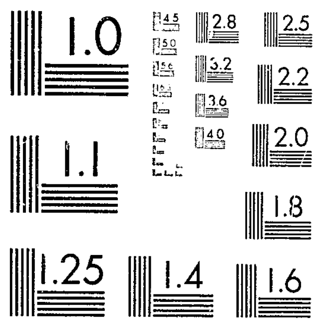

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Police Telecommunication Systems

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U.S. DEPARTMENT OF JUSTICE
LAW ENFORCEMENT ASSISTANCE ADMINISTRATION

Police Telecommunication Systems

PR 71-3

JUNE 1971

Product of Project Three, Phase Three,
of the Project Series Foundation of the
Associated Public-Safety Communications Officers, Inc.

Prepared by
IIT Research Institute

The material contained in this book has been produced using financial support provided by the National Institute of Law Enforcement and Criminal Justice of the Law Enforcement Assistance Administration, United States Department of Justice. The fact that the National Institute of Law Enforcement and Criminal Justice furnished financial support to the activity described in this publication does not necessarily indicate the concurrence of the Institute in the statements or conclusions contained therein.

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FOREWORD

In this period of modernization efforts almost all police departments are planning significant improvements to their communication systems. In sponsoring the studies that resulted in this report the Institute sought to develop new practical knowledge to assist departments in their programs and also to evaluate the knowledge and practices that already exist. This report presents the results of the effort in a format calculated to be of direct use to readers who have both technical and nontechnical backgrounds.

We were fortunate to have teamed up with the Associated Public-Safety Communications Officers, Inc., the major professional body concerned with the subject. The dedication and many days of work which their leadership provided without compensation throughout the project has been the essence of its success.

LEAA is placing a major emphasis on improved police telecommunications and as a result, we may expect a number of technological changes to take place. As this book is placed into use and the results evaluated, new developments will cause questions to be raised at various points. The Institute would appreciate receiving these questions and any comments you may have so that we may incorporate them into future projects to update this body of knowledge and text.

Irving Slott
Acting Director
National Institute of Law
Enforcement and Criminal Justice

PREFACE

This manuscript was prepared during Phase 3 of Project Three of the APCO Project Series Foundation. The program was conducted by IIT Research Institute under subcontract to the Associated Public-Safety Communications Officers, Inc., and was supported by Grant No. NI 70-091 awarded by the National Institute of Law Enforcement and Criminal Justice.

The program monitor for the National Institute of Law Enforcement and Criminal Justice was Walter R. Key.

The project director and chairman of the Steering Committee for Phase 3 of APCO Project Three was Capt. Frank D. Campbell.

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This manuscript was prepared under the direction of the APCO Steering Committee, whose members are listed on the following page. The authors wish to express their appreciation for the guidance the Committee provided throughout the program. Their contributions, helpful suggestions and constructive criticism were invaluable in assembling the material in this volume.

We also wish to thank Roger W. Reinke, author of the monograph "Design and Operation of Police Communication Systems" published by the International Association of Chiefs of Police, for permission to utilize selected portions therefrom.

B. Ebstein

February 1971
Chicago, Illinois

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CONTENTS

CONTENTS

CONTENTS

CONTENTS

CHAPTER I

INTRODUCTION

Purpose

This book has been written to provide a comprehensive guide to police telecommunication systems. Each step of the telecommunication process is considered—from the citizen's request for service to the officer in the field, from commanders to field personnel, and from the police department's headquarters to central information banks, other agencies and back to the public.

It is written primarily for communications, planning and supervisory personnel of police agencies, municipal and county officials, state planning agency staff and policy board members, frequency coordinators, and communications consultants. The information will enable readers to understand the concepts, elements and techniques of police telecommunication systems and to assess their effectiveness. It provides common standards and suggestions to evaluate performance for guidance in choosing equipment and system modifications, designing new systems, and planning for future demands and improvements. As such, the text will also benefit suppliers of equipment and groups associated with similar non-police systems.

Scope

Communication systems convey information from the public to a police department, to the officer who actually responds to the complaint, to other law enforcement agencies, and to information storage facilities (such as data banks of stolen articles and arrest warrants). The word "telecommunication" is intended to limit consideration to systems and their components that involve the transfer of information over a distance, utilizing electrical or electronic means. Included in such systems are the telephone links from the public to the police, the radio systems from a central location to and among officers in the field and to other police agencies, and teletypewriter, data transmission and telephone circuits to other agencies and data storage facilities.

Within the telecommunication systems described here, major attention is given to the radio system. This links a fixed police communications facility to officers in vehicles or on foot in the field, and links those officers to each other. *The main emphasis is on systems that serve municipal police departments.* The relationships between these systems and county sheriff and state police communication systems are, however, fully treated. Most of the information presented here is, of course, equally applicable to all public-safety agencies with similar communication requirements.

In order to be as useful as possible, this text concentrates on existing systems and equipment, but possible uses of advanced technology are also noted. Included here are concepts for which equipment is not yet readily available, or that employ system configurations that have not yet been thoroughly tested.

Principal Readers

This text is written for a variety of readers, each having some interest in or responsibility for police telecommunication systems. For continuity, the text is organized so that both technically oriented readers and communications laymen will read the same chapters and sections.

> *The lay reader will, however, frequently wish to skip over the technical portions. These are indicated by the change to italics and indentation found in these two sentences.*

The book addresses police communicators, administrators of police telecommunication systems and other police administrative and supervisory personnel. Material of interest to dispatchers and maintenance personnel as well as to those responsible for planning and directing the future development of a system is included. Another group of users will be those municipal, county and state officials who have a part in determining budgets for police communication systems, such as managers, trustees, councilmen, mayors, commissioners and budget directors at each government level.

Staff and policy board members of county, state, and federal planning agencies, frequency coordinators and members of frequency advisory committees, and communications consultants will find the text useful. The state planning agencies which administer funds from the Omnibus Crime Control Act granted by the Law Enforcement Assistance Administration (LEAA), as well as governmental and private planning agencies that make recommendations on county-wide, state-wide or regional basis are also among our intended readers.

The text provides specific information as well as general background knowledge about police telecommunication systems. It can be used to help plan, modify or design such systems, to evaluate and trouble-shoot their function and operation, and to perform fiscal planning and evaluation. A guide to the text to find particular kinds of information is provided in Chapter II.

CHAPTER II

USER'S GUIDE TO THE TEXT

General Introduction

A summary of each chapter's contents is given below. Several technical topics are extensive enough to require separate treatment in appendices.

Chapter III, *Introduction to Police Telecommunication Systems,* contains a brief, nontechnical description of such systems, their functions and basic organization. It introduces the vocabulary used in the rest of the book, and the overall structure and role of a communication system in the functioning of a police department.

Topics covered include:

- System functions
- Performance standards and requirements
- Common types of systems, equipment they use and the radio spectrum
- System evaluation
- Fiscal planning

This chapter is recommended to the reader who has no special knowledge of police telecommunication systems or the reader who wants a quick review of the subject.

The reader who is already familiar with police telecommunication systems should begin with Chapter V, *Description of Police Telecommunication Systems.*

Many details not covered in Chapter III are fully treated in Chapter V, so some of the material in the earlier chapter will be found in greater detail in the later chapter.

Chapter IV, *Elements of a Police Telecommunication System,* contains descriptions of the building blocks or elements of a system. These consist of certain intangible, operational elements, the physical equipment of the system and the personnel who operate it.

Among the operational elements discussed are:

- Frequencies of operation
- Radio channels
- Radio transmission and propagation
- Types of networks

Physical equipment described includes:

- Telephone equipment
- Base stations
- Antennas
- Teletypewriters
- Mobile and portable equipment
- Special and new devices

Personnel considerations discussed are:

- Basic qualifications
- Training requirements

Chapter V, *Description of Police Telecommunication Systems,* explains how the elements described in Chapter IV combine to form a *system.* The chapter is divided into three main sections, describing the functions of a system, the types of systems used, system performance requirements and external constraints. The functions are presented in terms of the originator and recipient involved in the conveying of information:

- The public and the police
- The members of the department
- The department and other police departments
- The department and other agencies
- The department and centralized data banks

The types of telecommunication systems are presented by giving particulars about the configuration of:

- Police telephone systems
- Police radio networks

and considerations in the

- Design of radio networks
- Administrative organization of systems

The performance requirements are classified by system

- Response time
- Reliability and flexibility
- Intersystem and emergency communication capability

The external system constraints are those imposed by

- Federal Communications Commission Rules and Regulations
- State and local laws and regulations
- Economic factors

Chapter VI, *Evaluation of a Police Telecommunication System,* sets forth the procedures to be used to gather information required to make a system evaluation. It then describes the methods for comparing system performance to the requirements and standards set up. The information needed for an evaluation includes:

- The functions the system performs
- The performance requirements and external constraints to be met

- A physical and organizational inventory of the system
- Data on how the system is performing

The methods to be used for making the evaluation are first, comparisons of the quantitative measures such as

- Communication center delay
- Radio system delay
- Inquiry delay

and second, comparisons which must be made on a qualitative basis.

Throughout the chapter numerous forms are shown which can be used to guide the procedures and organize the efforts into a series of logically connected tasks.

Chapter VII, *Design and Modification of Police Telecommunication Systems,* presents the factors that affect designing and constructing a new system, and planning and implementing modification of an existing one. The planning methods and procedures, the planning variables available, the procedures for determining the best plan and how to implement it are discussed in the following order:

The methods and procedures are discussed first. Then the means for

- Establishing the needs to be met by the system
- Identifying the specific problem to be solved

Next, procedures are introduced for

- Examining planning variables
- Specifying those applicable to the problem at hand

This leads to

- Formulating alternative plans
- Selecting the best plan
- Implementing and evaluating the chosen plan

The chapter ends with a brief discussion of some of the computerized mathematical techniques of systems planning that have come into use in recent years.

Technical topics treated in some detail in six appendices are

- Radio transmission, propagation and antennas
- Microwave systems
- Interference
- Facsimile systems
- Automatic vehicle monitoring
- FCC Rules and Regulations

A further aid to every reader is the Glossary which defines the most important terms used throughout the book and by the police communications community in general. References for each chapter and appendix are given. A Bibliography is provided as a guide to more complete treatments of the various topics covered in the book. The Index should be used to find all the places in the book where a given topic is mentioned.

Modifying an Existing System

The procedures for modifying an existing police telecommunication system consist of two main tasks—evaluating the existing system to find its strong and weak points, and planning the modification to be made. These procedures are intended to be utilized for any major modification, that is, any modification that cannot be handled by routine repair and maintenance procedures.

The ability to do this depends on knowledge of the information contained in Chapters III, IV and V, particularly the latter two. Chapter VI contains the directions for very complete and detailed procedures for system evaluation. Similarly, Chapter VII describes the planning procedures in great detail.

Not every modification requires carrying out every single step of these procedures, however. The size of the undertaking greatly affects the extent to which the methods presented are followed explicitly. In a small system the planner may have much information readily at hand that in a large one would require lengthy procedures and much paperwork to acquire. There are, moreover, several particular situations that enable the planner to achieve his goals with less effort.

One such situation occurs when the specific problem to be solved is confined to just one segment of the total system. For instance, if the problem involves improving radio system reliability by replacing obsolete base station radio equipment in an otherwise adequate system, then many of the procedures for evaluating the telephone system, the complaint processing procedures, identifying the complete system, etc. do not have to be carried out.

Another such situation applies to modification of a system that undergoes the continuous or periodic evaluation recommended as good practice in all cases. Much of the information about a system changes slowly, especially if adequate records are kept and updated as changes occur. (Equipment inventory, for example, is easy to keep up to date.) Then, when the time for making a modification arrives, a complete evaluation procedure starting from the ground up, such as is described in Chapter VI, is not necessary.

The experienced system planner will also find that he carries out some of the procedures described without doing all of the paper work suggested. Particularly in planning modifications, formulating alternative plans and selecting the best ones, he may carry out much of the process in his head. This results in significant shortcuts and saving in time and effort. However, caution must be observed when proceeding this way, to guard against overlooking subtle problems and effective solutions that are not at first apparent. Further, documentation of the steps taken may be of value in budget activities and for future reference.

Designing a New System

Designing a new system involves many of the same procedures as modifying an existing one. Just as in making modifications, designing a system requires the planner to be familiar with the material in Chapters III, IV and V. There are, however, several significant differences in the process.

While the designer of a new system has no comparable existing system to evaluate in the sense described in Chapter VI, he must still determine the functions the proposed system must perform and the appropriate standards, performance requirements and constraints. Therefore, the procedures described in the first two sections of Chapter VI apply directly.

Again, the size of the system under consideration and the experience of the designer will partly determine in what detail the steps outlined will be followed. That is not to say that a small system can, as it were, be designed on the back of an envelope. Every step must still be carried out. The way in which it is done and the amount of data that must be dealt with may, however, allow many simplifications to be introduced into the procedures described.

Other Uses

One of the prime uses of this text will be made by planners and officials responsible for evaluating police telecommunication system modification and design projects. These individuals should begin with Chapter III and consult those parts of Chapters IV and V that are applicable to their particular project.

If the project in question requires the collection of information about, and the evaluation of, an existing system, the methods proposed can be compared with those given in Chapter VI. Significant differences should be explored to determine whether they are justified by the special circumstances of the project or by the particular approach proposed; or whether they are omissions that may be detrimental to the project if not corrected.

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Posing the questions implied by the planning procedures of Chapter VII can uncover weak points in a proposed design or confirm the validity of the one proposed. It will also help the official evaluating or overseeing a project to do this systematically.

The text may in two ways also be used purely as a source of information. Specific items of information can be found by using the text as a handbook or reference work. The Table of Contents and the Index will help the reader locate material of interest.

The text may also be used for tutorial purposes. The material in Chapters III, IV and V is especially well suited for those who wish to gain a better understanding of police telecommunication systems. The reader interested in systems planning and design, on the other hand, may find the methods presented in Chapters VI and VII to be a helpful review of evaluation and planning techniques.

CHAPTER III

INTRODUCTION TO POLICE TELECOMMUNICATION SYSTEMS

Basic Concepts

Why does effective police service in any community or rural area require some kind of communication? Who needs to talk and how often? How fast do messages have to be sent? What are the costs for providing the police department with better communications? Should you expect better police service when the communications are improved? What Federal, State and local government bodies are involved in a change of the police communication system? This book has been written to help answer these and related questions.

While police activities and telecommunications involve highly technical work and words, questions and answers can be discussed in a manner that you will understand. Some parts of police communications, however, are complicated and often require technical skills for interpretation and understanding. In this book technical discussions of police telecommunications are included, but you will be alerted to technical matter by the change to italic type.

This introductory chapter is written in a non-technical style, but even readers with a technical background may wish to review it. Note at the outset that the word *system* will be used often in place of *police telecommunication system.*

Historically, various systems have been developed over the years to handle police communication efficiently and rapidly. In seventeenth century England, police carried bells or lanterns for identification and as a crude means of communication. Even during the nineteenth century, whistles were blown in various patterns to pass simple messages. With the invention of telephone and radio, police telecommunications took a giant leap forward.

No matter what method of communication is used, such systems enable police to maintain contact with personnel in the field. This, in turn, allows action necessary to carry out their responsibility of protecting the persons and property in the community. Vital services provided by a police telecommunication system include

- Communication between citizens and the police department
- Communication among members of the department in order to coordinate their activities and exchange information
- Communication among police departments
- Communication with other agencies

Any system which does not adequately provide these services restricts the department's effectiveness in protecting the public. How, though, do we know when adequate service is provided? This is the principal question to which this book is directed. A brief general answer is that *the system must be capable of handling the communication needs of an emergency situation as well as the normal daily activities of the department.* A bank robbery or major traffic accident in the community generates a much greater need for communications thar do normal daily activities.

It is crucial that r ssages must be sent and correctly received with no greater delay than the situation at hand will allow. Obviously, a message delay of ten minutes can be critical in a bank robbery. On the other hand, if lower priority messages are allowed to back up, overall police service will fall out of step with timely response. We see that delay and the number of messages to be handled are strongly interrelated with service.

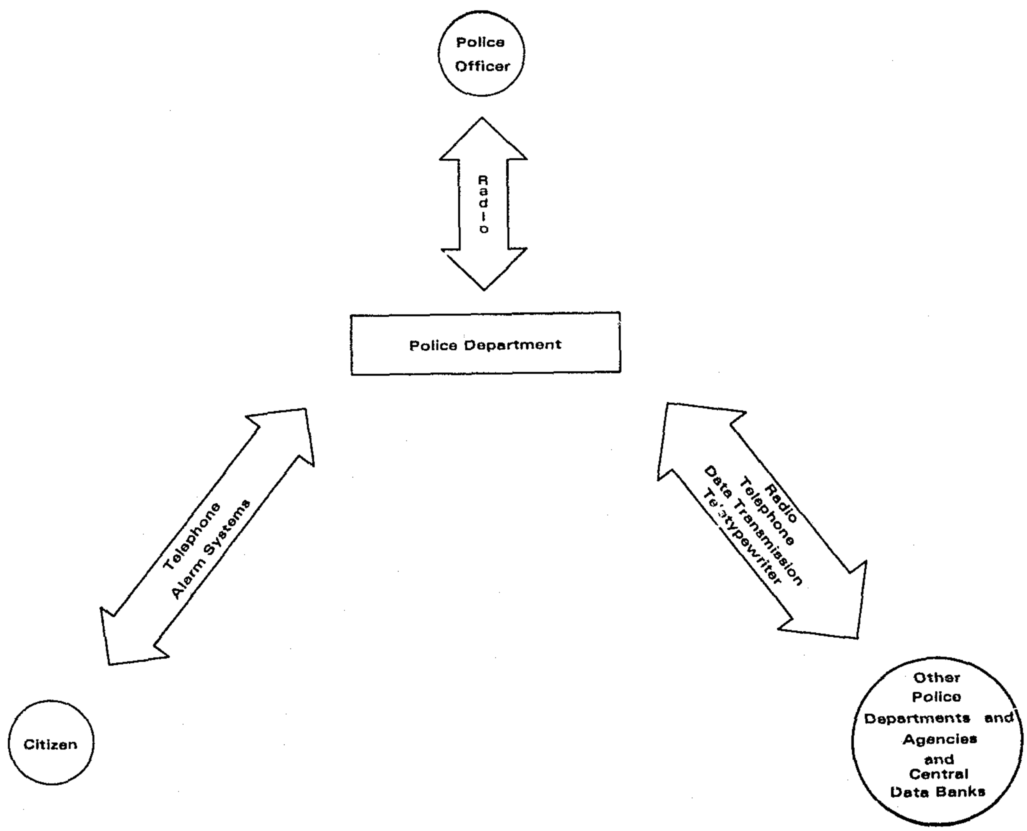

Fig. III-1 Police Communications

The three basic parts of a police telecommunication system usually are

1. A telephone system by which the citizen (and police officers) can reach the department for assistance or exchange of information. Alarm systems or call boxes may also perform this function.
2. A radio system by which police officers in vehicles and on foot can be in constant contact with headquarters and each other, and by which communication with other police departments can be carried out.
3. Data transmission systems, including means such as teletypewriter facilities, permitting the exchange by wire or radio of data and other information within the department or with other agencies, including centralized data banks.

These three basic parts, when coupled with experienced operating personnel, can provide a most effective and flexible system.

Telephone System

Since the citizen is being served by a police department, it is imperative that he be able to contact the police quickly when he needs their assistance. The telephone system is a natural means for citizen-police contact. It serves a large percentage of the population and is usually available everywhere. Most people know how to use it, even under stressful conditions.

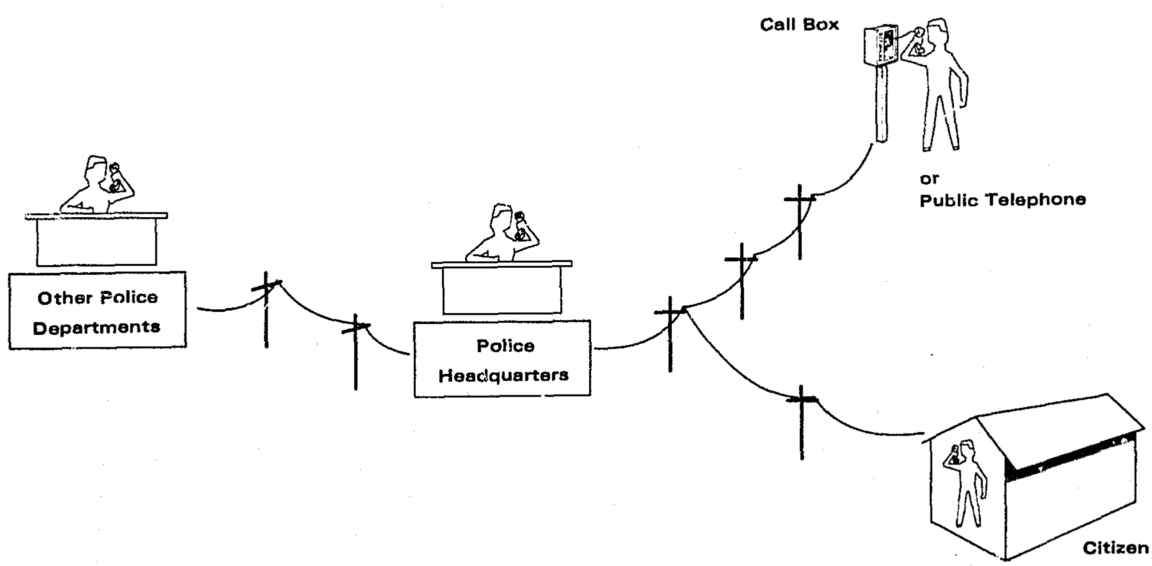

Fig. III-2 The Telephone System

In addition to its main purpose of providing citizen-police contact, the telephone system within the department gives:

- A back-up means of communication in case of radio failure at headquarters or in a police vehicle
- A means of passing lengthy or confidential information which may not be appropriate for radio transmission

In some cities a system of police or emergency call boxes is used for confidential or long messages. This provides an alternate, less convenient means of communication which may augment, though not replace, the radio system. Call boxes may sometimes also be available to the public for calls to the police.

The telephone system is also relied upon to varying degrees for the exchange of urgent information between police departments. In particular, the telephone may provide the only means of communication with some departments. This may take the form of special "hot lines" that connect specific departments and agencies.

