New York, 1960, pp. 374, 379, 397, 399.

3. The NAB does not specificcily establish a speed variation tolerance for magnetic recording. The CCIR standard for magnetic recorder speed variation is the same as for turntables, ± 0.5 percent. It seems reasonable to assume, therefore, that the NAB allows a ± 0.3 percent speed variation for magnetic recorders.

musical performance, one can say on strong intuitive grounds that those frequencies which are near the standard frequencies for musical tones will have a higher probability of appearing than those situated halfway between two adjacent standard frequencies. The actual probability distribution is, however, unknown at this time.

6.0 THE CHOICE OF FREQUENCIES

Having shown the advantages present in choosing frequencies in a specific area of the audio spectrum and having shown that none of these frequencies can be regarded as being "musical" per se, an attempt must be made to lay a groundwork for deciding which frequencies to use in the system. Thus far the analysis has assumed that n tones would be used for control. It is intuitively clear that the greater the number of tones used to activate the receiver, the less likely it is that a false alarm will occur. On the other hand, the greater the number of tones, the more complex must be the detection circuitry and, as a consequence, the more expensive and less reliable the receiver. The use of a single control tone does not provide any guarantee whatever against a false alarm unless a prohibitively long delay time is built into the receiver. It has been shown above that there can be no guarantee against any single frequency occurring in music. Furthermore, with a single tone there is no opportunity to make the nonrandomness of music work to prevent false alarms. The minimum number of tones necessary to utilize this nonrandom aspect of music to advantage is two. This number also minimizes the complexity of the circuitry involved and, thereby, for equivalent methods of detection, maximizes the reliability of the receiver. Therefore, two frequencies are recommended as the optimum choice for the Radio Warning System within the constraint that conventional signaling techniques are used.

As to the separation of the two tones in terms of frequency, it is apparent that the interval should be one not normally used in music. At the same time, the tones must be spaced far enough apart that the detection circuitry will be able to distinguish between them. In other words, the bandwidths of the two detectors must not overlap. It was pointed out in Section 4.0 that the minimum separation generally utilized in the octave bands below 100 Hz is a fifth (frequency ratio of 1.498: 1.000). Therefore, the control interval should be less than a fifth. An elegant choice is to use an interval which falls halfway between a major and minor third, the recommended frequency ratio being 1.22: 1.00. This interval at once meets the requirement of being less than a fifth and of being one which is extremely unlikely to occur in normal programming, particularly in the portion of the spectrum below 100 Hz.

The latter is true because musically the third is a very sensitive interval; it determines the modal state of the music, that is, whether a chord is a major or a minor chord. It is, with several other key intervals, one on which the intonation of the performer is critically judged. Furthermore, since it is critical in determining the modal state, it is generally put in a range of

the spectrum where it can be easily heard, in the octave bands well above 100 Hz. Therefore, two tones at the recommended frequency ratio will definitely be harmonically unrelated, sufficiently so that the probability of their joint simultaneous occurrence will be slight.

Using this interval, one cannot make both tones equidistant from the standard frequencies shown in Figure 10-1. Nor is it desirable to do so. Rather, it would be more advantageous to choose one of the frequencies as a standard frequency for the following reason. It was mentioned in Section 5.0 that the probability distribution for the occurrence of particular frequencies in music is not likely to be uniform. Rather it will show bunching around the standard frequencies, i.e., a greater probability of occurrence for frequencies in the immediate vicinity of the so called musical tones. Since the recommended interval (1.22: 1.00) is one which is halfway between two legitimate intervals, it would follow that if one of the tones is chosen as a standard frequency, with a correspondingly high probability of occurrency, then the second tone will be in what amounts to a trough on the probability curve and will have a low probability of occurrence. In the absence of empirical data it cannot be guaranteed that the probability of the joint occurrence of these two tones will be an absolute minimum. Nevertheless, on intuitive grounds, it would appear that a local minimum can be anticipated with this method. As frequencies vary with inexact tuning and speed variation in transcription equipment, one or the other of the frequencies will tend to have a higher probability of occurring, but the probability of joint occurrence will remain low.