Radio System

Radio is uniquely suited to the needs of mobile police officers. Radio allows the patrolman to maintain contact with headquarters for such things as receiving dispatching instructions, exchanging information concerning a wanted person, requesting a check on an auto

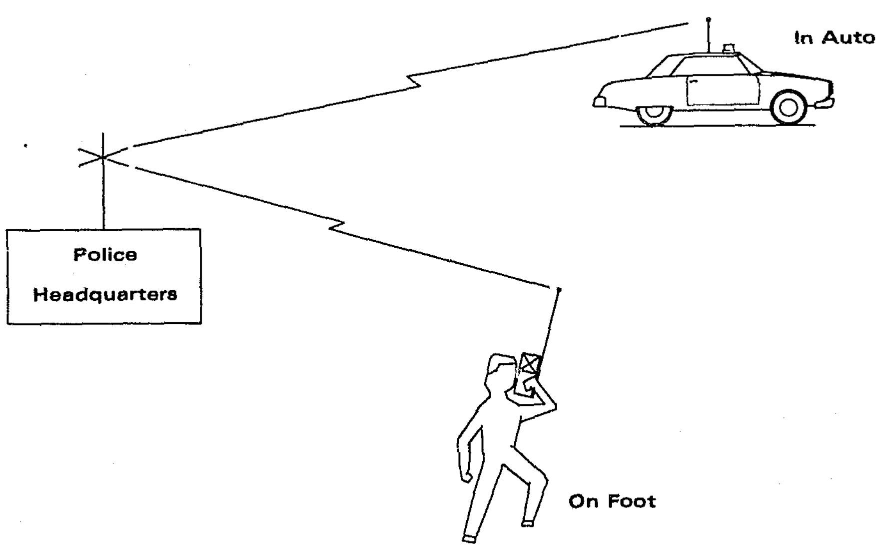

Fig. III-3 The Radio System

registration and receiving the reply, calling for assistance, reporting his status, etc. Some radio equipment has become so small that it is now feasible for every police officer to carry a personal portable radio. Thus he can be in constant and immediate contact with headquarters.

The radio system also serves as a means of communicating with other departments in the region. Sometimes the same radio channel is used for both purposes, especially in the case of neighboring departments. However, a separate radio channel, sometimes referred to as the "point-to-point" channel, enters the picture here. This channel serves as a giant "party line". Any department in the region can call another by point-to-point radio. In either method, the information exchanged is of regional interest, such as descriptions of stolen autos, persons fleeing the jurisdiction and so forth.

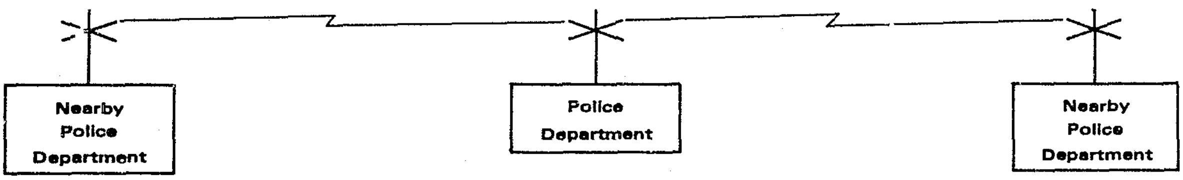

Fig. III-4 Point-to-Point Radio Communications

Police radio systems are now almost entirely Frequency Modulation (FM) systems. FM radio is free from many forms of interference problems which plague Amplitude Modulation (AM) radio. With today's equipment such systems are dependable, have good range, and provide good quality on reception.

Even more important than good equipment, however, is the manner in which a radio system is organized and the way it is used. Good organization in terms of equipment locations, the selection of frequencies and their use, etc., and the rules for using the radio system can make the difference between a mediocre and good system. Frequencies and their selection, though, deserve added explanation.

Frequencies make up the radio spectrum—the basic resource for radio communications. Frequencies, their assignment and the widths of channels are a regulated commodity, not only nationally but throughout the world. In the United States, the Federal Communications Commission (FCC) provides this regulation through allocation, licensing, and rule making for all except Federal Government allocations. The Office of Telecommunications Policy helps develop national spectrum utilization policy.

In order to send a message by radio, a radio channel is needed. This is often called a *frequency,* although a narrow band of frequencies actually constitutes a channel. The radio equipment for sending messages must generate a precise signal on one channel or frequency and the receiving equipment must select this signal without being disturbed by signals on nearby channels. Just as a highway (a channel for cars) or a river (a channel for water) can be narrow or wide, so a radio channel can be narrow or wide. The narrower the radio channels, the more conventional channels can be placed into a given section of the radio spectrum. However, as the channels are made narrower, the radio equipment then becomes more complicated and more expensive to purchase and maintain.

Data Transmission System

A data transmission system provides communication with regional and national computer based information systems, which are becoming an important tool of law enforcement agencies. Leased or purchased teletypewriter communication circuits and terminal equipment are frequently employed for this purpose. Many state-wide police agencies also have teletypewriter systems for passage of information between districts in the state. Facsimile and closed-circuit television systems may also serve to transmit data.

> To summarize, effective police service requires an effective communication system. The radio, telephone and teletypewriter equipment, operating procedures and personnel training, must enable messages to be conveyed as quickly and reliably as any police situation requires. To provide this service, attention must be given to message delay, the number and length of messages, the equipment capabilities, frequencies, and system organization. Effective operating practices must be developed for each part of the telecommunication system, and training provided to meet the needs of each individual department.

Basic Functions

What is a police telecommunication system supposed to do? The answer is given in terms of the functions which are introduced here. A police telecommunication system performs many functions which fall into four broad categories:

- Communication between the public and the police department
- Communication within the police department
- Communication among police departments
- Communication between the police department and other agencies

Each plays an essential part in enabling the police department to protect the community. While the particular method used to carry out each of these communications varies somewhat from department to department, every department must provide for each of the above communications in one way or another in order to be effective.

Communication between citizens and the police department revolves around several areas:

- Calls from citizens for emergency assistance
- Calls from citizens giving or requesting information from the police
- Calls from the police department to citizens

Emergency assistance calls from citizens must be handled quickly and efficiently by the communication system. Such calls are usually received through the telephone system. (Occasionally a police officer is hailed by a citizen or the citizen goes to police headquarters in person.) Calls from citizens giving or requesting information from the police may or may not be of an emergency nature. Whether or not the call should be treated as an emergency must be decided by the complaint operator or radio dispatcher who is assigned to receive the telephone calls. For these citizen-police calls, many police departments maintain different administrative and emergency telephone numbers in an effort to keep the two types of communications separate. Calls from the police department to citizens include items primarily of an administrative nature.

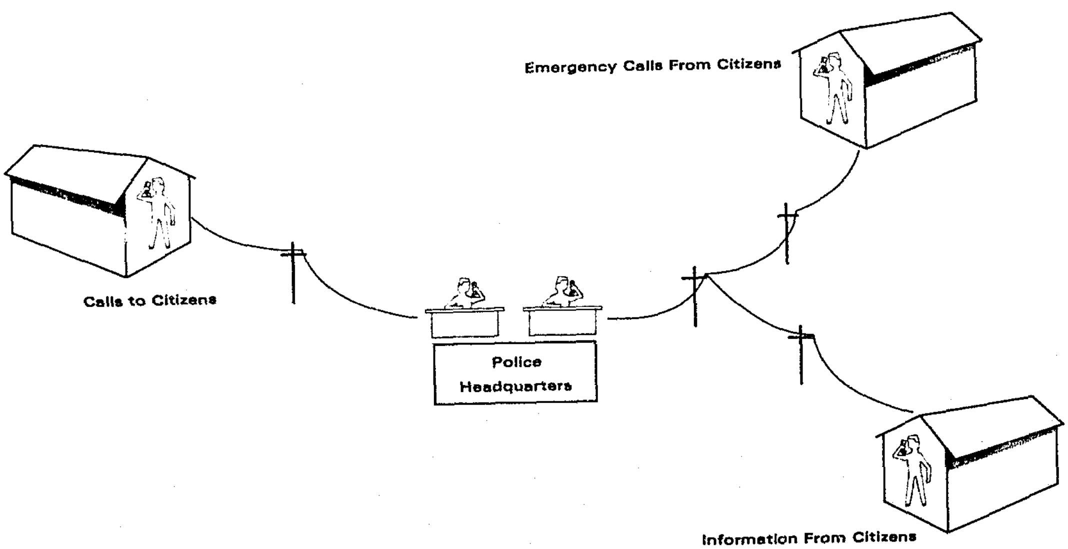

Fig. III-5 Typical Police Telephone Communications With the Public

The second category of communication—communication between members of the police department—is probably the largest in terms of amount of information exchanged. Almost all of these communications are made through the radio system. They may involve the dispatcher, officers in radio-equipped vehicles, or patrolmen equipped with personal two-way radios. Examples of such communications are:

- The radio dispatcher gives information to the patrolman about a complainant or about a crime which has just been committed
- The patrolman reports his location and work status so that the dispatcher knows whether he can call upon the patrolman for a task
- The dispatcher gives coordinating information to officers in pursuit of a speeding car
- A field commander gives instructions to the mobile units and foot patrolmen under his command in a tactical situation
- The patrolman requests information, the dispatcher obtains it from the records, and transmits it

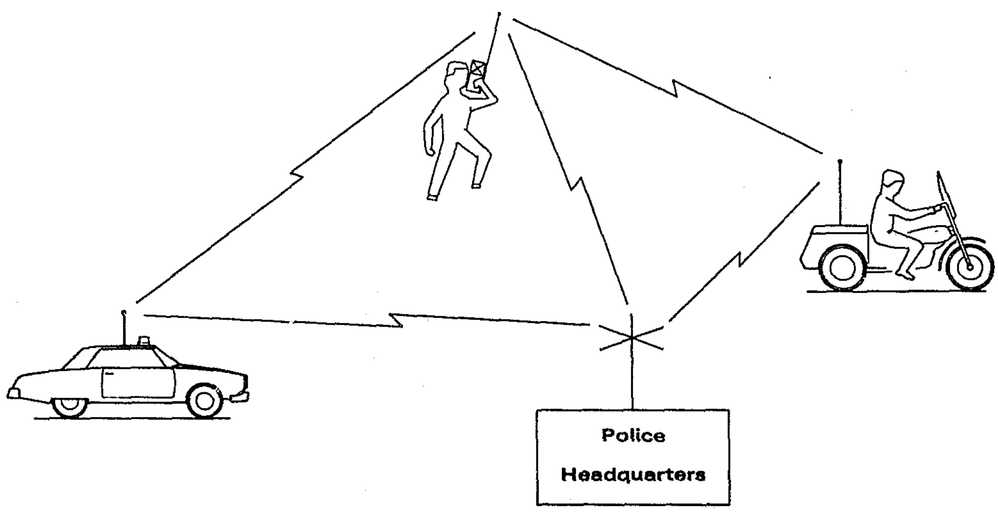

Fig. III-6 Base-Mobile Radio Communications

In the third category is found communication between police departments. Here, departments supply other neighboring departments with needed or requested information. Such communication is necessary for events or criminal activities which are likely to cover more than just the jurisdiction of a single department. An example is the theft of an auto in which the suspect escapes into a neighboring community. Departments may communicate on their local radio channel if the neighboring departments are on that channel, may use the "point-to-point" channel, a telephone or teletypewriter system, or a mobile interdepartmental radio network such as the ISPERN* system in Illinois.

A by-product of police radio communication is that it permits police officers of one department to listen to the radio messages of neighboring departments. This gives a continuous means of identifying certain events of possible importance to their own department. Unless the radio channel is shared in common and the equipment can work together, this by-product doesn't exist. Obtaining this capability will then require extra equipment and added cost.

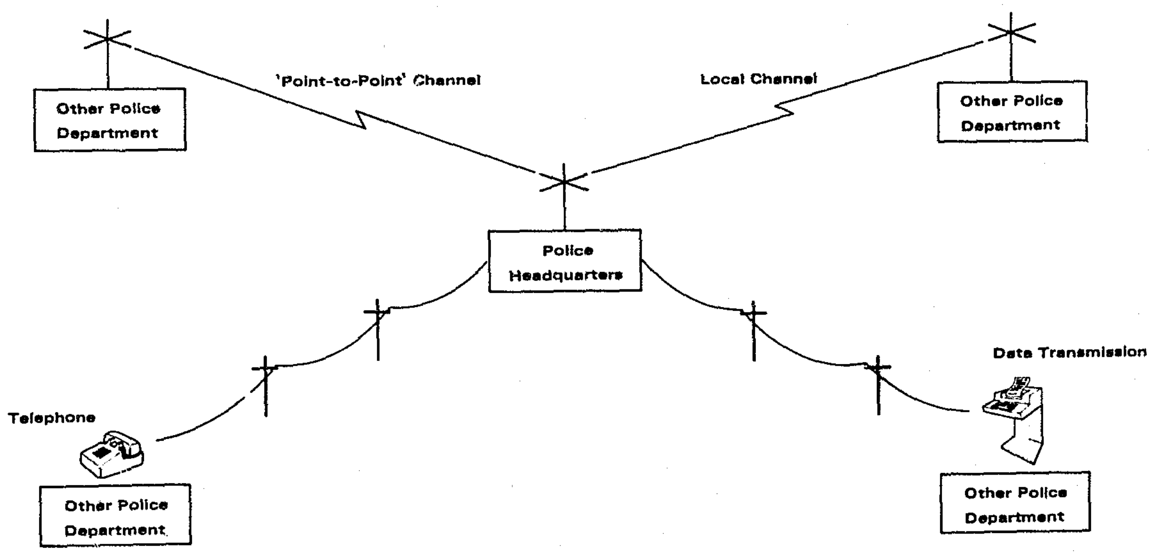

Fig. III-7 Interdepartmental Communications

*ISPERN stands for Illinois State Police Emergency Radio Network.

The final function of a communication system is to pass messages between the police department and other public-safety oriented agencies and services. These agencies include:

- Fire departments
- Public works, highway maintenance departments and utilities
- Hospitals and ambulance services
- Towing and wrecker services
- Regional, state and national crime information centers
- Civil defense units
- Government officials, such as the governor, mayor, city manager, etc.
- National Guard
- Federal Bureau of Investigation and Secret Service, etc.

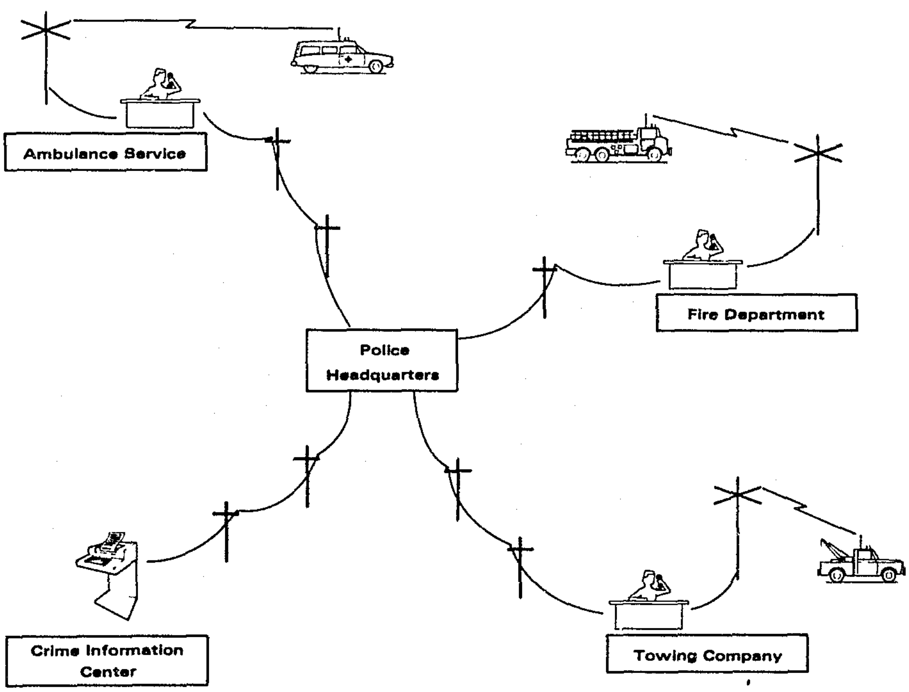

Fig. III-8 Communication With Other Agencies

In many cases police officers must coordinate with these agencies in the field. Such communications are generally handled through the police dispatcher because these agencies cannot use police channels for their radio traffic. The dispatcher may have a separate radio which can operate on the channels of these agencies. If not, he may have to contact them by public telephone or a special "hot line". Communications with computerized crime information centers are most often by means of a teletypewriter system.

> In summary, the police telecommunication system must fulfill many duties in order to serve the community effectively. First, it should provide a means of communication between the public and the police. Second, the system should furnish rapid communications between police headquarters and police officers in the field. Third, it should allow communications with other departments. And fourth, it should provide a means of communicating with other public service agencies. The system can fulfill these duties using the telephone system, a two-way radio network, and often a teletypewriter system. Together, they form a complete system, able to perform these tasks quickly and effectively.

Basic Requirements

How do we know when the communication system is adequate for effective police service? The answer is given in terms of the requirements discussed in this section. Every police telecommunication system, whether large or small, must meet certain basic requirements in order to be an adequate system. These requirements fall into two broad classes—those which are related to adequate performance of the system and those related to external legal and economic necessities. The former class of requirements includes factors such as the time delay incurred in conveying messages, how long the equipment operates without breakdown (reliability), and how flexible the system is in serving different and changing communication situations. The latter class includes the Rules and Regulations of the Federal Communications Commission (FCC), the costs of different levels and types of performance, recordings for possible court use and jurisdictional questions.

The Effectiveness of a Police Telecommunication System

The criteria for effective police communications are clearly more stringent than those for any other non-military use of the radio spectrum. Citizens depend on the police for prompt service in the most urgent emergencies. Such events can occur at any time.

A police telecommunication system must convey correctly and quickly all messages required for effective protection and service to the community. The ability to convey the messages means that:

- There are no excessive delays in sending messages to their intended destinations

- The length and content of the messages is appropriate to convey the required information
- The information is not degraded by interference on the radio system
- The means of transmitting the messages is determined by their emergency nature, privacy needs and length

When a means of communication such as police radio or telephone is not heavily used, the length of time to establish communication is generally short. However, when a large number of messages are handled over such a system, individual waiting times can be quite long. This principle is true of all systems of this type which are shared between many users in an area, for only one or a few people can use the system at any one time. Police telecommunication systems must be designed to reduce waiting times as much as possible.

A good measure of the quality and adequacy of a police telecommunication system is the amount of time which an officer in the field, the dispatcher at headquarters, or a citizen must wait in order to reach the person he is trying to call. This waiting time is extremely important because of the urgent nature of many police communications; personal safety may be in jeopardy.

Most authorities desire that in urban areas the average time to respond to a request for police service be three minutes or less. This interval includes all the steps from the initial complaint call to arrival of an officer on the scene. Only part of these three minutes can be used by the police radio system. A standard for waiting time in the Police Radio Service has been established.[1,2,3*] It is, that during a normal busy period:

> The average length of time that a radio operator must wait to get a message on the air after he initially attempts it, should not exceed five seconds.

This standard was developed in cooperation with a number of police administrators from all over the nation and has been accepted as both reasonable and adequate. This standard is, however, for an *average* delay of five seconds. This means many messages in a busy system could experience greater delays, even though the average delay is five seconds.

Police departments cannot have an exclusive channel for each officer. Therefore, radio systems should be designed with the goal of making the *average* waiting time during normal busy periods no more than five seconds. Further, the *maximum* waiting time should be kept to some tolerable length.

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*Numbered references appear under appropriate headings in the References.

The number of people wishing to use the system varies widely with various emergency situations. The result is that the waiting time increases during periods of heavy message traffic, even though the urgency of messages may be just as great.

The second general requirement for an effective system concerns the length and content of messages which can be sent over the system.[4] These must be adequate to convey the necessary information. If messages are too short, essential information may be left out. If they are too long, the system may become overcrowded with message traffic and waiting times may increase. Obviously, the average length of messages allowed on a system at a given time directly determines the average waiting time for any user of the system.

The third general requirement for an effective system is that the messages should not be degraded by interference. The radio system is, for example, normally more prone to such interference than the telephone system. Radio interference can consist of:

- Signals generated by electrical devices such as auto ignitions, electric motors, neon signs, etc.
- Other radio stations using the same or nearby frequencies
- Background noise picked up by the user's microphone
- Faulty radio equipment

The final general requirement is that the system provide a means of communication which is an alternative to the radio network. This is necessary since many messages are not urgent and do not require the speed that the radio system provides. Other messages may be lengthy, using excessive radio transmission time. They may also be of a confidential nature, requiring privacy. The public telephone system, for example, offers an alternate means. A police dispatcher often will call an officer by radio and ask him to telephone headquarters. The telephone system also provides a means of communicating with other police departments and public service agencies.

Reliability and Flexibility of a System

It is imperative that police telecommunication systems be reliable and flexible. From both an operational and equipment viewpoint, the system must rarely, if ever, be unavailable for use.

Reliability is dependent both upon equipment and the method of operation of the system. Equipment reliability can be increased with good quality equipment and competent preventive maintenance. Any system will have occasional failures, however, and it is important to have some back-up capability in the event of a failure. These may be due to mechanical breakdowns, or to inadvertent or deliberate action. Operational reliability can be increased by planning. There should be enough radio dispatchers and complaint or telephone operators to handle the message traffic during peak hours, and enough capable persons available to operate the radio system at all times, 24 hours a day. A system which breaks down due to an operational failure is just as useless as one which has an equipment failure.

Because police communication systems perform such a wide variety of functions, they must be flexible in order to be able to fulfill these functions. Flexibility includes the ability to communicate with special departmental units, other police departments and public and non-public safety agencies. It also includes the ability to circumvent minor equipment failures in order to get messages through. Part of this flexibility is attained by having prior planned operating procedures available for many contingencies. Flexibility also includes meeting the greater demands that future growth of the community may put on the telecommunication system which serves it.

External Legal and Economic Necessities

There are many legal and economic requirements imposed on a police telecommunication system. Some of the more important are outlined here.

First of all, the telecommunication system must meet all technical and legal requirements imposed by the FCC Rules and Regulations.[5] Among the more important of these are:

- The communications equipment must adhere to certain technical standards which are established by the FCC[6]
- The operators of the radio system must understand and comply with FCC Rules and Regulations
- Certain station records must be kept
- The radio station must be licensed by the FCC and operate on the frequency assigned to it

Many police departments use voice recorders to record all telephone and radio messages. The recordings are available to verify addresses, for training, and for investigative purposes (for example, in the event that a citizen brings suit against the department). Such systems usually record the incident time for easy verification of exactly when messages occurred. Such systems are not, however, required by the FCC.

The discussion of economic requirements always begins with the question—"How much does it cost?" Coupled with the question—"How well does it work?", we begin the process of analysis which relates cost, performance and need associated with each function. It is not possible to list particular economic requirements in terms of dollars because they vary too greatly from community to community, state to state, etc. We should observe, however, that many maxims of everyday and business economics apply directly to police telecommunications. A few examples are:

- Each additional function or service requested from a police department implies an increase in direct or indirect costs
- Building flexibility into a system leads directly to greater costs. Different modes of operation lead to more complex and diversified equipment and system organization
- The more each police department must coordinate with other departments or agencies, the greater the costs of operation
- Equipment costs tend to increase with the degree of automation required, and may not be compensated for by decreases in labor costs if services are increased
- Procurement and maintenance costs may be reduced by sharing with other agencies, but possible conflicts-of-interest may arise during emergencies
- The greater the area covered by a telecommunication system, the greater will be both the equipment and the operating costs
- A reduction in the time required to process information flowing through a system (e.g., reducing telephone and radio waiting times) causes an increase in cost, because it may require more personnel or more equipment

We also observe that police telecommunication systems have needs which are unique to emergency systems. Since police telecommunication systems must provide emergency service, the reliability requirements on equipment are much higher than for other, less critical communication services. Though a commercial service may be inconvenienced when a radio fails, or may suffer higher costs or economic loss due to reduced operating efficiency, yet their vehicles can still be used. In police application, on the other hand, a vehicle cannot respond to an emergency dispatch if its radio fails. The vehicle thus is out of service until the radio is repaired. Without a radio, the vehicle can be used for routine service calls only by returning to headquarters or calling by telephone for new instructions upon completing an assignment. To provide equipment with the necessary high reliability, high quality components and stringent quality controls must be employed.Both factors increase the cost of the product.

Another extraordinary cost is caused by the large differences in message traffic volume between busy and quiet periods. The telecommunication system must handle normal peak loads with almost the same rapid response as it does during those times when loads are light.

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This requires that both equipment and personnel capacities be geared to handle peak loads rather than average loads. The result again is increased costs. Finally, we note that these examples and others cited throughout the text show the need for sound economic planning.

In summary, every police telecommunication system must perform effectively at all times and in different ways. To perform effectively means the system, first, must handle all messages quickly and with minimum delays. (As an aid to the system, short or coded messages that convey all the necessary information can help keep delays to a minimum.) Second, messages should not be degraded by system-caused interference. And third, the telephone and teletypewriter systems can complement the radio network by providing an important and special means of communication.

To perform effectively at all times means the system must be flexible. For example, besides communications within the department, it should provide the means of communicating with other police departments and other public service agencies. The system should also have the ability to pass messages in the event of certain equipment or other unpredicted system failure. The system must meet all necessary legal and economic requirements. Legal requirements are mainly those imposed by the FCC. Economic requirements are usually those governed by the needs of the community which the system serves.

Common Types of Municipal and County Systems

There are many ways of organizing communications equipment and operating procedures into a working telecommunication system. Some of the more common and successful types of systems which have developed over the years are described here.

The Telephone System

The telephone portion of the telecommunication system usually consists of several trunk lines for complaint and emergency calls. Some of these may be reserved for the administrative affairs of the department. The number of lines available depends on the size of the police department, the city and the police workload.

In smaller police departments, the telephone is usually answered by the radio dispatcher, who may be the only person at the station at certain times of the day. In larger departments, the telephone calls may be divided between several persons who may be radio dispatchers or complaint operators. Very large cities are usually divided into zones. Telephone calls coming from a certain zone of the city are routed to a complaint operator who is thoroughly familiar with that part of the city. In effect, such a system divides a large city into a collection of smaller areas, each manageable by one or two operators.

The Radio System

Radio systems differ by the number of frequencies used to provide a base-mobile channel, by the number of two-way channels in a system (or network), by whether system operation is simplex or duplex*, and by whether or not repeater stations are used. The most commonly encountered systems are

1. Single-frequency simplex
2. Two-frequency simplex
3. Two-frequency half-duplex

The *single-frequency simplex* system is the most widely used two-way radio system. It requires the least radio spectrum space and is the most economical two-way system to purchase and operate. With this system, the base station (labeled Headquarters in Fig. III-9) and the mobile units share the same channel (frequency). This means that only one user of the system can transmit at any one time. Multiple transmissions usually will interfere with each other, although in an emergency a police officer will try to transmit his message despite this. All receivers within range can listen to the same transmission—somewhat like many people listening to the same station on their home radio. This significant feature provides some operational and psychological benefits.

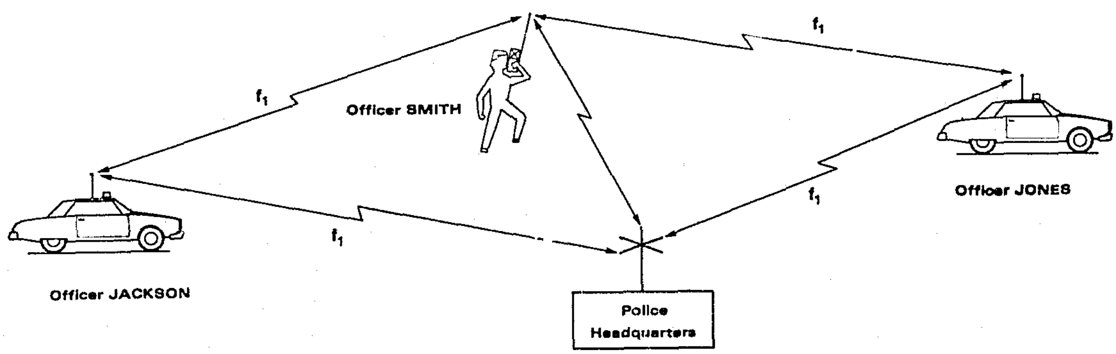

Fig. III-9 Single-Frequency Simplex Operation

*Simplex means that signals can be transmitted in only one direction at a time between two users. Duplex means that signals can pass in both directions at the same time between two users.

A second common type of radio system is the *two-frequency simplex* system. It is similar to the single-frequency simplex system except that the base station broadcasts to the mobile units on one frequency and they broadcast to the base station on a different frequency. This prevents the base station broadcasts of one department from interfering with the mobile unit broadcasts of another department when they are nearby and share the same frequencies. Thus, it is suited to areas requiring densely packed stations on the same frequencies. A disadvantage of this mode of operation is that mobile units cannot hear each other's transmissions because their receivers are tuned to f_1, the frequency of the base station transmitter. There are, however, several ways to overcome this drawback. One of these is readily implemented in the next system described.

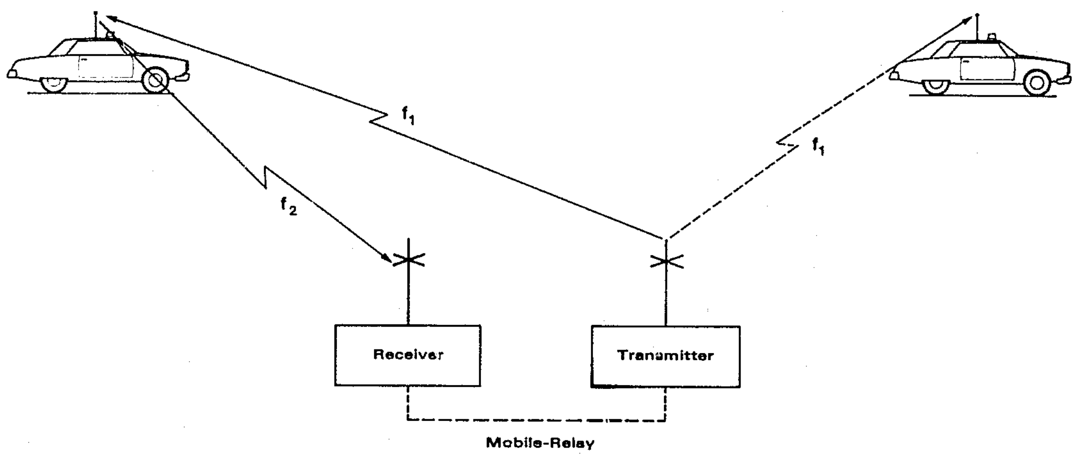

Fig. III-10 Two-Frequency Operation

A third common type of radio system is the *two-frequency half-duplex* system. It differs from its simplex counterpart in that operation at the base station is duplex; that is, the base station can receive and transmit simultaneously. A simple connection between receiver and transmitter (shown as a dotted line in Fig. III-10) thus permits all mobile transmissions to be rebroadcast by the base station. When this is done, the base station is said to operate as a *mobile relay*. All mobile units can usually then hear each other's transmissions.

It is common in larger cities, where one radio channel simply cannot handle all of the radio messages which are necessary, to use several channels. These may be assigned to different geographic zones (as in Fig. III-11) or to different functions (such as patrol, traffic, investigation). The individual channels may operate in any one of the three modes described.

If a large geographic area must be covered by radio communications, or if obstructions such as mountains separate the service area, it may be necessary to use one or more repeater stations to amplify signals and rebroadcast them. Repeater stations may also be used to insure complete coverage by low powered, personal portable radios. Many variations are possible to accomplish these objectives, depending on whether all transmissions, only those from mobile units or only those from base stations are to be rebroadcast. How many base stations are in the system, their geographical distribution and that of the mobile units also affect the particular method chosen.

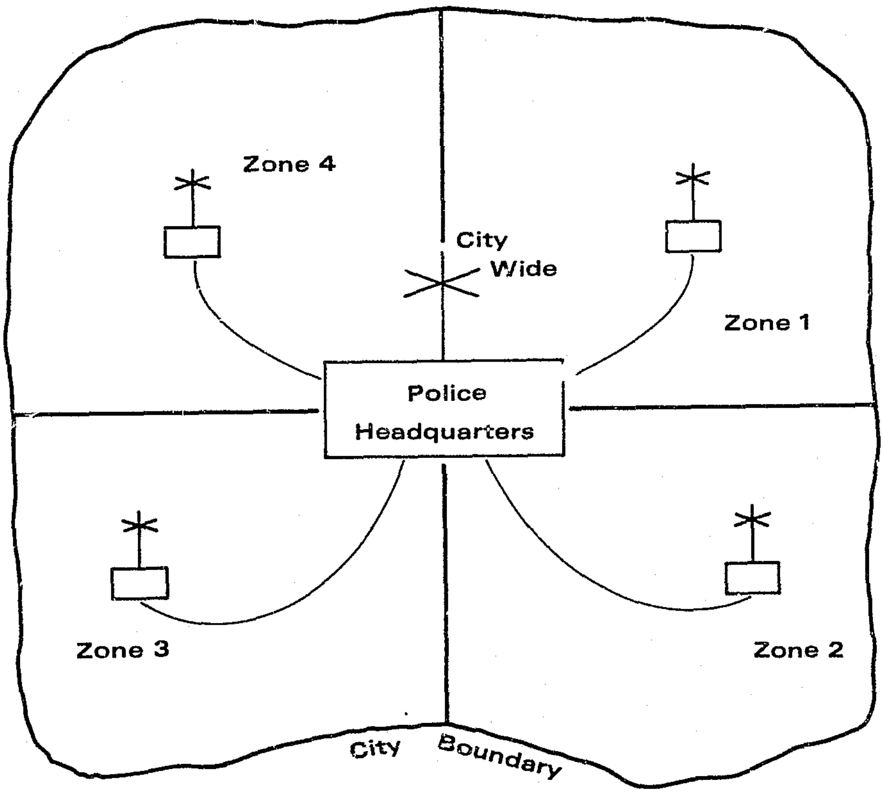

Fig. III-11 Multi-Channel Operation

In summary, the public telephone system, a radio network and a leased teletypewriter or data transmission circuit make up a basic police telecommunication system. The public telephone consists of telephone lines and switchboards at headquarters along with personnel to handle calls made to the department. It may also be used for special kinds of data and teletypewriter communication.

The radio network can consist of various types of equipment. The single-frequency simplex system is the most commonly used today. The two-frequency simplex system is similar to the single-frequency system except that the base station transmits on one frequency and the mobile units transmit on another. Like the single-frequency simplex system, all transmissions from the mobile units are on a time-shared basis. An advantage of the two-frequency over the single-frequency simplex system, is that interference caused by departments close to one another is less likely. A two-frequency half-duplex system has this advantage also. In addition, it allows the base station to act as a mobile relay and thus, to establish communication between mobile units. Larger cities may employ several channels assigned by geographic areas or function, in a multi-channel operation. Repeater stations may be utilized where irregular terrain or a large area make reliable radio coverage difficult.

Police Telecommunication Equipment

There is a large selection of police telecommunication equipment available from commercial sources. Some of it is intended primarily for police systems, while the rest is made for more general use and is adapted as needed for police systems. This section provides a brief non-technical discussion of the more important and basic types of equipment which are found today. In general, the larger the police department, the more sophisticated its telecommunication equipment must be in order to handle the larger volumes of message traffic which are generated as a department increases in size. Chapter IV gives a more detailed discussion of police telecommunication equipment.

Telephone Equipment

Telephone equipment is ordinarily leased from the local public telephone company. The company then also furnishes all special equipment needed by the department. Call boxes and associated lines are frequently self-contained systems owned or leased by the municipality. Alarm systems are generally leased from private companies.

Base Station Radio Equipment

Base station radio equipment carries all radio messages which the department needs to transmit or receive. In simplest form the base station radio equipment consists of:

- A radio transmitter
- A radio receiver
- A control console for the transmitter and receiver
- A radio antenna
- An antenna support
- A transmission line

This is the minimum base station equipment which, together with mobile equipment can provide two-way radio communication. Many smaller departments have only this basic collection of equipment for obvious reasons; a larger department might have several transmitters, receivers and antennas, and a complex control console with additional features which are useful for handling a large radio system. In such a system, however, the basic equipment works along the same principles as the smaller department's equipment.

Mobile Radio Equipment

Mobile radio equipment includes any type of radio equipment moved from place to place, used to communicate between or among officers and headquarters. The equipment includes:

- Radios mounted in patrol cars
- Radios mounted on motorcycles
- Radios mounted in aircraft
- Radios mounted in patrol boats
- Personal portable radios

In all cases, the units consist of a transmitter and a receiver to enable two-way conversation.

> **In summary,** many types of necessary equipment make up a police telecommunication system. First, the basic element of any system is the public telephone system. Next is the base station (headquarters) radio equipment. It consists of one or more transmitters powerful enough to send messages to every point in the

community, and one or more receivers sensitive enough to hear messages sent from the mobile units.

Often a control console is used to coordinate the headquarters' operations, such as transmitter and receiver control, telephone, teletypewriter and other communication functions. An antenna and tower, usually placed next to or on top of the headquarters building, completes the base station segment of the system.

The mobile equipment fully completes the system. It consists of two-way radio units in patrol cars, on motorcycles, or carried by the patrolman. With the continuing development and improvement of transistorized equipment, both base and mobile equipment have become smaller, lighter, use less power, and are more reliable.

Evaluation of Telecommunication Systems

An occasional evaluation of a police telecommunication system is a healthy exercise for a police department. Like a medical check-up, a thorough examination of a system can serve to locate existing and potential sources of difficulty within the system. An evaluation can also be done on a proposed system. In particular, an evaluation should be geared to answering the following questions:

- Is the system adequate and efficient in the sense that it meets the requirements placed upon it by the police department? In other words, does it do everything the police department needs it to do?
- If there are problems within the system, where are they located and what can be done to correct them?
- Will the system be adequate for the future needs of the department?

If the answers to these questions indicate that there are problems within the system at a certain point, modification or even more drastic measures may be needed to overcome them. The findings of an evaluation should not be ignored. Just as with a patient who is ill, if the system requires surgery and does not get it, it will limp along for awhile but will probably eventually fail.

The first step in evaluating a telecommunication system is to outline in detail exactly what the system is supposed to be doing (functions). For example, is it supposed to permit police officers using portable radios to communicate with police headquarters? This step may be rather simple in the case of small systems, but it is not so obvious in larger systems.

The second step is to determine the requirements which are placed on the system. For example: what are the FCC Rules and Regulations that apply to the system? If one of the functions of the system is to permit the use of portable radios, is the system required to enable officers to send messages to headquarters from *all* parts of the city using their portable radios?

The third step may be called "identifying" or getting to know the system. One should find out such things as:

- What equipment does the system contain?
- How is the equipment interconnected and operated?
- What are the characteristics of the equipment?
- How is the system operated under various conditions?
- Are the requirements on the system necessary and are they satisfied?
- How does the system go about doing what it is supposed to do?

The answers to these questions should be carefully recorded.

The fourth step is to determine how well the system is doing its job (or will do its job, in the case of a proposed system). In an existing system this may mean analyzing radio traffic, listening to how citizen complaints are handled, measuring the time between a citizen call and the dispatch of a police car, etc. For a proposed system, the basic question is "Will the system meet all of the requirements of the department at an acceptable cost?"

The final step is to look at the information collected and compare the actual communication system performance to what it should be doing. From this comparison, an idea of where the system has problems can be obtained. Often, some quick solutions to these problems will become readily apparent.

Evaluation of an existing system can be done to a certain extent by department personnel on a continuing basis. In fact, in any system an unconscious evaluation is constantly taking place. If personnel find that the system has a serious shortcoming which is affecting their efficiency and even safety, they will undoubtedly report the difficulty. These should be recorded in a continuing log. Particular methods of evaluation vary widely depending on the size and type of system being used. For smaller systems, evaluation tends to be a semi-formal process. Smaller departments often do not have the resources to make detailed evaluations. This text should help such departments make better use of the available resources.

> **In summary,** every police telecommunication system should be evaluated periodically. An evaluation will determine system efficiency

and indicate what improvements are necessary. The evaluation should consist of:

- Outlining what the system should be doing
- Determining the requirements on the system
- Analyzing equipment in terms of how it is used, and how well it performs
- Estimating how efficiently the entire system does its job and at what cost

Whatever changes should be made to keep a system up to date will be evident from the results of such an evaluation; frequently, the means to accomplish those changes will also be indicated.

The Radio Frequency Spectrum

No introduction to police telecommunication systems would be complete without a brief discussion of the radio frequency spectrum. Radio waves (or more precisely, electromagnetic waves) are the means by which radio communications are conducted. A police radio system operates on a certain channel or radio frequency and actually includes a small range—called a band of frequencies or sidebands—around that frequency. When all radio frequencies possible are taken as a group, the term *radio spectrum* is used.

This spectrum is in essence a finite natural resource which, unlike most other resources, cannot be detected by any of our human senses. This resource is an invisible means by which energy can be transmitted at one point and received at another and in the process convey information. Since electromagnetic energy can be transmitted without the use of wires, it is an extremely valuable means of conveying information whenever either the sender or receiver or both is in motion, as in police operations. Every radio transmission has three basic attributes:

- It occupies a certain geographic area
- It occupies a certain period of time
- It occupies a certain portion of the radio spectrum

These attributes are very important to remember when talking about a radio communication system. A basic rule is that no two radio users can use the same portion of the spectrum at the same time and in the same area without interfering with each other. In order to prevent interference, the users must be separated sufficiently in frequency, area of operation, or time.

The most heavily used portions of the frequency spectrum which are available to the Police Radio Service, as licensed by the FCC, extend from about 37 MHz* to 46 MHz, called the low-band; from about 154 MHz to 159 MHz, called the 150 MHz- or very-high-frequency (VHF) - or high-band and from about 453 MHz to 465 MHz, called the 450 MHz- or ultra-high frequency (UHF)-band.

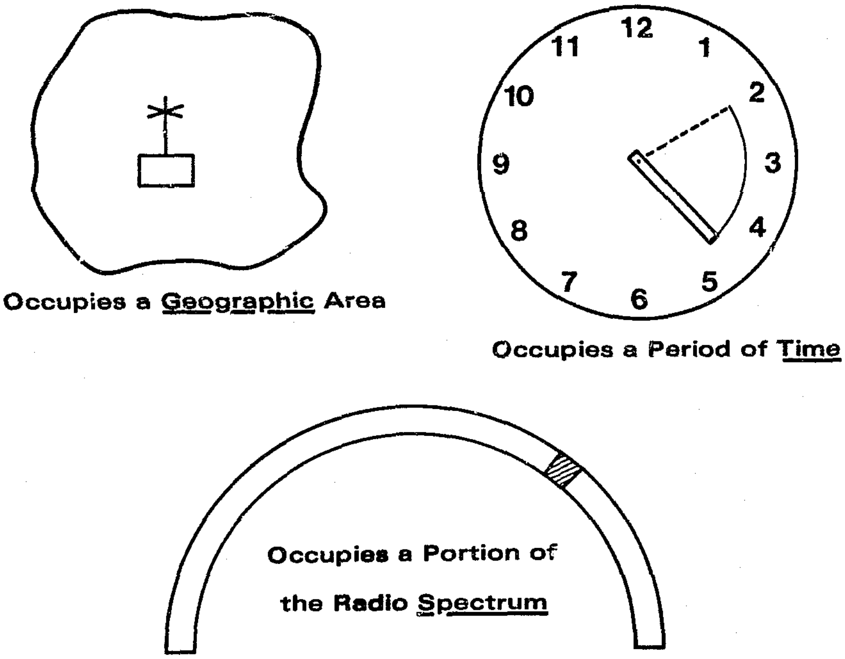

Fig. III-12 Basic Attributes of a Radio Transmission

In addition, the FCC has ruled that certain frequencies between 470 MHz and 512 MHz and between 806 MHz and 960 MHz may be used by land-mobile radio in the ten largest metropolitan areas in the U.S. A portion of these will be available for use by the Police Radio Service. The high-band and UHF-band are most popular[7] because radio waves at these frequencies have desirable "propagation" characteristics. This means, among other things, that if used properly the waves reach into all areas of a city but do not travel over long distances to cause interference in distant places.

Because of their desirability and the relatively small area of the spectrum available in each, the 150 MHz (VHF) and 450 MHz (UHF) bands have become extremely crowded with radio users. Much interference between users exists in some areas due to violation (often

*MHz is the abbreviation for MegaHertz, million Hertz, or million cycles per second.

unavoidable) of the basic rule that radio transmission must be separated in time, geographical area, or frequency.