As to the frequencies to use, reed manufacturers have stated that a definite price break occurs for reeds with a fundamental frequency above 80 Hz.[1] If one chose as the lower frequency the first musical tone above 80 Hz, E^2 at 82.41 Hz, the second tone would be 100.54 Hz. Since this tone is uncomfortably close to 100 Hz, a frequency often used for testing equipment in the radio industry, this combination must be rejected. Instead, it is recommended that the lower frequency be that of the second musical tone above 80 Hz, namely F^2 at 87.31 Hz. Then the second frequency will be 106.52 Hz, midway between G^2 sharp and A^2.

7.0 TIME DELAY

The analysis above is believed to be adequate to determine a recommended set of frequencies for use in activating public receivers in the Radio Warning System. In the absence of a foolproof signaling method, i.e., one which would utilize signals not otherwise found in program material and, therefore, incapable of appearing inadvertently, these frequencies, or two other

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1. Source: Telephone call to George Morgan, Gautney and Jones Communications, Inc., 31 March 1965.

frequencies spaced at the recommended interval, should serve to minimize the probability of accidental false alarms. If such a foolproof method is devised, such as the method of coherent signaling now under investigation at SDC, the signaling method recommended here will no longer be optimum and new recommendations will have to be made.

The critical nature of one parameter has not been considered in detail above. The amount of time delay built into the receiver will obviously affect its false alarm tendencies. In determining the proper amount of time delay, the system designer must trade false alarm protection for speed of warning, since there are operational requirements stating the time limits within which the system should function. As mentioned in Section 6.0, a single control tone will not be satisfactory unless it has a prohibitively long delay time. As more tones are added, it seems reasonable to predict that the amount of delay can be decreased for an equal level of false alarm protection. In the recommended technique, time delay is still required even though it is unlikely that the proper tonal combination will occur. On no grounds other than intuitive, it would seem that a 10-second delay would be adequate and this is recommended.

APPENDIX A

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APPENDIX B

GLOSSARY

Alert. The attention getting signal or alarm used to call the intended recipient to a state of action. An alert provides only an initial awareness of a threatening situation and does not in itself define that situation or the appropriate response to it. (See Warning.)

Ambient Noise. The total residual (or background) noise, exclusive of any intentional signal.

Area Warning Circuit. That portion of the National Warning System (NAWAS) which is within one of the warning areas and connects the warning points of that area with a warning center.

Articulation. A comparison of the sounds, syllables, or words recorded by a listener with those originally spoken yields a percentage of those sounds, syllables, or words that are correctly interpreted. This percentage is called the articulation.

Attack Warning System (AWS). The system by which a warning or other emergency information is transmitted throughout the nation. It consists of three parts -- the federal, state, and local portions. (See National Warning System (NAWAS).)

Auditory Threshold. The sound pressure level of the minimum acoustic signal that evokes an auditory sensation for 50 percent of the number of times a signal is presented.

Authentication. A message or signal from an initiation or relay point indicating the validity of another message.

AUTODIN (AUTOmatic DIgital Network). An automatic teletype message switching and circuit switching network operated by the Defense Communications Agency (DCA).

AUTOVON (AUTOmatic VOice Network). An automatic voice circuit switching network operated by the Defense Communications Agency (DCA).

BREACOM (Broadcast Emergency Communications). A system that allows the transmission of teletype via standard (AM) broadcast stations without interruption of normal program material. This development is being undertaken by FCC and the broadcast industry for the Defense Communications Agency--DCA (q.v.).

Clear Channel. A commercial AM broadcast channel on which the dominant station renders service over a wide area and which is cleared of objectionable interference within the primary service area of that station and over all (or a substantial portion) of the station's secondary service area.

Clear Channel Station. A commercial AM radio station that is assigned the use of a clear channel (q.v.).

Complex Tone. A sound wave composed of several frequencies (pure tones).

Control Signal (or Control Message). A signal or message used in the alerting and/or warning system to activate or deactivate other components or subsystems of the system.

Defense Communications Agency (DCA). An agency within the Department of Defense charged with overseeing the design and operation of military communications systems.

Decibel. See Sound Pressure Level.

Demuted Receiver. An alerting and warning receiver that has been rendered capable, by receipt of a demuting signal (q.v.), of sounding an alert and warning.

Demuting Signal. The signal that causes muted alerting and warning receiver to be capable of sounding an alert signal and a warning message. In some receivers (in particular latching receivers, q.v.) the demuting signal and the alert signal are the same; in others (in particular nonlatching receivers, q.v.) the demuting signal is different from the alert signal.

Emergency Action Notification (EAN) System. Circuits and associated equipment designed to transmit an Emergency Action Notification message containing authorization to initiate emergency procedures to implement the Emergency Broadcast System plan.