In order to transmit information, a certain amount of frequency spectrum is needed. The amount of spectrum required increases as more information needs to be transmitted simultaneously. For example, a television picture uses several hundred times as much spectrum as voice. The amount of spectrum occupied by a transmission is termed the bandwidth of the transmission.

Each user of spectrum is assigned a certain amount of spectrum space for his use. The assignments include a small amount of buffer spectrum space, called the guard band, which serves to prevent interference from adjacent channels. For police radios in the low-band, the present assignments are spaced 20 kHz* apart, in the VHF high-band the spacing is 15 kHz, while for the 450 MHz UHF-band it is 25 kHz.

> **In summary,** radio waves are the means by which radio messages are conveyed. These radio waves occupy a narrow band of frequencies. Certain channels have been made available within a group of frequencies allocated by the FCC for use by the various police departments around the country. These groups of frequencies are also part of a much larger group which also convey information such as television pictures and sound, and AM and FM radio broadcasts. All these frequencies are often referred to as the radio frequency spectrum. The bands, or portions of the spectrum, most used by police radio systems are the VHF high-band, which extends from about 154 MHz to 159 MHz, and the portion of the UHF band, which extends from about 453 MHz to 465 MHz. Each individual channel consists of a range of frequencies with center frequencies 15 kHz apart in the VHF high-band and 25 kHz apart in the UHF-band. Radio channels located in these bands are popular since they provide the best and most efficient coverage of an area.

Funding and Fiscal Planning

The primary source of revenue for municipal police departments is local taxation. The police department must compete with other municipal services for the limited funds, and within itself, the needs of the telecommunication system must be weighed with the other needs of the department.

*kHz is the abbreviation for kiloHertz, one thousand Hertz or one thousand cycles per second.

With limited funds, it is necessary to determine what allocation of those funds will result in the most effective law enforcement service to the community. Unlike an industrial firm where both the cost and return can be measured in dollars, a police department does not have a simple, single, overall measure of effectiveness. It is therefore difficult to define how to justify expenditures. Some sort of justification is required, however, by any good budget procedure.

A budget for the telecommunication system includes operating expenses and capital expenditures (including costs of planning and implementing system improvements). Operating expenses include staff salaries (supervisor or director, complaint clerks, dispatchers, radio technicians, etc.); utility costs (such as electric power and telephone services); leased alarm system lines and teletypewriter rental; costs of office supplies and radio parts; and costs of equipment maintenance and repair.

Requests for capital expenditures or expanded operating capabilities are the more difficult part of budget preparation. Typically, local government officials must review these requests; however, they are rarely knowledgeable in the area of police telecommunications. The department must be sure that the requests they make for funds are justified fiscal representations of their needs. The requests must be stated clearly to allow the government officials to make sound decisions. The preparation and presentation of a budget is a time consuming task, requiring knowledge of the entire department's operations. For all but very small departments, delegating responsibility for budget matters to a specific individual may be the most efficient way to obtain well-drawn budgets.

Recently, other sources of funds have become available for specific purposes. The primary source of interest to police communicators is the Law Enforcement Assistance Administration (LEAA), created by the Omnibus Crime Control and Safe Streets Act of 1968. Another source is the National Highway Safety Program which was created by the Highway Safety Act of 1966. While law enforcement agencies and communication systems are not the prime recipients for funds from this latter program, some aspects of it include improvement of highway safety related police communications.

In establishing LEAA, Congress decided that crime was primarily a state and local problem and therefore the major responsibility for meeting it should not rest with the federal government. The principal focus of LEAA activity thus came to be the administration of block action grants to the states. These are called block grants because they are allocated to the states on the basis of population. They are called action grants because they are designed to implement the plans which states have already made. These plans are drawn up by state planning agencies (SPAs) which were established with LEAA planning funds and which are maintained by LEAA planning grants. The state plans call for comprehensive improvement in the criminal justice system within the state. When LEAA has approved a comprehensive state plan, the state is eligible to receive its full block action grant.

The first grant LEAA gives to a state is a planning grant, either to establish or to maintain a state planning agency (SPA) which has the responsibility to draw up a comprehensive plan. After that plan has been approved, the state may receive the full amount of its state block action grant to implement the program. In order to meet necessary needs which might not come under planning or block action grants, Congress also authorized LEAA to give discretionary grants. These are action grants given at LEAA's discretion to states, cities or other agencies.

The Omnibus Crime Control and Safe Streets Act requires that state plans should "incorporate innovations and advanced techniques and contain a comprehensive outline of priorities for the improvement and coordination of all aspects of law enforcement." It also requires that state plans assure that federal funds will not supplant state or local funds, but will increase the amount of such funds to be made available in accordance with various matching formulas. For most programs in fiscal year 1970, the formula required that 60 percent of the cost consist of federal funds and that 40 percent be borne by local (state, regional, county, municipal) funds. (Exceptions were programs dealing with civil disorder and organized crime, in which case the federal share was 75 percent, and construction projects, in which case the federal limit was 50 percent.) In fiscal year 1971, most programs require the non-federal governmental units to bear only 25 percent of the cost. Block grant support makes up 85 percent of all LEAA action funds. The remaining 15 percent of action funds is earmarked for discretionary grants by LEAA. Finally, each state must make at least 75 percent of its LEAA action funds available to local governments. Cities and counties seeking block grant funds must file application with their State Planning Agency or regional branch.

The federal reimbursement funds of the Highway Safety Act are also administered by the states. According to the Act, each state shall have a highway safety program, approved by the National Highway Safety Bureau, designed to reduce traffic accidents and deaths, injuries and property damage. At least 40 percent of the funds available to a state are allocated to municipalities and counties. Municipal and county projects are incorporated into the state Highway Safety Program.

Projects related to police communication include developing:

- Requirements for coordination of ambulances and other emergency care systems
- Procedures for dispatching aid
- Procedures for reporting hazardous highway conditions
- Communication procedures to coordinate detection, notification, dispatch, and response for hazard control and cleanup

Requests for funding under both acts must meet requirements of the state and federal programs. Developing programs and establishing justification to utilize these funds requires considerable time and effort. Police departments and other municipal and county agencies have often found it necessary to assign this responsibility to specific planning personnel in order to enable them to take full advantage of the opportunities presented by these programs. Smaller communities and departments may not be able to assign the major portion of one person's time to this task. They may then find it helpful to coordinate these efforts with other communities and agencies.

Standards and Specifications

A necessary and important step in the development of any part or all of a police telecommunication system is the preparation and use of performance standards and equipment specifications. The quality of the standards and specifications used to purchase equipment will play a significant role in determining the effectiveness of the communication system established. As with budget preparation, writing standards and specifications is a time consuming and difficult task. The burden can be eased by drawing upon the experience of other agencies in previous procurements. Effort expended in this area will pay big dividends in the final results.

Summary

A police telecommunication system must effectively handle four basic types of communication: (1) between citizen and police department, (2) among members of the police department, (3) between any two or more police departments, and (4) between the police department and other agencies. Any police telecommunication system will consist of the public telephone system, a two-way radio network, and often access to a data transmission or teletypewriter network.

The two-way radio network is most often a one- or two-frequency simplex system, or a two-frequency half-duplex system. Multi-channel systems are often found in larger cities. Two-frequency systems are often found where there are adjacent communities whose radio transmissions might interfere with one another if the single-frequency system were used; they are required for all UHF systems. Repeater stations are found where the service area is large, contains irregular terrain or where extended coverage is required for personal portable radios.

The basic equipment found in all of these systems is the headquarters transmitter, receiver, antenna assembly, antenna tower and control console, as well as the mobile and portable transmitters and receivers for men in the field. The quantity and complexity of this equipment in any system is dependent on the size of the department and the nature of its workload.

All communications must be conveyed to the intended recipient both correctly and with minimum delay, especially in emergencies. This objective must be fulfilled within the economic restraints imposed by the community and the legal restraints imposed by the Federal Communications Commission.

CHAPTER IV

ELEMENTS OF POLICE TELECOMMUNICATION SYSTEMS

A police telecommunication system consists of three kinds of elements—certain intangible and operational elements such as frequencies, network structures and message flow; the equipment in the system; and the personnel that operate and use it. The first kind is discussed in Section IV.1, Operational Elements. The discussion of equipment is separated into various categories in Section IV.2 to IV.4. Personnel, their qualifications and training are discussed in Section IV.5. The way these separate elements are fused into a complete system, the methods used to evaluate a system and then modify it, or to design a new one are presented in the chapters that follow.

The heart of a police telecommunication system is the base-mobile radio system by which headquarters personnel and officers in the field maintain communication with each other. The telephone and data transmission systems that are part of a police telecommunication system are equally necessary to enable a department to carry out all its functions. Modifying or designing the total system, however, generally requires fewer technical decisions to be made about these two subsystems than about the two-way radio subsystem. Therefore, the discussion of the radio system presented here is more detailed than that for the telephone and data transmission systems. These latter two are treated in Section IV.2.7 and IV.2.8 of this chapter, and Section V.1.5 of the next chapter.

IV.1 Operational Elements

Radio signals transfer information from one point to another by means of electromagnetic waves. These waves have a number of characteristic properties that enable them to be employed as radio signals. Those of primary concern to us here are their frequency and power (or energy contents).

IV.1.1 Frequencies, Channels and Radio Communication

Electromagnetic waves are familiar to us as broadcast radio and television signals, radiant heat, light and x-rays. All are manifestations of electromagnetic waves that transfer energy and information over a distance. One of the basic differences between these various forms of electromagnetic waves is their frequency. The totality of frequencies of such waves is called the electromagnetic spectrum (or just spectrum). The police radio systems we are concerned with occupy a very small part of the lower portion of the radio

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spectrum. In particular, the Police Radio Service uses some of the frequencies in the ranges listed in Table IV-1. It has exclusive use of some of the frequencies in these ranges, but shares the range from 72.02 to 76.00 MHz*, the 450 MHz band and the microwave frequencies with other radio services. The VHF high-band and 450 MHz band are used more extensively by municipal and county systems than the other bands, because radio waves at those frequencies have desirable propagation characteristics. In brief, a limited area can be covered by radio signals at these frequencies more completely, but without causing as much interference outside the desired area as frequencies in the other bands.

Frequency assignments in the MF-band and the VHF low-band (see Table IV-1) are not preferred for municipal and county radio systems because of their propagation characteristics. In both bands signals are subject to "skip", resulting in strong signals appearing at great

Table IV-1

Spectrum Ranges Containing Police Radio Frequencies

Frequency Range	Designation	Band	Use
MHz	(See footnotes for abbreviations)		
1.610 – 2.812	–	MF	Base, mobile, zone and interzone
5.135 – 7.935	–	HF	Zone and interzone
37.02 – 46.02	VHF low-band	VHF	Base and mobile
72.02 – 76.00	–	VHF	Operational fixed
154.650 – 159.210	VHF high-band or 150 MHz-band	VHF	Base and mobile
453.050 – 465.500	UHF or 450 MHz-band	UHF	Base and mobile
952 – 40,000	Microwave	UHF, SHF and EHF	Base, mobile, operational fixed and radiolocation

MF Medium-frequency (0.3–3.0 MHz)
HF High-frequency (3.0–30.0 MHz)
VHF Very-high frequency (30.0–300.0 MHz)
UHF Ultra-high frequency (300.0–3000.0 MHz)
SHF Super-high-frequency (3000.0–30,000 MHz)
EHF Extremely-high-frequency (30,000–300,000 MHz)

*MHz is the abbreviation for megaHertz, the technical designation for one million cycles per second.

distances from the transmitter. This can cause serious interference problems to distant systems operating at these frequencies. In both bands confining coverage to a limited area is more difficult than in the higher frequency bands, even when skip is not a factor. That makes these frequencies useful in systems covering large areas. For this reason frequencies in the VHF low-band are often used by state-wide agencies such as state police and highway patrol departments. Only a few police agencies still use frequencies in the MF-band for base-mobile operations. Their proximity to the AM broadcast band makes police calls on these frequencies easy for the public to monitor. That, and their unfavorable noise and interference characteristics have caused most police departments to seek assignments in the VHF or UHF bands for base-mobile systems. The police radio frequencies in the HF band are restricted to Morse code transmission for zone and interzone communication.

Another propagation characteristic limits the usefulness of microwave frequencies for base-mobile operations. Radio waves at these frequencies begin to take on an attribute commonly observed in the behavior of light waves. Large objects, such as buildings, cast definite shadows. In an urban area, coverage of all locations becomes more difficult. Further, little, if any, commercial two-way mobile radio equipment has been developed at microwave frequencies. This has confined their use mainly to fixed station (microwave relay) and traffic law enforcement with radar speed monitoring units.

In order for a radio signal to contain information it must consist of a band of frequencies; that is, a certain amount of frequency spectrum. The amount of spectrum occupied by a signal is called its *bandwidth.* The nominal bandwidth for radio signals in the land-mobile service is 20 kHz*. For FM voice signals the maximum authorized frequency deviation** is 5 kHz on either side of the center frequency. The frequency assignments are called *channels.* They consist of a band of frequencies wide enough for the transmission of the information being conveyed, and a small amount of buffer spectrum space, called the guard band. This serves to prevent interference from adjacent channels. In the Police and Local Government Radio Services, low-band frequency assignments are spaced 20 kHz apart. In the high-band the spacing is 15 kHz, while at UHF it is 25 kHz. Thus, two adjacent channels in the high-band cannot carry 20 kHz wide signals without some overlap. If the signal strengths in the adjacent channels are comparable at the intended receivers, the receivers will most likely experience interference. Adjacent channel assignments at high-band must therefore be made with sufficient geographic separation (or other precautions) to prevent this kind of interference.

*kHz is the abbreviation for kiloHertz, which is one thousand cycles per second.

**Frequency deviation of an FM signal is the change in the carrier frequency produced by the modulating signal.

Frequency assignment in the land-mobile services is a difficult task, because in many areas of the U.S. and in most services, there are more users than can be readily accommodated in the spectrum space available. This is particularly true for the Police Radio Service in and near metropolitan areas.[1,2,3] The FCC, which issues the licenses and which has the ultimate authority over frequency allocation and assignment, has enlisted the aid of user groups in various land-mobile services to coordinate the assignments in a given service and geographical area. In the Police and Local Government Radio Services, the Associated Public Safety Communications Officers, Inc. (APCO) performs this function through designated frequency coordinators and frequency advisory committees. Its function is to coordinate applications both for new licenses and for license modifications (involving power and antenna height) with existing frequency assignments, and to advise the FCC and the applicant by making a recommendation in each case. The names of the frequency coordinator and chairman of the Frequency Advisory Committee can be obtained from the local APCO chapter or the national chairman.

IV.1.2 Radio Propagation, Transmitted Power and Antennas, Receivers and Squelch

Fundamental to any police telecommunication system are the basic concepts which help to explain the actual transmission, propagation and reception of the radio frequency signals by which messages are sent. The treatment of these subjects here is introductory. For detailed treatment of the concepts discussed, refer to Appendix A.

In any radio communication system it is necessary that at least a certain minimum signal level be present at the receivers. This is required independent of location within the operating area of the users. Since it is neither economically nor legally permissible to use excessive transmitter power, estimates must be made of the minimum power necessary to reach the most remote points of the area. These estimates can be made by calculating the approximate propagation loss suffered by the signal between the transmitter and the receiver at the most remote points of the system's service area. The propagation loss and the minimum amount of power acceptable at the receiver can then be related to the required transmitter power. There are several methods available to approximately determine propagation losses. These losses are mainly dependent on:

- The radio frequency used
- The type of terrain and buildings in the area
- The heights of the transmitting and receiving antennas

Calculating propagation loss can only give approximate results. An engineering survey is usually required before system parameters are finally chosen. Propagation losses are only one part of the "losses" and "gains" of power which exist in a radio system, as shown in Fig. IV-1. In particular, power gains usually occur in the following places:

- The radio transmitter
- The transmitter antenna
- The receiver antenna

and power losses usually occur in:

- The transmitter transmission line to the antenna
- The mismatch between the transmission line and the transmitter antenna
- The propagation to the receiver
- The mismatch between the receiver antenna and receiver transmission line
- The receiver transmission line from the antenna
- Radio Frequency (RF) cavities and filters, duplexers and isolation elements

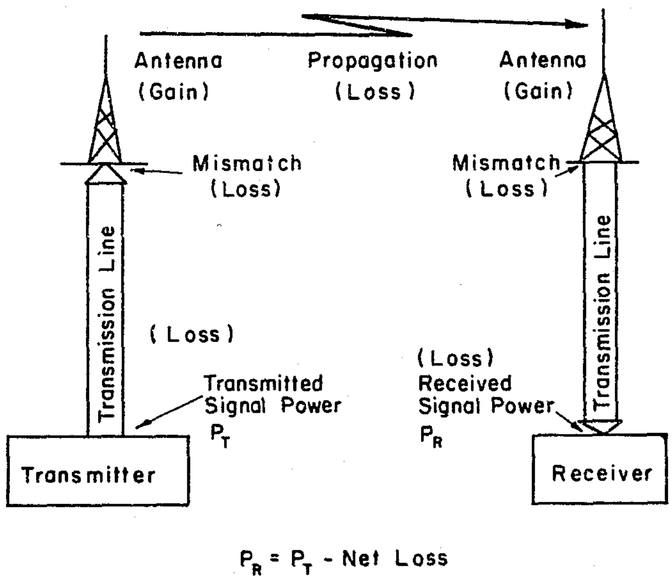

Fig. IV-1 Gains and Losses in a Radio System

All of these losses and gains must be considered in determining the *total* or net loss in power between the transmitter and the receiver.

Transmitting and receiving antenna gain is usually specified relative to a standard antenna, a half-wave dipole. By restricting their ability to transmit and receive in certain directions, certain antennas display an effective gain over the half-wave dipole because they concentrate their transmitted or received energy in certain directions. The direction of this concentration is usually along a horizontal plane for base-mobile systems since most mobile units are located on the ground. (Aircraft units are the obvious, but rare, exception.) There is a practical limit to maximum achievable antenna gain because of restrictions on antenna size. The allowable size of an antenna must take into account factors such as FCC regulations and structural ruggedness.

It is common to speak of the "effective radiated power" (ERP) of a radio station. This is the power that actually leaves the antenna. It is *not* the same as the radio frequency power of the transmitter itself, since losses occur in the transmission line to the antenna and from the lack of exact matching to the antenna. Further, a gain usually occurs in the antenna itself. Thus, the net power emitted by the antenna, the effective radiated power, may be either higher or lower than the radio frequency power generated by the transmitter itself.

The propagation losses in the signal between the transmitter and the receiver cause the signal power at the receiver to have a very small magnitude, unless the distance between them is small. All receivers have a power level threshold below which their output is not intelligible. This threshold is referred to as the *receiver sensitivity*. Radio noise from such sources as auto ignitions, electric motors and natural sources (called *ambient noise*), or interfering signals from other radio stations often exist at power levels above receiver sensitivities. The received signal power usually must be greater than these interfering signals in order for the receiver output to be intelligible. In general, a receiver rejects signals which have different frequencies than the desired signal. When the interfering signals have the same or nearly the same frequency, in-band interference results. In FM receivers, when the desired signal is stronger than the interfering signals by a given ratio, called the *capture ratio,* the desired signal may often be received in spite of the in-band interference.

Improving the coverage over the area to be served by the existing system can be accomplished in five possible ways:

- Change the transmitter power or the receiver sensitivity
- Change the height of the base station antennas
- Change the gain of the base station antennas
- Reduce any system transmission line losses
- Move the transmitter antenna site

The first two improvements are usually restricted by legal (FCC, FAA, etc.) and economic factors. Limits in transmitter power are often imposed by the FCC. Costs involved in improving receiver sensitivities or raising an antenna can be excessive. Increasing the gain of the antenna and reducing system losses, especially losses in the transmission line between the transmitter and antenna provide the most economical way of increasing coverage. This can be accomplished using improved antenna designs or special low loss cables.

IV.1.3 Network Organization

There are a number of different channel and network configurations which can be used in police telecommunication systems. As an introduction to a detailed description of this subject given in Chapter V and to better understand some discussion given in this chapter, the basic configurations will be presented here.

IV.1.3.1 Channel Configurations

The word *channel* as used in police base-mobile telecommunications has two definitions which should be understood at the outset. In the first, a channel is a certain, single portion of radio spectrum assigned to a user for his messages. The second meaning arises from the fact that many base-mobile systems use one channel (as just defined) for the base station transmissions and a separate channel (or more than one) for the mobile unit transmissions. In such systems, this combination is also called a *channel*.* Thus, in general, all of the slices of spectrum needed to carry on two-way communication, taken together, are called a channel. Ordinarily, no confusion results since the meaning intended is usually clear from the context. It is also common to use the words *frequency* and *channel* interchangeably, where here the first definition of channel is intended, and the frequency referred to is the center frequency of the channel. The common channel configurations in police radio telecommunications are:

> *Single-frequency, One-way Operation*—permitting transmission of information from user A to B, but not vice versa.
>
> *Single-frequency, Simplex Operation*—permitting transmission from A to B or from B to A, but not in both directions simultaneously, and using the same frequency in both directions.
>
> *Two-frequency, Simplex Operation*—permitting transmission from A to B or from B to A on two distinct frequencies, but not in both directions simultaneously.

*In the Phase Two, Project Three reports of the APCO Project Series Foundation, the term "link" was used to designate a two-way information path consisting of one or more single-frequency band channels.[4,5]

Two-frequency, Duplex Operation—permitting transmission from A to B or from B to A on two distinct frequencies, and simultaneously in both directions.

Two-frequency, Half-Duplex Operation—permitting transmission from A to B or from B to A on two distinct frequencies, and simultaneously at the base end of the link, but not simultaneously at the mobile end.

In order to more clearly visualize these definitions, a diagram of a generalized base-mobile communications channel is presented in Fig. IV-2. The channel consists of a base frequency and a mobile frequency, each with its own transmitting and receiving equipment. In a two-frequency channel, the base and mobile frequencies, f_1 and f_2, are different. A single-frequency channel uses a common frequency for the base and mobiles and consequently f_1 and f_2 are the same in that case.

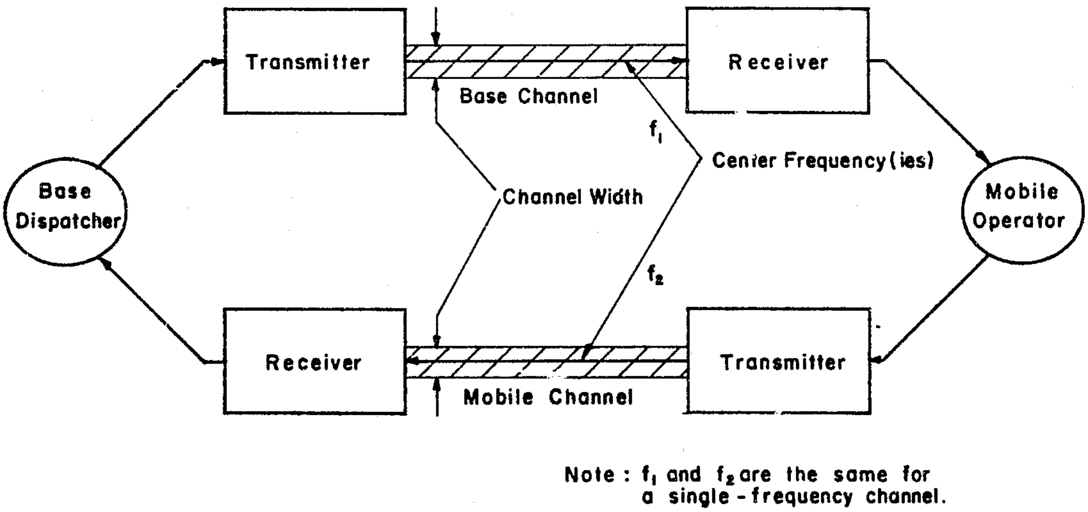

Fig. IV-2 A Base-Mobile Communications Channel

IV.1.3.2 Network Configurations

A network in general is defined as a collection of several radio channels operated by one or more departments in a coordinated fashion to provide radio service in a certain area. The size and degree of formal organization of police radio networks varies widely. Many networks have been formed as a result of unstructured evolutionary growth and exhibit little cooperation between users. Others are highly organized and have strong cooperation between users.

A network is a complex sys...n composed of many pieces of equipment and many persons working together to fulfill the communication needs of the departments within the network. Examination of network structures, however, yields the following basic factors which roughly characterize them:

1. Location of the dispatching points
2. Location of the base station radio equipments
3. The number of frequencies in each channel
4. The number of channels in the network
5. The operation of the channels which make up the network

In general, one can consider each of the factors to be more or less independent of the others. For each, there exists a pair of trade-offs which one considers when building up a network. These trade-offs are the following pairs:

1. Dispersed or central location of dispatching points
2. Dispersed or central location of base station equipment
3. Single or multi-frequency channels
4. Single or multi-channel networks
5. Simplex or duplex operation of the channels

These trade-offs can be combined to give twenty-four basic network configurations. Experience has shown that certain of these configurations are superior to others in serving the needs of a given department or group of departments. Networks can best be compared to each other by examining the following:

- The types of interference to which the network is susceptible
- The available methods of channel "isolation" to prevent interference within the network
- The performance under heavy message loads
- The radio coverage characteristics
- The existence or nonexistence of mobile-to-mobile and base-to-base communications in the network
- The possibility of using special devices (such as radio teleprinters) within the network

The network for any particular area is the one which provides the most effective service in view of the particular advantages and disadvantages of each configuration. Detailed discussion of typical successful system configurations can be found in Chapter V, Section V.2.

IV.2 Fixed Equipment

A variety of equipment designed for use at a fixed location is employed in police telecommunication systems. Fixed location two-way radio equipment includes base-station transmitters, receivers, antennas, towers and control units; remote repeaters; and microwave systems. Communication with the public is usually maintained by means of the public telephone system. Another device, the teletypewriter, is used in communication between public-safety agencies. It is also used for the retrieval of information from computerized data banks and for the transfer of information to teleprinter equipped vehicles. Finally, because every telecommunication system requires electric power for operation, an emergency power supply should always be included in the system.

IV.2.1 Base Station Two-Way Radio

A base station includes a radio transmitter and one or more radio receivers. These are permanently installed at a fixed location such as a police station. The primary purpose of the base station is to provide the police dispatcher with a means of sending and receiving information from the mobile units. The base station is also used for point-to-point communication with other police and public safety agencies.

Two types of messages may be handled by the base station—voice and data. Either one may consist of analog or digital signals. Digital messages occur in systems which employ equipment such as teletypewriters, teleprinters, and computer terminals.

Base-station radio equipment varies widely in physical appearance. The transmitter and receiver may be mounted in the same housing or may be completely separate. Receivers tend to be smaller and more uniform in size than transmitters; they are usually about the size of a typewriter or smaller. The size of a transmitter depends mainly on its power rating. Some of the low-power units may be no larger than a common table radio while a high power unit may occupy a rack about two-feet wide and seven feet high. Equipment sizes also depend upon the type of circuitry used—whether vacuum tube or solid state. Solid state circuitry, which employs transistors and other semiconductor devices, allows significant reduction in size over vacuum tube circuitry. Low-powered base-station transmitters and most receivers are often small enough for desk-top operation. High-powered transmitters, however, generally stand on the floor or are mounted on a wall or a pole.

Almost all police radio systems employ frequency modulation (FM) equipment. Commercially manufactured FM base-station equipment is available for operation in the low-band, high-band, and UHF *band. The FCC requires that communications in these bands be confined to assigned channels in order to minimize interference among users. Transmitters and receivers designed for use in these bands operate only on the assigned channels. They cannot be tuned in the manner that one tunes an AM or FM broadcast receiver, because crystals are used in frequency generating circuits; the equipment is often referred to as crystal-controlled. Base station radio equipment is produced with both single- and multiple-channel capabilities. A multiple-channel transmitter or receiver is able to operate on any one of several channels at a time—all of the channels being contained in the same frequency band.*

Figure IV-3 shows a base station two-way radio designed for desk-top operation. The radio cabinet houses both the transmitter and the receiver. A desk stand microphone is

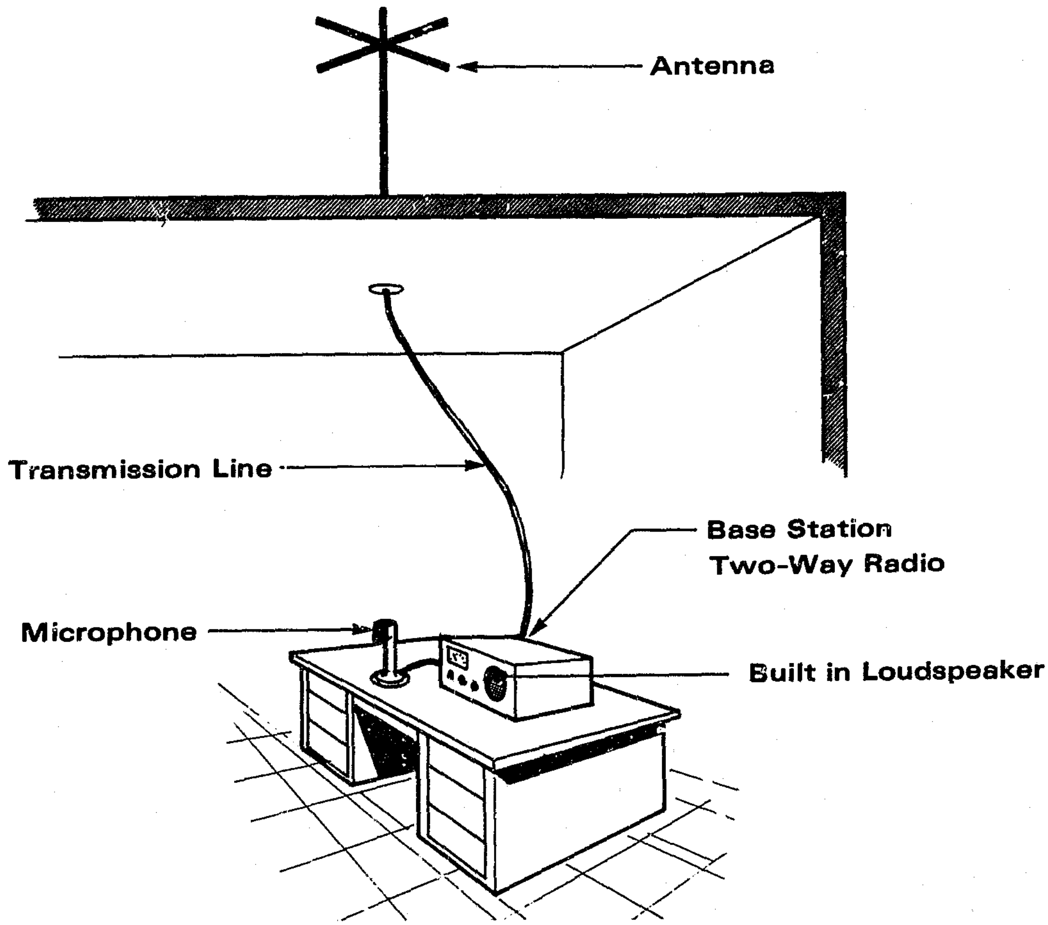

Fig. IV-3 Typical Small Base Station

shown next to the radio. The receiver loudspeaker is built into the radio cabinet. Every radio station requires an antenna that functions for both transmission and reception, and this is shown on top of the roof.

The operation of the base station is explained by reference to Fig. IV-4, which shows a functional block diagram of the system. When the operator presses the push-to-talk switch on the microphone (not shown) he activates the transmitter and may disable the receiver. He then speaks into the microphone which converts sound waves into an electrical voice signal. The strength of the voice signal is increased (amplified) by the audio amplifier, processed and fed to the modulator. Also fed to the modulator is a radio frequency (RF) signal at frequency F1, which is produced by a crystal-controlled oscillator. The transmitter shown has two channel capability and therefore a second oscillator at frequency*

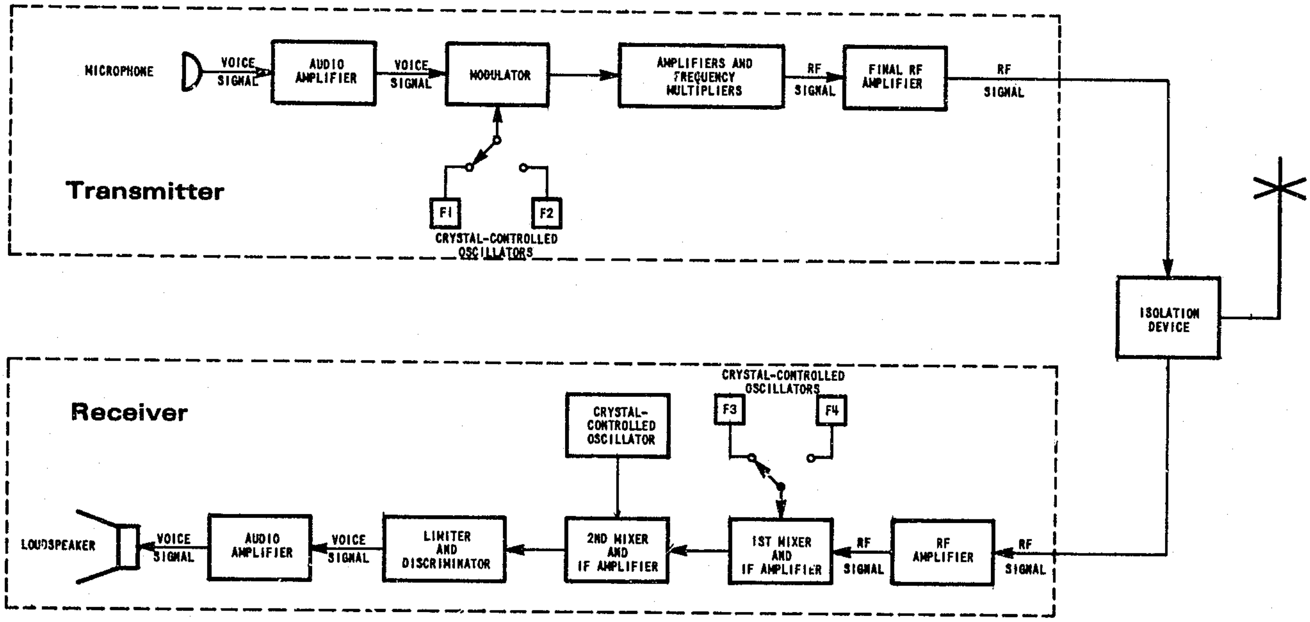

Fig. IV-4 Base Station Two-Way Radio

*The voice signal is pre-emphasized and passed through a peak limiting and filtering network.

F2 is indicated. Transmission can occur on only one channel at a time and only one oscillator or the other operates at a time. The oscillator frequencies F1 and F2 are many times higher than any frequency in the voice signal.

The modulator causes the frequency of the oscillator signal to vary with the amplitude of the voice signal. The modulator output is then amplified in strength and multiplied in frequency to a frequency which is suitable for transmission. Next, this RF signal goes to the final RF amplifier, which significantly increases the signal power level, and then through the isolation device to the antenna which radiates it into space. The isolation device may be an antenna relay, solid state switch, or duplexer. Its purpose is to allow one antenna to be shared by both the transmitter and receiver without damage to the sensitive receiver input circuitry from the relatively powerful transmitter output.

When the operator releases the push-to-talk switch on the microphone, he activates the receiver and disables the transmitter. A large number of signals picked up by the antenna are fed through the isolation device to the input of the RF amplifier. The RF amplifier contains filters which reject most of the undesired signals and accept those in the desired frequency range, which are amplified. The output is fed to the first mixer and intermediate frequency (IF) amplifier, where the signal frequency is lowered to a value more suitable for processing and then amplified. Additional filtering also occurs in the IF amplifier. The mixing process requires a signal with precisely controlled frequency, produced by a crystal-controlled oscillator. Another oscillator is shown, and is used when operation on another channel is desired.

The output of the first IF amplifier goes to a second mixer, IF amplifier, and associated oscillator where the signal frequency is lowered still more and where additional amplification and filtering occurs. The signal from the second IF amplifier is then fed to the limiter and discriminator which convert the frequency variations in the signal back into the amplitude variations of a voice signal. The signal is de-emphasized and the audio amplifier next increases the power level of the voice signal, which is used to operate a loudspeaker. The loudspeaker converts the *electrical voice signal back into sound waves which are heard by the operator.*

The emission bandwidth of FM transmitters used in the low, high, or UHF bands is limited by the FCC to a maximum of 20 kHz. In other words, the frequencies which are generated by the transmitter and have appreciable amplitude must fall within this 20 kHz channel. Frequencies which are generated outside of this channel, on either side, must be reduced in amplitude. Receivers, on the other hand, must be most sensitive to frequencies within the 20 kHz channel. Frequencies on either side must be rejected. This means, in effect, that an adjacent channel signal will not be heard at the receiver output. This receiver characteristic is referred to as adjacent channel selectivity.

Receiver sensitivities are generally better than 0.7 μV for a 12 dB** signal plus noise and distortion-to-noise and distortion ratio, referred to as SINAD ratio. This means that a signal of at least 0.7 μV in amplitude at the receiver antenna terminals is necessary to produce a clear, or readable, audio output. With typical adjacent channel selectivities of 70 dB, signals with amplitudes about 3000 times larger in the adjacent channels will not be heard; i.e., they will be rejected.*

Base-station transmitters are manufactured with a large selection of radio frequency (RF) power ratings. Limitations on transmitter power are imposed by the FCC in order to minimize interference among users of the frequency bands. The limitations are stated in terms of the power input to the final RF stage of the transmitter. This final RF stage is commonly the vacuum tube or semiconductor amplifier circuit whose output goes directly to the antenna. Specifically, the limitations are 500 watts for low-band units and 600 watts for high-and UHF-band units at operating frequencies less than 460 MHz. For frequencies greater than 460 MHz, the maximum power input is specified in the station's FCC authorization. However, special authorization may be obtained from the FCC to operate at higher power levels. For example, some state police low-band transmitters operate with 10,000 watts of power input to the final RF stage. The power figures just discussed are upper limits and not necessarily common values. Base-station transmitters are available with final RF stage power inputs of only one or two watts. Finally, transmitter power output is less than power input since the efficiency is usually about 65 percent or less.

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*"μV" is the abbreviation for microvolts or 10^{-6} volts. Thus, 0.7μV is 0.0000007 volts.
**"dB" is the abbreviation for decibels (see Glossary).

The FCC assigns frequencies to various base stations within a geographical area depending upon the limitation of RF power outputs to certain levels. When these levels are exceeded, the transmitted signal may be strong enough to obscure signals in other geographical areas. FCC regulations state that:

> *"The RF power output of a station shall be no more than required for satisfactory technical operation considering the area to be covered and the local conditions."*

In the interests of preventing interference, adherence to the above regulation is imperative. Excessive RF power output level can cause interference, as can antennas with unnecessarily high power gain or height above the ground.

One feature which is standard on all base-station receivers is carrier squelch. The purpose of carrier squelch is to eliminate disturbing background noise when no transmitted signal is present, thus reducing operator fatigue.

Another type of squelch, usually offered as an option, is tone-coded squelch. A receiver equipped with tone-coded squelch is activated only by signals containing a specific tone or tone combination and not by other signals. By equipping the mobile transmitters with the proper tone generating circuits, only the mobile units of the desired system will be heard by the dispatcher. Base-station transmitters and mobile receivers may also be equipped for tone-coded squelch. Tone-coded squelch has certain disadvantages when used in police radio systems, however, and if not used properly, may lead to destructive interference among users of the channel. Detailed consideration is given to tone-coded squelch in Section IV.4.6 of this chapter.

IV.2.2 Base-Station Antennas

The base-station antenna is a device used to excite or radiate into space the radio frequency (RF) energy carrying the messages. It is also used to receive RF signals transmitted from mobile units. The antenna is a metal structure whose length depends upon the wavelength of the transmitted and received signals. Often, the height of the antenna relative to the surrounding terrain can affect the entire system performance. Normally, a higher antenna increases the area covered. Many times, the antenna is placed on a high point, such as the top of the police headquarters, or at a remote site such as a hilltop. The RF transmitter is located near the antenna and in the case of a remote site, the transmitter is controlled by a land line, or a separate radio or microwave link. An unmanned transmitter and receiver station may act as a repeater station, retransmitting the radio signals sent to it by both base

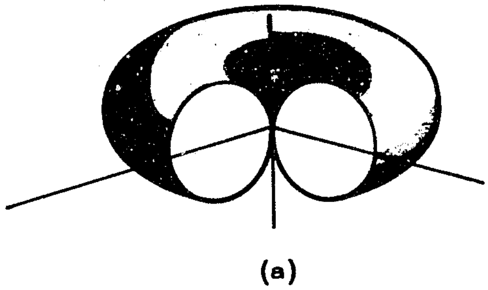

Fig. IV-5 Three Dimensional Sketches of The Radiation Patterns of (a) a Dipole Antenna (b) an Antenna with Directivity Gain

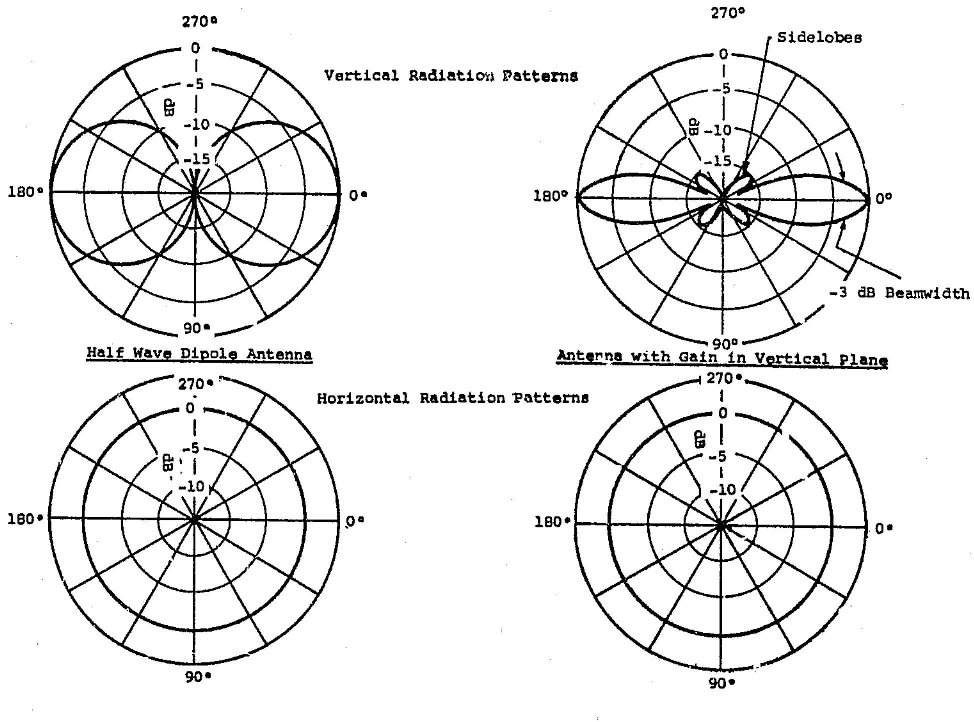

Fig. IV-6 Typical Principal Plane Radiation Patterns for a Half-Wave Dipole Antenna and for an Antenna Exhibiting Directivity Gain in the Vertical Plane stations and mobile units. The base-station antenna is usually centrally located in the service area. The radiation patterns of two types of antennas are shown in Figures IV-5 and IV-6. The pattern of a centrally located base-station antenna should be uniform (in the horizontal plane) in all directions, to achieve maximum coverage. The radiation pattern in the vertical plane is normally kept narrow, that is, squeezed into a doughnut shape, to achieve some gain in the horizontal direction. If the antenna is not centrally located, a suitable antenna type is used to make the radiation pattern more directional—that is, at a given distance from the antenna, the signal is stronger in the preferred direction than in others. By confining the RF energy to the intended service area the system can be operated more efficiently.

A proper impedance match between antenna and transmitter through the connecting transmission line is necessary for maximum operating efficiency. Normally, the characteristic impedance of the antenna, transmitter and line is 50 ohms.

Antenna length, as mentioned, is a function of the operating frequency. One antenna may, however, be required to handle several channels. Antenna dimensions must then be carefully chosen so that it will perform well on all channels used. The antenna must also be physically able to handle the maximum transmitted power.

Lastly, base-station antennas must perform their functions with little or no attention in every environment, in every type of weather condition. This affects primarily the antenna's physical characteristics, and the tower and support structure.