Emergency Broadcast System (EBS). Those broadcasting stations and interconnecting facilities which have been authorized by the Federal Communications Commission to operate in a controlled manner during a war, threat of war, state of public peril or disaster, or other national emergency.

Emergency Operating Center (EOC). The protected facility in which governmental and civil defense officials having direct emergency responsibilities can safely carry on their emergency operations.

False Alarm Failure. A system failure which results in the activation of the alerting and/or warning system when such activation is not desired by the system operators. (See No Alarm Failure.)

Situation	Response	
	Signal	No Signal
Attack	OK	No Alarm Failure
No Attack	False Alarm Failure	OK

Frequency. A phenomenon that occurs periodically or cyclically in time. The number of repetitions of a pattern or of an event that occur in unit time.

Ground Wave Transmission. Radio transmission via radio waves that are propagated over the earth and are ordinarily affected by the presence of the ground and the troposphere. Ground waves include all components of radio waves over the earth except ionospheric and tropospheric waves. Distinguish from skywave transmission (q.v.).

Harmonics. Those components of a complex tone whose frequencies are integral multiples of the fundamental frequency of the tone. The fundamental is also called the first harmonic; the second harmonic has a frequency twice that of the fundamental, etc.

Industry Advisory Committee. One of the advisory committees to the Federal Communications Commission. Each committee is composed of representatives of the broadcasting industry at national (NIAC), regional (RIAC), state (SIAC), or local (LIAC) level. These committees assist the FCC in the execution of its responsibilities pursuant to the Executive Order that directs the creation of the Emergency Broadcast System.

Intelligibility. The measure of the ability of a listener to understand the meaning of the sounds he hears.

Jamming. The radiation or reradiation of electromagnetic waves in order to impair the use of a specific segment of the radio spectrum.

Latching Receiver. A receiver that demutes on receipt of a predetermined signal. A latching receiver may be unlatched, or demuted, by more than one method. It may be demuted by the transmission of a distinct demuting signal. It may be automatically demuted after some predetermined period of time by a timing device in the receiver. It may also be demuted manually by means of a switch on the receiver. (See Nonlatching Receiver.)

Local Industry Advisory Committee (LIAC). (See Industry Advisory Committee.)

Local Warning Center. A facility capable of 24-hour operation found normally at the city or county level. The local warning center must be capable of performing all functions required to provide warning to the inhabitants within its jurisdiction.

Loudness. The intensive attribute of an auditory sensation in terms of which sounds may be ordered on a scale extending from loud to soft. Loudness is determined largely by the intensity of the sound stimulus, but is also affected by frequency and waveform. The unit of loudness is the sone (q.v.).

Loudness-Level. See Phon.

MODEM. Modulating and demodulating equipment.

Muted Receiver. Descriptive of the normal operating mode of any alerting and warning receiver, i.e., power-on, operative, receiving any material transmitted by the transmitter to which it is tuned, but silent because it has not received a demuting signal.

National Defense Emergency Authorization (NDEA). An authorization issued by the FCC permitting operation of a station as part of the Emergency Broadcast System during an emergency condition.

National Industry Advisory Committee (NIAC). (See Industry Advisory Committee.)

National Warning Center (NWC). The OCD facility staffed by Attack Warning Officers and situated within the Combat Operations Center at NORAD Headquarters. The NWC controls the NAWAS and activates the Emergency Broadcast System.

National Warning System (NAWAS). The federal portion of the Attack Warning System used for the dissemination of warning and other emergency information from OCD warning centers to warning points in each state.

No Alarm Failure. A system failure in which the alerting and/or warning system does not function even though activated by system operators. (See False Alarm Failure)

Nonlatching Receiver. A receiver that demutes upon the receipt of a predetermined signal and remains demuted only as long as that signal remains present. Demuting occurs upon a failure to receive the demuting signal.

North American Air Defense Command (NORAD). A coordinated defense of the North American continent against aerospace attack. The defense is coordinated between American and Canadian Services with full use of early-warning radar.

Phon. The loudness-level of a sound is the intensity-level of a 1,000 Hz tone which sounds equal to the sound in loudness. Loudness-level is measured in decibels or phons above the reference-intensity. The 1,000 Hz tone is the reference-tone for loudness comparisons, and the loudness-level of all other sounds expressed in terms of the equally loud reference tone.