Beside the antennas used in normal police communication, special-purpose antenna systems exist for auxilliary system uses. Highly directional antennas are used in microwave point-to-point communication. These antennas are designed to provide pencil-like beams with narrow beamwidths both vertically and horizontally. This results in a high-gain antenna, suitable for use at higher frequencies. More complete information on base-station antenna specifications is found in Appendix A.

IV.2.3 Communication Control Equipment

In some police radio systems the dispatcher and the base station may be situated in two different rooms or even in different buildings. It is often desirable to place the transmitter in a separate room because of the heat which is generated during operation. Also, the base station should be located fairly close to the antenna to minimize RF-power losses in transmission lines which connect the receiver and transmitter to the antenna. Some systems employ several base stations and a number of dispatchers. This necessitates separate locations for radio equipment and operating personnel because of space limitations.

439-911 O - 71 - 5

All of the situations above require the use of special control equipment which enables the dispatcher to operate the base station from a separate location. There are three basic types of control units. The simplest type is the desk set, which is similar in appearance to an ordinary telephone and is designed for desk-top operation. Small control consoles are generally more elaborate than the desk set and are larger in size. Small control consoles are usually box-shaped and are small enough for desk-top operation; they also offer more control capabilities than desk-sets. The most elaborate type of control unit is the control console, which offers more extensive capabilities than either the desk set or the small, desk-top control console. A control console may consist of several control panels mounted side by side in a single housing and often includes a desk as part of the overall unit. In addition to standard production models, some companies build special control consoles on request to meet particular system requirements.

Desk sets, small and large control consoles may be interconnected with each other in various ways to allow several dispatchers to operate a base station without interfering with one another. There are basically two types of control, local control and remote control. A system may be locally controlled when less than 100 feet of cable are used to connect the base station with the most distant control point. A system must be remotely controlled when the base station and control point are separated by more than 100 feet. A telephone line is used rather than a cable for remote control.

Every system must have at least one "control point" from which the system can be turned on and off. In a system with several control units, the FCC requires that the control point be capable of taking over complete control of the base station. This is generally accomplished by means of a supervisory switch at the control point which can remove control from the other units. In a system with more than one remote control unit, FCC rules state that each control point must also have a transmit indicator which shows when the transmitter is being used. The FCC also requires that a station record and an identification card displaying station license information be kept at each control point.

IV.2.3.1 Control Unit Features and Options

Some typical features of the desk-set control unit are:

- Microphone and earphone mounted in a telephone type handset
- Audio volume control
- Multiple channel operation
- Compatibility with tone-coded squelch systems
- Intercommunication with other control units
- Transmit indicator
- Compression amplifier which compensates for varying voice levels among different operators and other adverse effects
- Line gain control for balancing parallel units

Small, desk-top control consoles have most of the desk-set features with some differences. Usually, the small control console microphone has its own stand and the speaker is mounted in the console housing. In addition, the small control console may have a time clock and a volume unit (VU) meter. The VU meter provides a visual indication of audio volume level.

There are numerous features and options available on control consoles. Besides those mentioned above, a control console's features may include:

- Control of several base stations
- Control of electric door locks, lights, and alarm systems
- Card files for frequently used information
- Tone encoder panels to provide selective calling of individual mobile units

IV.2.3.2 Communication Control Centers

Desk sets, small and large control consoles may be combined in various ways to form a communication control center of almost any level of complexity and sophistication desired. The communication control center is the hub of the police telecommunication system. It is the focal point to which citizens report emergencies and crimes and direct requests for assistance. All of the numerous activities of the field personnel are monitored, coordinated, and directed from the communication control center.

Communication control centers have different levels of complexity in response to the requirements of the individual police department. The number of mobile units and consequently the communications traffic generally increase with the size and population of the policed area.

All communication control centers include telephones and switching equipment for incoming emergency and routine business calls. Also, status boards for field personnel and illuminated map displays of the patrol area are usually provided. Other equipment which may be included in the communication control center are teletypewriters for communication with other agencies and for information retrieval from computerized data banks; tape recorders for logging telephone calls and radio traffic; closed circuit television (CCTV) for visually monitoring remote locations; and alarm indicators for automatic burglar and security alarm systems.

IV.2.4 Microwave Systems

There are many different types of communication systems in use by the police department today. For the most part, each system has been designed to meet the specific and often unique requirements of the individual police agency. Microwave systems for point-to-point communication are being used more and more. Microwave refers to electromagnetic waves in the higher frequency portion of the radio spectrum. Radio signals whose frequencies are above about 1000 MHz are referred to as microwaves.

Some microwave systems are used to establish radio communication between individual departments. Others serve as data transmission links between the police departments in a wide area and a central information storage and retrieval facility. Microwave systems are also used to link remotely located transmitter sites with the control and dispatching points. Operating frequencies of police microwave systems range from 960 MHz to about 12,000 MHz.

A simplified block diagram of a microwave line-of-sight system is shown in Fig. IV-7. The system shown consists of two terminal stations and one repeater station. Many police and municipal microwave systems are direct, however, and do not use any repeater stations. The stations each have a transmitter and receiver connected to the same antenna for two-way transmission. The repeater station (if there is one) has an antenna for two-way communication with each terminal station. The frequencies of the transmitted and received signals differ by a fixed amount, so that they can be readily separated.

Consider the operation of the system of Fig. IV-7. The input signals are in analog or digital form containing voice or data information. The system can transmit many such signals simultaneously. These are customarily assigned a channel number, as shown. The signal from each channel is fed into a circuit called a frequency-division multiplexer. This circuit

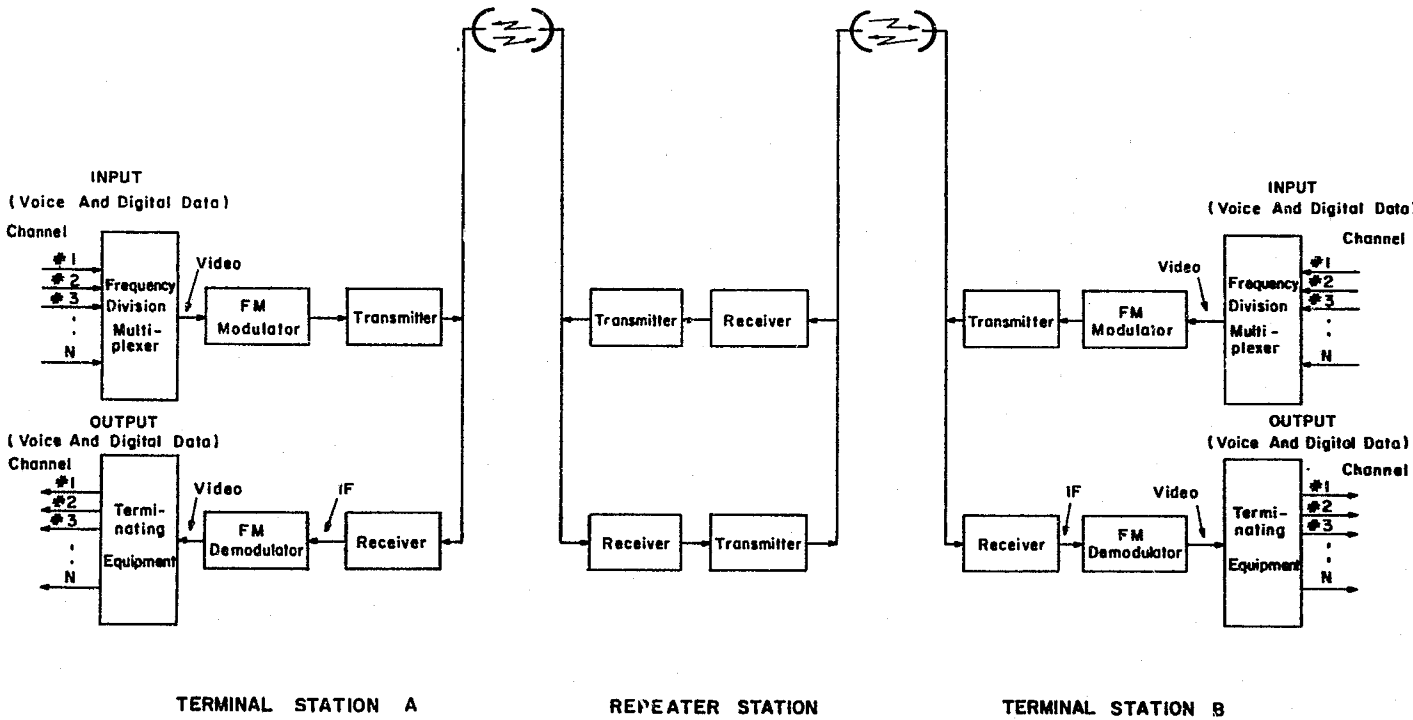

Fig. IV-7 Microwave System

combines all the channels into a single composite signal in such a way that the individual signals can later be separated again.*

The composite signal frequency-modulates a radio frequency (RF) signal. This signal is at a frequency somewhere between that of the video signal and the final microwave frequency. The transmitter changes the RF signal to the desired microwave frequency and amplifies it for radiation to the next station. The receiver at that station brings the signal down to the IF frequency for amplification. Its output is connected to another transmitter for radiation to the next station or to an FM receiver. The output from the receiver is connected to a demodulator which delivers a video signal to the terminating equipment.

The composite signal is then separated into its original channels. Voice information is heard by operators and data signals are translated by teletypewriters or other digital display devices into readable copy. If the microwave link is used to communicate with a remote mobile-relay station, some of the digital channels may merely activate controls on the station's conventional transmitters, while signals on the other channel modulate them for retransmission to mobile units.

The desirable characteristics of microwave repeater systems for police use are their ability to:

- Transmit many channels of information simultaneously
- Replace wire lines where these may be impractical or uneconomical
- Link together specific points by beaming signals only in the direction of the intended receiver
- Increase reliability of point-to-point communication

The design of a microwave relay system requires considerations somewhat different than those for the design of a VHF or UHF land-mobile radio system. In most cases system design begins with site selection and path design. The criteria for these, as well as the choice of directional antennas, transmitter power requirements and other related topics are discussed in Appendix B.

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*Microwave engineers often refer to this as the *video* signal.

IV.2.5 Teletypewriters and Teletypewriter Networks

A teletypewriter is a special kind of typewriter which is used for the transmission and reception of printed information. It encodes information typed on a keyboard into electrical signals for transmission and decodes such electrical signals on reception into printed messages. The coded electrical signals may be conveyed over a distance by means of telephone or telegraph lines or radio waves to achieve communication between two points.

Teletypewriters have been used by police agencies since the 1920's. In large cities teletypewriter networks link central and district stations together and also join the department with other public safety agencies. The types of information sent and received include bulletins on stolen property or missing persons, suspect descriptions, data on crimes such as robbery or burglary, automobile registration and drivers' license checks, details on hit-and-run and other traffic accidents, and messages of an administrative nature. Since all messages are recorded permanently on paper, accurate as well as fast conveyance of detailed information is provided. The standard teletypewriter transmission speed is about 100 words per minute, although higher speed equipment is available.

Present teletypewriter networks exist which are not limited to single cities but extend between cities and states. One such interstate network is LETS[6] (Law Enforcement Teletypewriter Service), which provides interconnection among locations from coast to coast. Headquarters for the network is located in Phoenix, Arizona. The Phoenix control center is designed to automatically route messages to their destinations. The control center switching equipment is capable of sending a single message simultaneously to multiple addresses, holding a message until a busy line becomes available, and giving transmission precedence to priority messages. Networks such as LETS provide means for the rapid transfer of essential information.

In addition to providing communications between law enforcement agencies, teletypewriter networks now form links between police departments and computerized information retrieval systems. One example is the FBI's National Crime Information Center (NCIC) which became operational in 1967. The goal of NCIC is "to place at law enforcement's disposal a computerized information system, national in scope, to complement the development of similar systems at local and State levels."[7] Low-speed leased telephone or telegraph circuits, capable of handling up to 135 words per minute, link each terminal agency directly to the center's computerized file. Direct and immediate communication with the NCIC computer is thus obtained, providing access to regional and state law enforcement agencies.

IV.2.6 Telephone Equipment

The telephone equipment component of the police telecommunication system must be tailored to the needs of the department. There is leased equipment available which can handle effectively just about any volume of calls anticipated. It should be noted that in some cases the type of equipment which exists at the telephone central office may restrict the use of certain types of equipment at the police headquarters. Hence, consultation with the telephone company is always needed when deciding on telephone equipment. Among many others, two subjects of importance concern design for overflow conditions and load control, so that the department retains some telephone capability during extreme emergencies such as earthquakes, severe storms, etc. The discussion here is limited to automatic or dial telephone exchange systems, found throughout the United States.

When a telephone line terminates at a station or telephone, it is known as a *station line* or *extension line*. When a line connects the central office equipment and the department's switchboard or individual stations, it is called a *trunk line*.

There are several types of lines available. There are, for example, the facilities available through the public *switched network* such as those found in most homes and offices. Another type of line commonly used by police departments is the *automatic private line*. With this line, whenever either station lifts its receiver, the other station is signalled (rung) automatically with no dialing. Such lines are used mainly for quick, dependable communication between headquarters and its district stations, the fire department, or other nearby police departments. Another type of line is the *push-button automatic private line* which is used to communicate between two or more specific telephone stations. Using this line, a key or button must be pushed in order to reach a specific station. Signalling is automatic upon lifting of the receiver. A related type of line is the *push-button—push-button private line* between two or more stations where one of a set of buttons may be pushed at each station to signal another station. Within the department itself, lines can be provided which serve as *intercommunicating lines* between users who are usually in the same building.

The particular type of telephone used at the dispatcher's or complaint clerk's location depends on the preference of the department and the people using the telephone. Ordinary desk telephones are often used, but many dispatchers find the use of headsets in place of the hand-held receiver more convenient, because it leaves their hands free. The telephone headset can be shared with the radio system, with the radio push-to-talk switch automatically selecting telephone or radio capability. Besides the standard-dial telephone, there are various modifications in dialing procedures presently available.

When several telephone lines are required, push-button or "key" telephones offer flexibility and a variety of uses valuable to effective handling of the telephone lines. Features available include pick-up and holding, intercommunication between lines, visual and audible signals, cutoff, exclusion, and signalling. Illuminated push-buttons on the telephone set give a visual indication of incoming calls, held lines, or busy lines. The hold key enables the user to hold any line picked up, if necessary. The cut-off and exclusion features can provide privacy or emergency override of other users on the line, by enabling the user to disconnect other extension telephones from the line. This is accomplished by relay equipment which cuts off other telephones upon lifting of the receiver.

When many lines are needed, a CALL-DIRECTOR* is sometimes used to answer calls at a common point or at appropriate extension phones. For larger telephone systems in police departments where switching is required, a Private Branch Exchange (PBX) system is used. A system called Centrex provides PBX stations with direct inward and outward dialing at all extensions without having to go through a PBX switchboard. It is comparable to having a private telephone for each extension. A three-digit exchange code is assigned to the Centrex system and all extensions are reached by dialing the additional four-digits of a standard telephone number. Under such systems, it is often less expensive to do the PBX switching at the central office (Centrex CO) rather than on the police department premises (Centrex CU), mainly because of maintenance considerations.

It is usually possible to consolidate the telephone equipment for the handling of emergency calls into the communication console, if desired. This is sometimes convenient from an operational viewpoint, because it reduces clutter at the console and the equipment can be arranged for the most convenient use.

Maintenance on the telephone equipment is almost always performed by the telephone company since the equipment is leased from them. Normally there is no charge for this maintenance above and beyond the monthly lease charges.

Police have always recognized the need for citizens to be able to reach the police quickly no matter where they are when an emergency arises. In 1968 it was proposed to implement a single, universal emergency telephone number throughout the country which citizens could use to reach the police, fire department, and other emergency agencies from wherever they might be.[8] The number "911" was chosen and, as of July, 1970, has since been implemented in 102 cities in 32 states.

*Registered service mark of the Bell System.

The call for help has to terminate at a point where responsive action can be initiated. That point, therefore, is going to serve all kinds of emergency services: police, fire, medical, and so forth. The selection of a point to receive emergency calls raises the problem of jurisdiction. This is, because telephone exchange boundaries oftentimes include several towns or cities, and also encompass areas served by different varieties of the same function having concurrent jurisdiction, such as state police, sheriff's departments and local agencies.

There are several ways in which the selection of an answering point could be accomplished. One way is to route any call dialed to the emergency number to telephone company operators, who would intercept the call promptly because it would appear as an emergency call, distinguished from other calls generally dialed to "operator". They would determine the location and nature of the request, and relay the call to the appropriate agency. This is the manner in which calls dialed to "999" in England are handled. This procedure is an improvement over the long standing "Dial 'operator'" approach, since some of the inordinate delays in reaching the operator are avoided. But, there remains the problem of the non-public safety interface between caller and action agency.

Telephone companies use several kinds of central office switching equipment. With some modification, these equipments can provide Automatic Number Identification & Centralized Automatic Message Accounting operation, primarily for billing purposes. The calling number is thus identified and recorded. About 25 cities are now served by operator Traffic Service Position Systems, which include the automatic display of the calling number for calls dialed to "operator".

It should be evident that if the number of the telephone the distressed citizen is using can be thus identified the location can also be immediately determined. That would help solve most of the jurisdiction problems. There is still a need to determine the type of emergency involved, but this is not nearly so difficult as the problem of finding the correct jurisdiction.

A computer is required to reconcile telephone numbers and addresses, and it would need continual updating as telephones are installed, disconnected, and so forth. Application of computer switching to this problem is certainly feasible. There would be a few minor exceptions, such as calls originating as off-premise PBX extensions, calls made at one location concerning an incident at another, etc., but for the most part, the knowledge of the specific location of the caller would be extremely valuable.

The question of who should answer the call remains. Experience to date indicates that most single-number emergency calls are for the police. For example, in Minneapolis-Hennepin

County, Minnesota, a seven digit emergency number serves most of the public-safety agencies. In November, 1967, 82% of the calls received were for police service, 13% for fires, 2% for sheriff, and 3% for medical and other miscellaneous services. In New York City, of the 13,000 calls per day dialed to the "emergency" number of 440-1234, about 200 are for fire service.

Short of "911" there are other services available from local telephone companies which can be useful. Included here are direct tie lines to central office toll boards. These allow incoming emergency police calls to be intercepted in the event that deliberate attempts are made to jam the published emergency numbers. Also, "called party hold" and "forced disconnect" features permit the complaint operator to hold the caller's telephone on the line to enable tracing and give him the ability to disconnect the caller's telephone from police circuits.

IV.2.7 Physical Security, Emergency Power, and Back-up Equipment

Three important considerations in maintaining the operating effectiveness of any police telecommunication system are physical security, emergency power, and back-up equipment. Communication equipment and personnel must be protected from either human or natural forces that might cause injury. Also, an alternate source of electrical power must be provided for emergency situations which may shut down the normal commercial power supply. Power outages due to downed power lines or generating equipment failures happen at one time or another to almost every electric utility. Lastly, communication equipment failures are generally unpredictable. Back-up equipment should consequently be provided for standby service.

Police communication must continue under all circumstances. The disruption of communication greatly increases the difficulty of performing law enforcement tasks. Without communication, for example, it is not possible for command personnel at headquarters to receive information from or give directions to officers in the field.

Experience has shown that groups dedicated to civil disorder recognize the importance of communication to police operations. This recognition is evidenced by attacks and bombings of police stations with the destruction or disabling of the communication facilities as the goal. Tactics such as the cutting of above-ground telephone lines or power cables to station buildings can have crippling effects on operations.

Disasters such as earthquakes, storms, floods, and fires may paralyze the telephone system. Power stations and transmission lines might be destroyed, or power may be shut off in a stricken area to prevent fires and accidents. The police are also called on to aid other public safety agencies and to make preliminary surveys to assess the extent of a disaster. Consequently, the need exists for protective measures to guard against injury to communication personnel and equipment and to insure a continuing supply of electrical power under a multitude of adverse circumstances.

Another requirement for reliable communications is back-up equipment for such essentials as the base-station transmitter and receiver. The failure of a component can occur at any time. Resulting complications may be avoided, however, if auxiliary radio gear is available for standby service until the regular equipment is repaired.

IV.2.7.1 Physical Security

There are a number of steps that can be taken to improve the physical security of communication personnel and equipment.

(1) *Telephone and Power Cables.* Telephone and power cables that are located above ground are easily accessible to individuals with destructive intentions. Greater protection from damage by severe storms or sabotage is furnished by buried cables. Consequently, telepone lines and power cables which service structures such as police stations, remote transmitter sites, and repeater installations should be run underneath rather than above ground level, whenever possible.

(2) *Antenna System.* Another possibly vulnerable link in the communication chain is the antenna system. Since proper operation requires that the antenna be mounted above ground level, it cannot be protected from damage in the same manner as telephone lines or power cables. Antenna damage might arise from severe weather conditions or intentional sabotage.

Severe weather conditions such as high winds, lightning, and icing must be considered in choosing an antenna structure. The structure, which includes the antenna and the supporting mast, tower, and/or guy wires, should be strong enough to withstand the highest velocity winds which might be encountered at the particular location. In some areas wind speeds in excess of 100 miles per hour may be expected at times and must be taken into account. In areas subjected to freezing temperatures, structural loading of the antenna resulting from ice formation must be guarded against.

One way to achieve security from intentional sabotage is to restrict access to the antenna system. Locating the antenna on the roof of, or close to, the police station has the advantage of providing convenient surveillance. When another location is necessary, access to the antenna should be restricted with measures such as fences and locked doors or gates. Where the assignment of personnel to guard the antenna system may not be feasible, electronic detectors and surveillance devices might be used.

Another factor to consider is lightning. If an antenna is struck by lightning, severe damage may result to both the antenna and the radio equipment connected to it unless the proper precautions are observed. The antenna support structure, if not already grounded, should be grounded by means of a number four or larger diameter wire connected to a grounding stake by the shortest possible path. If the antenna is on the roof of a building, the wire should be insulated from the roof by standoff supports.

The shield of the coaxial cable which feeds the antenna should be connected to the grounded antenna support, if the antenna is not the type that forms the connection by virtue of its design. Every other cable leading up to the antenna structure, such as the power cable for a light, should have a lightning arrester installed. All components should be grounded to a common point for best performance. The purpose of the arrester is to protect any equipment which is connected to the end of the cable.

(3) *Communication Personnel.* The security of the communication personnel is of the utmost importance. Sources of danger might be individuals or groups seeking to disrupt the communication function. Such disruption could result from an attack on the building which houses the communication center and conceivably might include the use of small arms fire and/or bombing. Extensive injury to the communication center and personnel may conceivably result from an explosive device such as a hand grenade, if uncontrolled access to the center is permitted. Several steps may be taken to insure the safety of communication personnel.