Pitch. That attribute of auditory sensation in terms of which . nds may be ordered on a scale extend'ng from low to high frequency such as a musical scale. Pitch is determined largely by frequency, but it is also affected by intensity.

Pure Tone. A continuous sound of a single frequency; a tone not accompanied by overtones, harmonics, or other sounds.

Radio Frequencies. Normally expressed in kilo Hertz (kHz) at and below 30,000 kHz, and megacycles per second (kHz) above this frequency.

Frequency Sub-Division:

Very Low (VLF)	Below 30 kHz	Myriametric Waves
Low (LF)	30 to 300 kHz	Kilometric Waves
Medium (MF)	300 to 3,000 kHz	Hectametric Waves
High (HF)	3,000 to 30,000 kHz	Decametric Waves
Very High (VHF)	30,000 kHz to 300 mHz	Metric Waves
Ultra High (UHF)	300 mHz to 3,000 mHz	Decimetric Waves
Super High (SHF)	3,000 mHz to 30,000 mHz	Centimetric Waves
Extremely High (EHF)	30,000 mHz to 300,000 mHz	Millimetric Waves

Regional Industry Advisory Committee (RIAC). (See Industry Advisory Committee.)

Regional Warning Officer. A staff officer located at each OCD Regional Headquarters to assist states and local areas in solving warning problems.

Skywave Transmission. Radio transmission via radio waves that reach the receiving location after reflection from the ionosphere. Distinguished from groundwave transmission (q.v.).

Sone. The sone is a unit of loudness. By definition, a simple tone of frequency 1,000 Hz, 40 db above a listener's threshold, produces a loudness of one sone. The loudness of any sound that is judged by the listener to be n times that of the one sone tone is n sones.

Sound Pressure Level. The pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure P for this sound to the reference pressure P_o. Unless otherwise specified, the reference pressure is understood to be 0.0002 dyne per square centimeter.

Spoofing. The action of deceiving or misleading the enemy in electronic operations. An example of spoofing is the transmission of radio messages containing false information for interception by the enemy.

State Industry Advisory Committee (SIAC). (See Industry Advisory Committee.)

Strategic Warning. A notification that enemy-initiated hostilities may be imminent.

Subsidiary Service. An application of an alerting and warning technique to some application other than nuclear attack warning. Possible subsidiary services include providing weather information and distributing short news bulletins.

Survivability. The degree of liklihood that an object will be unaffected by an attack directed against it.

System. An assemblage of personnel, hardware components, and/or procedures functioning together in an orderly and prescribed manner to carry out a predetermined task.

Tactical Warning. A notification of enemy initiated hostilities.

Threat Warning. A report, originating at the NORAD Combat Operations Center, disseminating early warning information from DEW Line, Mid-Canada, and Pinetree Lines to lower echelons of the air defense system.

Verification. A return message or signal to an initiation or relay point indicating that a signal or message has been received, understood, and/or acted upon.

Vulnerability. The degree to which an object is survivable and is likely to be attacked by an enemy. (See Survivability.)

Warning Area. A geographical area consisting of a number of states which are the responsibility of one of the presently existing OCD warning centers.

Warning Point. A facility which receives warning and other emergency information over NAWAS and which relays this information according to instructions contained in state and local civil defense plans.

Washington Warning Area. The geographic area within a 20 mile radius from zero milestone, Washington, D. C., excepting that part of Howard and Ann Arundel Counties in Maryland falling within the 20 mile radius.

Washington Warning Area Control Point (WWACP). The location that controls the origination and/or dissemination of warning information to the Washington Warning Area. The WWACP also acts as an alternate to the National Warning Center in initiating the operation of the Emergency Broadcast System.

White House Communication Agency (WHCA). A subordinate agency of the Defense Communications Agency which provides all communications facilities for the President.

White Noise. The spectrum of white noise is characterized by the presence of all the frequencies in the audible range at the same amplitude or pressure.

WWV, WWVH, WWVB, WWVL. Radio Stations operated by the National Bureau of Standards which provide time and frequency standards for various users. Stations WWV and WWVH broadcast on several frequencies in the HF band. WWV is located in Beltsville, Maryland. WWVH in Maui, Hawaii. WWVB and WWVL broadcast in the low (60 kHz) and very low (20 kHz) frequency bands, respectively. Both transmitters are located in Ft. Collins, Colorado.

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