First, all prospective employees should be screened to eliminate the possibility of sabotage from within the department.

Next, access to the communication center should be restricted, so that only persons with proper authorization can enter the center. It is the policy of some police agencies to permit public viewing of communication center operations, the purpose of this policy being to foster good relations between the agency and the general public. Perhaps persons ought to be checked for weapons before being allowed near the communication center.

One method of protecting from external attack is to employ heavier than ordinary construction techniques in the building which houses the communication center. Steel shutters on windows offer protection from small arms fire and also increase the difficulty of throwing a grenade or bomb into the building. Another measure is to locate the communication center in the basement or underground, thus providing bomb shelter-like protection. In some cases, construction of underground tunnels connecting with other buildings may be needed.

Security measures should include preparation for events which might confine personnel to the communication center for more than the usual interval of time. It then becomes desirable for the center to be as self-contained as possible with regard to living and eating accommodations. Some kitchen facilities for the preparation and storage of food, first aid equipment for the treatment of minor wounds, rest and sanitary facilities should be provided to serve for a limited period of time.

IV.2.7.2 Emergency Power

For maximum reliability, a police communication center should not depend upon the commercial power company as the only source of electrical power. A continuing supply of electrical power may be insured, however, by equipping the communication center with a standby power plant. Normally, the standby plant does not operate. If a power blackout occurs, however, the standby plant is started, either automatically or manually, and takes over as the power source.

There are various types of generator sets suitable for communication center standby use. In general, they consist of an internal combustion engine mechanically coupled to an alternator. During operation, the engine develops mechanical power from the combustion of oil, gasoline, or gaseous fuel and drives the alternator which produces alternating current (AC) electricity. The selection of a generator set should include consideration of several factors--primarily, the expected power load.

It is necessary to ascertain types of circuits, starting currents, and generating practices to determine the size of an electric plant for standby. The power required for illumination is the total wattage of all emergency lighting circuits. Appliances, particularly motor driven equipment, must be added, taking into consideration the generator reserve needed to satisfy the heavy power demand when motors are started.

The standby plant should be capable of handling the essential load of the building. However, the plant need not supply the entire electrical load since it is unlikely that all equipment will be in use at one time. Non-essential appliances and lighting circuits can be disconnected during a power blackout. In new buildings electrical wiring plans should segregate essential load circuits to simplify connections to a standby plant.

> *Several types of engines are used in standby generator sets, the common ones being diesel, gasoline, and liquefied petroleum (LP). A diesel engine driven alternator forms the principal kind of generator set used for standby operation. The advantages of diesel power are*

comparatively low fuel and maintenance costs. The main disadvantage is the relatively high purchase price. Diesel generator sets are available with power ratings ranging from about 10 to 2000 kilowatts and are recommended for installations requiring long continuous runs.

The safest installations store the fuel in buried tanks and have pumps on the set equipped with return fuel lines. This arrangement decreases the hazard of fire. Gravity fuel feed may be employed to eliminate the pump. However, this system creates the risk of filling the engine cylinders with fuel in case of a leaky valve, since the fuel pressure is maintained even when the engine is not running. Such a condition would result in extremely difficult starting.

Gasoline driven generator sets are generally lower in initial cost than diesel units of similar power ratings. Also, gasoline units are usually designed for smaller power requirements than diesels, with power ratings in the range of 5 to 10 kilowatts being common.

As a consequence of the highly volatile nature of gasoline and the resulting fire hazard, the storage of this fuel is strictly governed by state and city regulations. Gasoline systems should have an underground fuel tank with enough capacity to keep the electric plant running for several days. In addition, a priming tank is desirable to insure fast starting. Another problem with gasoline is that it turns into varnish when allowed to stand for an extended period of time. It is therefore necessary to regularly change the fuel in the tank.

Small generator sets which burn liquefied petroleum (LP) are also offered. This fuel is stored in pressurized tanks and requires care to prevent fires. Even with LP tanks located outside the building and equipped with pressure reducing valves, fires and explosions have resulted when the generator sets are located indoors. In general, there is more danger with LP than with gasoline. Other gaseous fuels similar to LP which are sometimes used to power standby generator sets include butane, propane, natural gas, and manufactured gas.

Other areas which should be considered in the selection of a standby power plant are starting, transfer equipment, and cooling methods. Starting of the power plant engine may be either manual or automatic. Automatic systems offer faster load pickup in the event of a power failure but are also more costly. Transfer equipment is necessary to switch over the load from the normal to the standby power source. A failure here would prevent the generated power from ever reaching the load. Various cooling methods are employed in standby power plants, depending upon the type of installation and the amount of heat to be removed. Air cooling is used for small systems while water cooling with radiators or heat exchangers is employed in larger systems.

It is generally best if the standby power plant is kept in a room which is separate from the personnel and communications equipment. The same security requirements apply, of course. This increases safety and reduces heat and noise problems. The power plant should also be tested on a periodic basis--as often as every week—and records of the test runs kept in a log book.

Another kind of power plant which is becoming attractive for larger installations is the gas turbine. It offers fast starting and load pick-up, but is also quite noisy during operation. For installations requiring relatively low power, such as remote repeaters, power supplies which use solar cells to convert sunlight into electricity are also feasible. The electricity generated during sunny periods is used to charge a storage battery which acts as the power source when sufficient light is unavailable.

IV.2.7.3 Back-up Equipment

Even the best maintenance procedures cannot guarantee total reliability of communication equipment. The failure of a major system component such as the base-station two-way radio can result in a communication blackout unless preparations for the occurrence were previously made. A standard technique used to avoid the problems associated with component failures is to provide back-up equipment. When the breakdown occurs, the back-up unit is substituted for the defective unit and system operation continues.

A major factor to be considered in the selection of back-up equipment is cost. Duplicate equipment is undoubtedly preferable from the standpoint of compatibility and ease of substitution but may not prove feasible because of the high cost, especially when new equipment is involved. Older but serviceable gear, on the other hand, is generally less expensive. Care should be exercised when older or different equipment is used for back-up service to insure rapid replacement of the defective unit. If any modifications are necessary, unacceptable delays may result. The back-up equipment should be tested according to a schedule. It should also be in continuous use during certain periods to guarantee that it will be operable when an emergency need occurs.

Even the physical security precautions and back-up equipment provisions discussed might not prevent base-station failure in extreme cases. At such times it is necessary to improvise. For example, the facilities of another agency, a patrol car, or a communications van might be employed to provide substitute radio service. The specific choice depends upon the alternatives available.

If the communication center of a nearby department on the same radio channel is to provide back-up capability, arrangements should be made with the telephone company to switch all calls for the disabled department to the back-up facility. To be effective, this technique requires exchanging standard procedures between cooperating departments. Such relatively simple matters as having up-to-date maps showing boundaries of the patrol beats, lists of important telephone numbers and squad car call numbers readily available at the back-up facility must be planned and arranged beforehand.

In order to use a police vehicle as a substitute base station, provisions must be made to convey the complaint information received by telephone to the dispatcher using the vehicle radio. In some cases a short cable run from a car trunk to the dispatcher's station may be feasible (if the cables have been made up before the need arises); in others, separate intercom systems or even a mobile radio-telephone installation in the vehicle may be required.

From these few examples, it is clear that any method chosen for back-up in case of equipment failure is only as good as prior planning and preparation have made it. The need for such planning, and periodic testing of the back-up method, can hardly be stressed too highly.

IV.3 Mobile Equipment

Mobile equipment is used by field personnel to communicate with the police station and with each other. Two-way radios installed in vehicles or carried on the person of field officers are among the most important types of mobile equipment. Such two-way radios, often referred to as "mobile-units", are indispensable links of the communication chain which aid supervisory personnel in command and control of the officers in the field.

IV.3.1 Vehicular Two-Way Radios

The primary purpose of the vehicular two-way radio in police telecommunication systems is to provide for the exchange of information between the police station and the officer assigned to a patrol car, truck, or motorcycle. In addition, with proper system design, radio communication may also be obtained between vehicles and between a vehicle and the patrolman on foot.

438-911 O - 71 - 6

A vehicular two-way radio usually consists of a transmitter and receiver packaged as a single unit. Some units are designed for installation under the dashboard of a car or truck. This type has built-in controls and speaker and an external hand-held microphone. Other units are designed for installation in an automobile trunk or elsewhere. In this case, the radio is operated through a control head which mounts under the dashboard and is connected to the unit with a multi-conductor cable. The control head may contain a built-in speaker or the speaker may be a separate assembly. The control head also provides for connection of an external hand-held microphone.

Two-way radios designed for motorcylces are generally smaller and less powerful than automobile or truck units. The transmitter-receiver package is usually mounted on the rear fender or in a saddlebag on two-wheel motorcylces, and in the trunk on three-wheel motorcycles. The radio is operated through a control head which contains a built-in speaker and provides for connection of an external microphone. Two types of microphones are commonly used, the hand-held type and the shoulder type.

Use of the hand-held microphone requires one of the operator's hands. This is a potentially dangerous situation if the operator is riding a motorcycle. The shoulder microphone, however, is worn on the operator's clothing thereby leaving both hands free for driving. Also available is a helmet which contains earphones and a special bone-conductance microphone. While the hand-held microphone is used with a push-to-talk switch for transmitting, the shoulder microphone and helmet may or may not. If not, an electronic voice operated switch (VOX) is supplied which responds to human speech and automatically activates the transmitter. Unfortunately, with the shoulder microphone, the VOX also responds to loud noises which may activate the transmitter falsely at times. Another problem is that the VOX can introduce a slight delay, thereby clipping the initial part of the transmission.

As discussed previously, most police telecommunication systems employ frequency modulation (FM) radio equipment. FM vehicular two-way radios are commercially produced for operation in low-band, high-band, or UHF-band. The tuning is of the fixed, crystal-controlled type, allowing operation only on the specific channels assigned by the FCC. Single- and dual-channel radios are most common in the police service, although units with multi-channel capabilities with as many as twelve channels are available. In some police radio systems, multiple channel operation is used to achieve communication between mobiles as well as communication between mobile and base.

Vehicular two-way radios are available with various transmitter power ratings. Maximum RF output powers range from about 1 watt *to 110 watts for low band and high band units, and from about 1 watt to 90 watts for UHF band units. The physical dimensions and input power requirements generally increase with transmitter power ratings. A factor which has resulted in decreased size and power requirements in recent years is the replacement of vacuum tube circuitry by solid state, transistorized circuitry. Input power for vehicle radios is obtained from the vehicle's electrical system, which may range in voltage from 6 to 70 volts DC, with 12 volts being a common value.*

Vehicular transmitter emission bandwidths are limited by FCC regulations to a maximum of 20 kHz, and most commercially available equipment is rated at 16 kHz when proper maintenance is observed. Corresponding transmitter frequency deviation limits are ± 5 kHz. Adjacent channel selectivities of vehicular receivers are generally of the order of 70 dB, and receiver sensitivities are usually lower than 0.7 µV for a 12 dB SINAD ratio, the EIA standard for signal plus noise and distortion-to-noise and distortion ratio. Receiver audio output powers range from about 2 watts to 15 watts. Motorcycle radios usually have the higher audio output powers to compensate for the high noise levels encountered under heavy street traffic conditions.

One feature which is standard on vehicle receivers is carrier squelch. Tone-coded squelch is offered on an optional basis and may or may not be desirable in a particular system, as discussed in Section IV.4.7 of this chapter. Another option offered by some manufacturers is selective calling, which allows mobiles to be called individually. Selective calling in police radio systems is usually coupled with a "recall" feature which informs an officer who is away from the vehicle of a call by activating the dome light, headlights, siren, or horn.

IV.3.2 Portable and Personal Two-Way Radios

The portable two-way radio has become a fairly common item in police radio systems in recent years. Portables are designed with self-contained power supplies and antennas, making them suitable for completely independent operation. Size and weight are kept low enough so that these units may be carried by field personnel, providing two-way radio communication to the man on foot.

The use of solid state semiconductors rather than vacuum tube circuitry in portable units has resulted in substantial size reductions, so that some of the smaller portables are often referred to as "personal" radios. Personal radios are carried in various ways. Some units are held in the hand, while others are carried with a shoulder strap or clipped on a belt at the waist. The larger portables may be carried by hand or as a back pack. Weights of portable radios range from about 15 pounds for the larger units down to about 15 ounces for the personal types.

The advantages of the personal radio are many; the officer always has with him the means of communication to summon assistance whenever he is unable to reach his car, and the foot patrolman can remain in constant contact with the dispatcher.

Various microphone and speaker options are available for portable radios. In some types the microphone and speaker are contained within the unit's case. Hand-held microphones are employed in some cases and many also function as a speaker. In acoustically noisy environments, a telephone type handset containing both microphone and earphone is sometimes preferred. Shoulder microphones which attach to clothing leave hands free for other tasks. Helmets with built-in microphones and earspeakers are a fairly recent development. They offer no-hands operation and high immunity to acoustical noise for both sending and receiving.

The type of circuitry employed in a portable radio—solid state or vacuum tube—affects the size, weight, and power requirements. Portables may use all vacuum tubes, all solid state, or both types of circuitry in the same unit, in which case the circuitry is often referred to as "hybrid." In general, solid state circuitry occupies less space, is lighter, and consumes less power than vcauum tube circuitry. In personal units, the more stringent limitations on size and weight result in the nearly universal employment of solid state circuitry rather than vacuum tube.

Portable two-way radios of the FM type are commercially produced in low-band, high-band, and UHF-band versions. Fixed, crystal-controlled tuning is employed and units with multiple channel capabilities, as high as five channels or more within a single frequency band, may be purchased.

> *The emission bandwidth of the transmitter, limited to a maximum of 20 kHz by the FCC, is specified as 16 kHz by most manufacturers, with the frequency deviation limited to ± 5 kHz. Receiver adjacent channel selectivities are usually in the neighborhood of about 70 dB, and receiver sensitivities are generally better than 0.7 μV for 12 dB SINAD ratio.*

Maximum RF power outputs of portable two-way radios range from about 0.05 watts to 15 watts. Portables in the personal category have RF power outputs less than about 5 watts. Maximum audio power outputs vary from about 0.1 watt to about 3 watts.

Because of the relatively low RF output power of portables, it is frequently necessary to provide a relay system of some sort at an intermediate point between the portable and the base station. Two commonly used methods are (1) relay of the portable messages through a nearby police vehicle and (2) relay of the messages by means of fixed satellite receivers at suitable locations throughout the operating area of the portables. If the messages are relayed through a vehicle, two separate channels must be used for the portable and vehicular transmissions. If there are many portables, this can lead to considerable loading of the mobile-base channel due to personal radio message traffic. With the satellite receiver system, the personal radio transmissions can be relayed either by a separate radio channel or wire lines. Satellite receiver systems are discussed in greater detail in Section IV.4.9 of this chapter.

Portable radios are designed to obtain input power from a variety of battery power sources. Some units use dry cell batteries of the kind used in flashlights or lanterns. Others use longer lasting mercury batteries or the nickel cadmium rechargeable type. Certain models are capable of using either the dry cell, mercury, or nickel cadmium batteries. Some portables can be easily connected to draw power from a vehicle electrical system, and contain other features which make them suitable for vehicle usage. In addition, some portables are available with AC-to-DC power supplies and have features which suit them for base-station usage.

An item which is standard on portable units is carrier squelch. Tone-coded squelch is generally optional. Selective calling capabilities achieved by various methods of tone coding are also offered optionally by many manufacturers of portable radios. Selective calling is discussed in greater detail in Section IV.4.7.1 of this chapter.

IV.3.3 Mobile Equipment Antennas

Mobile antennas serve the same purpose as base-station antennas, i.e., reception and transmission of RF energy. However, mobile antennas are subject to more stringent restrictions on size and ruggedness. These antennas are vertically polarized* and radiate in an omnidirectional pattern in the horizontal plane. Some gain can be achieved by narrowing the beamwidth in the vertical plane. To achieve gain, antenna length should be long with respect to operating wavelength. This means that higher frequency (i.e., shorter wavelength)

*See Appendix A.

systems are more suitable for mobile use due to shorter antenna length. Mobile antennas are usually mounted on car roofs, the most efficient location. The electrical specifications discussed for base station antennas in Section IV.2.2 and in Appendix A apply to mobile antennas as well.

IV.3.4 Communication Vans

Emergency situations resulting from large fires, floods, severe storms, riots and transportation accidents often create a need for a temporary communication center located close to tne scene of disaster. This need is filled by a communication van.

The communication van is a mobile command and control headquarters. It serves as a hub from which the various activities necessary to control an emergency situation may be directed and coordinated. These activities include not only the efforts of municipal, state, and county law enforcement agencies but also of other public-safety organizations such as fire departments and civil defense, in addition to public utilities concerned with the distribution of gas, water and electricity. Being near the site of disaster gives the communication van personnel immediate access to the latest information in situations where rapid change is commonplace. Further, the ready availability of communication equipment provides the means with which to act, whether to call for additional help or to inform other areas of approaching danger.

In order to be effective, a communication van should carry a variety of equipment. The communication equipment must allow communication with other law enforcement agencies, public-safety organizations, and utilities. Mobile communication equipment in this category includes several single-frequency FM two-way radios for operation on various emergency channels, or a unit with multiple channel capabilities, or various combinations. Another radio equipment which increases the flexibility of the system is a citizens' band (CB) transmitter and receiver. Personal FM two-way radios are also desirable items. Some vans may be equipped for mobile-relay operation; that is, to pick up the transmissions of mobile units and retransmit them at higher power levels to regular police headquarters.

Electric bullhorns and public address systems for the direction of personnel and crowd control are useful. Commercial radio and television receivers and telephones (connected by the phone company at the site) also prove valuable in some situations. In areas where telephone lines are unavailable, radiotelephone or microwave equipment can be employed to obtain telephone service. Further, to insure reliability in case the normal power supply is not available, a back-up power system should be incorporated.

A communication van should be "hardened" against attack, since communication facilities may become targets during civil disorders. In the interests of efficiency and security, access should be allowed only to the necessary operation personnel. The congregation of other officers within the limited confines of a van tends to hamper operations.

Depending upon the complexity of the van, it may have provisions for more than one dispatcher, with a communication control center type of arrangement. If it is to serve as a temporary headquarters, the van should contain chairs, a typewriter, and one or more work-tables so that maps, for instance, may be studied. Adequate lighting is also necessary. Some emergency situations may warrant usage of the communication van for extended periods of time. Under such conditions it is advantageous if the vehicle is self-contained, including kitchen, sanitary and sleeping facilities for personnel.

IV.4 Special and New Devices

There are many areas of advancing technology which have and will continue to find direct application to police telecommunication systems. An awareness of special communication devices and new developments in equipment is necessary if law enforcement effectiveness is to be maintained.

For many years, the demands on police telecommunications were adequately met with a simple radio system. Today, however, police are faced with an increasing demand for expanded service and faster response. This increases the rate at which new technological developments are adopted for police use. Among other things, adoption of improved and new equipment in the near future will help police departments to:

- Keep in constant personal contact with all officers on patrol
- Automatically keep a record of the status and location of police vehicles at all times
- Retrieve information concerning auto registration, criminal histories, fingerprints, etc. quickly and accurately
- Send coded or scrambled messages when necessary to maintain privacy
- Exchange written messages between vehicles and base station, to provide accurate, rapid transmission of certain types of information
- Use television for surveillance of buildings and high crime rate areas, traffic monitoring, lineup displays, and educational purposes

This list is, of course, incomplete. It should be pointed out that the actual technology for doing most of the above already exists and that experimental tests by police agencies have been performed. Some special and new devices are examined next.

IV.4.1 Voice Privacy

With the increased availability of low cost monitor receivers for the police frequencies, more and more people are tuned to these frequencies. A survey of 2098 municipal police chiefs was conducted to obtain more information on the nature of public eavesdropping.[9] A list of the types of groups of people that created the most problems according to the chiefs is given below. The listing proceeds from the most frequently mentioned to the least:

1. *Juveniles:* the monitoring of police voice communications by juveniles aids such improper activities as vandalism, drag racing on public streets, and disruptive demonstrations, and encourages prank phone calls reporting imaginary crises.
2. *Criminals:* house-breakers, burglars, bookies, and movers of narcotics use monitor radios to follow police movements and avoid capture.
3. *Auto towing companies, ambulance services and news media:* interference from these special interest groups often causes disruption of normal police operations.
4. *General public:* the problem arises when citizens listening to police transmissions decide to go to the scene of an incident, making the situation more difficult for law enforcement personnel. Also, in small towns, knowledge of the names and places involving police activity has a potential gossip value which can lead to complications.
5. *Militant groups:* knowledge of police movements is of benefit to groups which are dedicated to the creation of disorder.

In order to alleviate the monitoring problem, several types of voice privacy systems have been developed. The technique employed is to encode the voice in some manner at the transmitting end and decode it at the receiving end. If the encoded signals are sufficiently unintelligible and unauthorized persons do not possess the decoding equipment, privacy of communication results.

Most of the voice privacy devices currently available fall into two basic categories: inversion scramblers and band scramblers.

> *Inversion scramblers simply invert the voice frequency band so that the frequencies at the low end of the voice frequency spectrum are converted to frequencies at the high end of the spectrum and vice versa. The scrambled signal is actually a frequency-inverted image of the original signal. At the receiving end, the frequencies are reinverted for intelligible reception.*
>
> *In the band scrambling method, the 300-3000 Hz voice range is divided into a number of narrowband sub-channels. These sub-channels are then interchanged in a preselected manner. The receiving equipment rearranges the sub-channels in the proper order so that the message is once again intelligible.*

Voice-privacy equipment is also available which combines the techniques of inversion and band scrambling in a single device. Various sub-channels may or may not be inverted, according to the user's choice. A signal which is scrambled in this fashion is generally more difficult for unauthorized personnel to decode than one scrambled by either technique alone, since the number of possible coding combinations is increased and the decoding equipment necessary is more complex.

At least one manufacturer offers a series of voice privacy devices which employ a digital encoding technique. The advantages claimed for this system are a large number of different possible codes and a higher degree of security than is attainable with the inversion and band scrambling techniques.

It should be emphasized that none of the systems discussed above offers absolute security from eavesdropping. In some cases a trained listener may be able to decode a scrambled message by ear. Usually, though, special equipment will be required to obtain intelligible reception. Needless to say, it is desirable that the decoding process be made as difficult as possible for unauthorized personnel, while simultaneously keeping the cost of voice privacy equipment within the reach of most police departments. Unfortunately, the complexity and cost of voice privacy equipment generally increases greatly with the effectiveness. The various privacy techniques are listed in the order of the relative security which they provide as follows:

1. Inversion scrambling (least effective)
2. Band scrambling
3. Combined band and inversion scrambling
4. Digital encoding (most effective)

Voice privacy devices are produced for use with base station, vehicle, portable, and personal communications equipment. Both send and receive capabilities are generally provided in one unit, usually using a simplex type system. However, models which allow full duplex operation are also available, mainly for base station usage. These devices are usually designed for connection to existing transmitters and receivers with a minimal amount of modification. It is important to observe that voice privacy devices designed for police radio communications equipment do not increase the bandwidth of the transmitted signal. In addition, most units contain a switch to disable the privacy function and allow normal operation if desired.

Some models permit the convenient selection of different code combinations for operation by means of front panel switches. Other models employ plug-in circuit cards or modules to change codes and may have a lock to prevent unauthorized personnel from tampering with the plug-in code unit.

The use of voice privacy devices is accompanied by several disadvantages that must be weighed before such devices are used. Additional equipment components reduce system reliability and often increase maintenance requirements. The additional weight and bulk of the

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1 OF 5

POLICE TELECOMMUNICATION SYSTEMS NCJ 00341

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units may be undesirable, especially in personal portable radios. If a channel is shared by several departments, the use of voice privacy may become a problem to those users not employing them. Nuisance interference from scrambled or coded signals is generally much more annoying than intelligible but irrelevant messages. Finally, some police communication officials believe that only the more sophisticated—and therefore, more costly—methods are at all effective. Thus, effective voice privacy systems may cost a considerable amount, both in initial acquisition, and overall reliability and maintenance costs.

> *Power requirements of voice privacy devices necessarily vary with the application. Models designed for base station usage generally require 115 volts AC and use less than 20 watts. Vehicular units usually operate at 12 volts DC and consume from about 2 to 12 watts. Voice privacy devices used with portable and personal transceivers generally require 10 to 15 volts DC at less than 1 watt.*

The cost of a voice privacy device depends upon several factors, namely, the type of scrambling or coding technique employed, the number of different codes available, the application (base station, vehicular, or portable), and whether the operation is simplex or full duplex.

IV.4.2 Mobile Teleprinters

Mobile teleprinters are used in police vehicles to record messages transmitted by the base station in printed form. The word teleprinter is used here to designate a device with receive-only capabilities as opposed to a teletypewriter which can send as well as receive messages of a printed nature. The production of mobile teleprinters suitable for police service is a fairly recent development, the first commercial units appearing about 1967.

In a police radio system, the purpose of the mobile teleprinter is not to replace the voice communication from base station to vehicle but rather to complement it. There are many types of messages received from the base station which are of a lengthy, descriptive nature. Such messages consume much air time when transmitted by voice. In addition, the field officer must either record them by hand or memorize them. With two-man patrol cars, errors are likely to occur during the writing process, particularly while the car is in motion. With one man patrol cars, it is impractical and unsafe for the officer to attempt to write while driving, so he must memorize the information instead. Memorizing long messages can be a difficult and error-prone task. Such problems can be alleviated by mobile teleprinters.

In addition to saving air time and increasing message accuracy,[10] other benefits of mobile teleprinters include:[11]

- *Unattended operation*: The officer need not be in the car for the teleprinter to record a message. A properly equipped teleprinter can be automatically controlled by the base station operator. This feature is of considerable advantage since an officer may be away from his car as much as 82 percent of the time during a busy period[11] and 61 percent of the time on the average.[12]
- *Printed copy of radio traffic*: A printed copy of received messages relating to an incident is provided and may be useful at a later time.
- *Greater security*: Monitoring of police radio transmissions requires special equipment since digital signals are used in teleprinter communications. Also, encrypting devices may be added to teleprinter systems.
- *Computer interface*: Since teleprinters are digital devices, they are suited for direct reception of information from computers and electronic data processing (EDP) systems, which are also digital devices.
- *Selective calling*: Mobile teleprinter signals are compatible with selective calling techniques. These allow the base station to address the mobile units individually or in various groups.

Not all of the features of mobile teleprinter usage are desirable, however. Some of the disadvantages are as follows:

- *Special frequencies*: Separate frequencies, in addition to those used for voice communication, are required by some mobile teleprinter systems.
- *Operational problems*: Some mobile teleprinter systems share a standard 3 kHz voice channel. This can lead to operational problems and sometimes degrades the quality of the voice signal.
- *Cost*: Mobile teleprinters are costly at present, and may be beyond the fiscal capabilities of some agencies.
- *Message input time*: In order for the dispatcher to send a teleprinter message, he must first enter the message on a teletypewriter keyboard. This can be more time consuming than a voice transmission.

Two kinds of mobile teleprinters are currently produced, narrow band and wide band. In both systems, coded audio tones are used to carry the message information. The narrowband type requires about 200 Hz bandwidth for a 100 word per minute transmission rate and uses a type font as the printing element, similar to an ordinary *typewriter. The wideband teleprinters generally require a full voice bandwidth of about 3000 Hz to achieve a 100 word per minute printing rate, although higher rates are being achieved. The wide band systems transmit multiple tones for control and printing of dots corresponding to the desired alphanumeric characters in a dot matrix pattern.*

Various kinds of paper are employed by the different makes of mobile teleprinters, depending upon the method of printing. Pressure, heat and electrically sensitive papers in addition to ordinary paper are used. Paper widths vary from about 3½ to 5 inches, while rolls from 150 to 250 feet in length are utilized. Printing speeds also vary with the different makes of teleprinter. The narrowband types have speeds from about 100 to 150 words per minute while the wideband types range from about 100 to 300 words per minute.

Power requirements for mobile teleprinters range from about 20 to 60 watts at 12 volts DC. The units are usually designed to mount on the transmission hump or under the dashboard in a patrol car.

IV.4.3 Digital Transmission from Vehicle to Base

The advantages of digital transmission of information from base station to vehicle were considered previously under the discussion of mobile teleprinters. It was pointed out that such teleprinters are now produced commercially and will probably find increasing use in police telecommunication systems in the next few years.

Still in the experimental stage, however, is digital transmission from vehicle to base station. The capability of digitally transmitting information and requests for information from vehicle to base station offers several benefits in improved communication. Certain types of vehicle to base messages can be handled much more efficiently by digital transmission than by voice transmission.

One advantage of sending a message digitally is a savings in time spent on the air. Less air time results in decreased channel congestion and hence greater availability of the channel. Another desirable aspect of digital transmission is high compatibility with automated message processing systems. Large numbers of digitally encoded messages could be handled quickly by a computer with little or no intervention necessary by the dispatcher. This can result in a considerable decrease in dispatcher workload during periods of high communication traffic volume. A third benefit of vehicle to base digital transmission is increased privacy from listeners with criminal intentions. This security is obtained because digital transmissions cannot be made intelligible without the use of special equipment.

Ordinarily, the type of message which is best suited for digital transmission is one that is frequently sent, such as status reports. Most non-routine messages are best handled by normal voice procedures. An exception to this rule is when an officer requires immediate help in an emergency. In this case, a special button or switch in the vehicle which, when activated, would immediately set off an alarm and identify the vehicle at the base station.

A description of one digital communication system employed by a large police department follows.[13] The system features two-way digital communication between base station and vehicle and includes a computer for automatic message processing and distribution. The digital messages are sent over a standard voice radio channel which is used to convey both digital and voice information on a time shared basis. Time sharing means that either digital or voice type information is present on the channel at any one time, but not both simultaneously.

The system also includes access to remote or on-site computerized data banks. The dispatcher is kept constantly aware of all non-voice exchanges between vehicle and base station by information displayed on a video terminal (television screen) at his position.

Frequently sent messages are available in text format by activating separate buttons at the dispatcher's console, as well as on the vehicle mounted typewriter keyboard. To enter a message, the field officer or dispatcher pushes the button corresponding to the desired message and then depresses the transmit button on his unit. This causes a tone-coded burst to be sent over the voice channel. These prearranged codes are restricted to the most frequently occurring messages such as *in-service, out of service, message received, officer needs help, send ambulance* and others. License or registration numbers, addresses and non-standard messages can be typed in on a conventional typewriter keyboard. The vehicle mounted unit contains a cathode ray tube display similar to that at the dispatcher's position.

Upon receipt at the base station, the message is decoded and entered into a small computer which checks for errors, determines the identification of the field unit, sends an acknowledgment (message received) to the vehicle, and routes the message to the proper destination. License plate numbers are directed around the dispatcher to the data bank access terminal, while messages for him are displayed on his video terminal. The display consists mainly of numerically coded status information for each vehicle. The number of voice transmissions for routine messages is reduced with this system, as is some of the dispatcher workload in updating status information.

IV.4.4 Television

Law enforcement agencies are finding television a useful device in various areas of their work. Although television has existed in readily available form for many years, it is only recently that certain types of television equipment have been developed which meet the particular needs of police departments. The main areas of use now center around:

- Surveillance of all types
- Remote transmission of pictorial information, such as line-ups, to district stations or other departments
- Training of police personnel

Surveillance consists of several distinct types. The first is observation of high-crime areas such as certain streets and stores for deterrence or detection of crimes and as a means of identification of suspects. Another type of surveillance is that of crowds of all kinds. This can be carried out by remotely placed TV cameras on tops of vans, on buildings and in helicopters. Many police agencies with responsibility for lockup facilities are using closed-circuit TV for cell areas, hallways and doors. The final type of surveillance is that which is popularly called a stake-out. In this case, hidden cameras can take the place of police personnel, who observe the scene from a remote location. There are cameras small enough to be easily concealed.

Some police departments are now using television as a means of distributing pictorial information such as line-ups to district stations for observation by policemen and witnesses. For security reasons, the transmissions are usually scrambled and can be unscrambled only by specially equipped receivers.

One of the major police uses of television is for training of personnel. Lectures and demonstrations can be recorded on video tape cassettes and replayed for training purposes.

> *Commonly available systems use a 525 line, 60 Hz scan, requiring a 4 MHz bandwidth. Performance of such systems is comparable to that of broadcast television. Television cameras are typically compact enough to be hand-held. They consume little power and can be battery operated.*
>
> *Special applications may require non-standard systems. Where high resolution (detail) is required in the picture, a 945 line system can be used, which almost doubles picture resolution both horizontally and vertically. Because of the increased resolution at the same scan rate, a 20 MHz bandwidth is required for these systems. Such systems have enough resolution for transmission of normal documents on 8½ x 11 inch paper and for such things as fingerprints, if they are enlarged.*

Standard television cameras using vidicon tubes can handle light ranges of about 10,000 to 1. However, special cameras are required in areas where there is almost total darkness. These use image orthicon tubes which are much more sensitive than vidicon tubes. Cameras using these tubes are both larger and less rugged than the conventional types.

The transmission of the video signal usually is over a closed-circuit cable. Signal losses in such cables require either short cables (less than 1000 feet) or periodic amplification of the signal along the cable to its final destination. The bandwidth required for a standard TV picture, 4 MHz, is the equivalent of 200 voice channels each 20 kHz wide. (Broadcast television channels are 6 MHz wide, including voice signal and guard bands, or 300 times as wide as a 20 kHz land-mobile voice channel.) Television broadcasts by police would thus require new frequency allocations or use of special slow-scan techniques.

IV.4.5 Facsimile System

Facsimile is a form of communication that reproduces graphic copy at a remote point by electronic means. A facsimile system systematically converts a picture or other fixed graphic copy into electrical signals. These are transmitted by wire or radio to a receiving point where they are converted back into a replica of the original. This process of transmitting copy requires little time, usually not more than ten minutes and often as little as a few seconds.

In the simplest system, the copy, which may vary in size depending on the machine used, is wrapped around a drum. The copy is scanned with a small, bright light as the drum rotates. The reflected light is focused onto a phototube, converting the light into electrical signals suitable for transmission. If these signals are in the audio frequency range, ordinary voice-type communication equipment such as police transmitters or ordinary phone lines may be used as the sender. At the receiving point, the electrical signals are converted back into light focused on film and mounted on a receiving drum. In this way the film is exposed and a copy of the original is made.

Normally, any transmission system devoid of voice communication problems can be used for facsimile. Facsimile, in fact, suffers less from the effects of poor voice quality characteristics than does voice communications. This means that legible copy will be received even when voice communications are marginal. Leased telephone lines are the most popular transmission medium used. In addition, facsimile equipment suitable for use in mobile units is commercially available.

The characteristics of facsimile which make it a desirable method for transmitting graphic information are:

- It provides a permanent durable copy suitable for general office use.
- It requires less special handling than systems which require retyping or other encoding. As a result, facsimile saves time and eliminates the need for specially trained personnel.
- Many different types of graphic material can be transmitted. These include typed and handwritten material, photographs, fingerprints, and search and arrest warrants, where legally possible.
- Facsimile equipment is available which is compatible with both base station and mobile equipment and power systems. Mobile equipment is on the order of one cubic foot in size and 20 pounds in weight.
- Equipment is available which provides access to stored data. For instance, microfilm data may be retrieved remotely by facsimile, using special telephone links.

More complete information on facsimile systems and technical characteristics, including scanning systems, signal characteristics, transmission links and methods for printing copy, are discussed in Appendix D.

IV.4.6 Automatic Vehicle Monitoring

Efficient deployment of police vehicles requires knowledge of the location of each vehicle. If the locations of all units are known at the time a complaint call arrives, the dispatcher can assign the unit closest to the incident, thus reducing the response time. Automatic vehicle-location systems are now under development which periodically determine and display the locations to the dispatcher.

In order to accomplish the main purpose, namely speeding and automating the dispatch function, a vehicle monitoring system must have sufficient resolution. Resolution is the accuracy with which position may be determined. The resolution required is that which permits a dispatcher or a computer-automated decision process to determine which of several available vehicles, spread over some area, is closest to an incident. In general, the resolution required for optimum performance at lowest cost is related to the size of the beat patrolled by the vehicles.[14] An automatic vehicle monitoring system with higher resolution than necessary should not be employed, since system costs rise sharply with resolution.

To a large extent, the radio spectrum requirements imposed by a vehicle location system are proportional to the resolution and the number of vehicles to be located. The higher the resolution and number of vehicles, the more spectrum bandwidth is required. Shortening the time interval between location determinations also increases the bandwidth requirements.

A number of different types of automatic vehicle monitoring systems are described more fully in Appendix E.

IV.4.7 Tone Coding and Coded Squelch

Coded audible and subaudible tones, sent prior to or during transmission time, are used in police radio systems to implement a number of functions which are not obtainable with voice alone. Coded squelch, recall, automatic mobile identification, radio relay control, and remote transmitter keying are examples of tone coding applications. Tone coding techniques often require optional equipment not usually a part of the normal system. An encoder is needed for transmission of the coded tones, and a decoder is necessary in the receiver to properly interpret the coded tone.

Some tone-coding schemes employ single tones which are sent continuously with the regular voice transmission, while some schemes use two simultaneous tones with different frequencies. In another variation, two sequential tones are sent, first one and then the other. The first sequential tone has a short duration, usually a fraction of a second, whereas the second tone may or may not continue throughout the voice transmission, depending upon the specific application.

The number of tones employed in a system depends on the number of codes, that is, distinct messages, required. The more tones used, the more codes are possible.

IV.4.7.1 Coded Squelch

The purpose of coded squelch is to eliminate nuisance interference caused by other users of the radio channel.

Interference may be categorized as two types, either nuisance or destructive. Nuisance interference is caused by undesired signals on the same channel which are weak compared to the desired signal. An undesired signal which is too weak to override a desired signal may still be sufficiently strong to open the receiver's carrier squelch in the absence of the desired signal. It will then be heard by the operator, causing him annoyance which will eventually produce fatigue.

Nuisance interference is eliminated through the use of coded squelch. In this case, the desired signal contains one or more coded tones in addition to the voice information. The receiver is equipped with a decoder that responds only to the proper tone coding. When a signal with the correct coding is detected, the receiver squelch opens and the desired signal is heard by the operator. However, the squelch cannot be opened by signals without the correct coding. Therefore, relatively weak undesired signals on the same channel are not heard by the operator and fatigue is lessened.

The second type of interference, destructive interference, results from undesired signals on the same channel which are as strong as, or even more powerful than, the desired signal at the receiver. The effect on the output of a receiver *without* coded squelch is either severe garbling of the desired signal or total "capture" of the receiver by the other signal. In the second case, only the undesired signal is heard at the receiver output, the desired signal being totally suppressed.

In a receiver with coded squelch, the output may also be garbled if the undesired signal has about the same strength as the desired signal. However, if the undesired signal is stronger, it usually captures the receiver front end, completely suppressing the desired signal. In this case, the squelch is not opened since the other signal does not contain the proper tone coding. Because the receiver is quiet, the operator may not know that a message was sent, causing the message to be missed. Therefore, it is seen that coded squelch does improve operation in the presence of nuisance interference but not in the presence of destructive interference.

> *Consider next two systems in the same area on adjacent channels in the VHF high-band (that is, with only 15 kHz separation). By using coded squelch the unwanted signals of the other system are blocked until a properly coded signal from the desired system opens the squelch. Then both systems may be heard at the same time producing interference. In extreme cases the signal from the other system may override the desired signal. It cannot open the squelch and no message is heard at all.*
>
> *Another undesirable situation arises when several users with coded squelch operate in the same area on the same channel. In this case it is necessary to listen with the coded squelch defeated before transmitting on the channel. Failure to do so may result in destructive interference to transmissions already in progress. Coded squelch eliminates the voices of other users from the receiver output but it does not remove them from the channel. To put it another way, coded squelch does not create any more air time, it only eliminates the fatigue of listening to unwanted signals.*

Thus it can be seen that coded squelch has both advantages and disadvantages which should be carefully considered before including it in a system.

IV.4.7.2 Other Uses of Tone Coding

Tone coding is used in a variety of ways in police radio systems. A few of these are briefly discussed below.

> Selective Calling and Recall: *In a system with selective calling, the base station is equipped with a tone-encoder console capable of generating a number of different code combinations. The desired code is selected by one or more push-button switches. Particular receivers and mobile radios may be provided with unique decoders corresponding to the selectable codes. The decoder only allows the properly coded signal to be heard at the receiver output. This system gives the base station the ability to call one or a group of receivers and mobile radio units at a time rather than all simultaneously. Most selective call decoders also provide a "recall" feature which alerts an officer to a message for him when he is out of the vehicle. When in the recall mode, the receipt of a properly coded signal causes activation of a call indicator light, the horn, headlights, or dome light of the car to inform the officer that the base station called.*
>
> Automatic Mobile Identification: *Tone coding is used in some police radio systems to automatically identify the mobile unit calling the base station.*[15] *In such systems each mobile radio unit is equipped with a unique encoder that codes all transmissions. The base station is provided with a decoder which determines the mobile unit from which the coded transmission originated. The decoder output is either used to illuminate numbers on a board or panel, each number corresponding to one mobile unit, or to actuate some other type of identification device, such as a message on a video display.*
>
> Remote Transmitter Keying: *Tone coding techniques are used for remote control of base station transmitters. The need for special and costly DC telephone lines to provide for transmitter keying from a remote dispatch point is eliminated. The ordinary voice grade telephone line which carries the voice information to the transmitter is used to carry the tone also. A simple encoder at the dispatch point generates a tone when the push-to-*

talk switch on the microphone is actuated. This tone is sensed by a decoder at the transmitter, causing the transmitter to be keyed on.
Repeater Control: Tone coding may be used in systems with repeaters to insure that the repeater will be activated only by transmissions from the desired system and not by signals from other channel users.

IV.4.8 Scanning Receivers

A scanning receiver provides the capability of monitoring several channels automatically with a single unit. To illustrate, consider the operation of a two-channel scanning receiver. Assuming initially that transmissions are absent on both channels, the receiver samples each channel sequentially, waiting for a signal to appear. As soon as a signal is detected on a channel, say Channel 1, the receiver "locks on" to that channel and stops scanning. Channel 1 is then held for as long as the signal remains, even though a signal may appear on Channel 2.

When the signal on Channel 1 ends, the channel is released and Channel 2 is sampled. If a signal is detected, Channel 2 is held for the duration of the signal; otherwise, the scanning process continues and Channel 1 is again sampled, and so on. For scanning receivers with more than two channels, the operation is the same, with the scanning of the channels occurring in some preselected sequential order which may be determined by the operator.

An optional feature on some scanning receivers is scanning with priority. This feature is useful where it is desirable to give one channel precedence over the others when signals appear simultaneously on the "priority" channel and another one. If the receiver is already locked on to the priority channel (as the result of a signal) and a second signal appears on another channel, no change occurs and the first signal is still heard at the receiver output. However, if a "non-priority" channel is being held (as the result of a signal) and a second signal then appears on the priority channel, the non-priority channel is released and the priority channel held. For the case where no signal is detected on a sampled channel, the scanning of the remaining channels proceeds in preselected sequential order as in the case of scanning receivers without the priority feature.

Scanning receivers with multichannel capabilities usually have switches on the front panel to include or delete channels from the scanning process. Thus one, several, or all of the channels may be monitored, allowing operational flexibility for different situations.

Scanning receivers are used in both base stations and vehicles where it is desirable to monitor several channels automatically without having a separate receiver for each channel. Some vehicle two-way radios also offer scanning, with or without priority, as an optional feature for the receiver section.

Scanning receivers are manufactured for use on the low-, high- and UHF-bands. Some models are available which contain low- and high-band capabilities in a single unit. Crystal-controlled tuning is employed in scanning receivers, and units which can monitor as many as eight channels are commonly available. Selectivities are such as to allow operation on the low, high and UHF bands with channel spacings of 20 kHz, 30 kHz, and 25 kHz, respectively. Sensitivities as low as 0.3 μV for 12 db SINAD ratio are found in some models. Maximum audio power outputs range from about one to five watts. Carrier squelch is usually a standard feature on scanning receivers; whereas tone-coded squelch is generally not offered.

Input power requirements of scanning receivers depend upon the usage. Units designed for base station operation require 117 volts AC, while vehicular units require 12 volts DC. Some models are manufactured for either base station or vehicle employment, using either AC or DC power.

IV.4.9 Receiver Voting

In police radio systems the base station transmitter should be sufficiently powerful to cover most or all of the patrol area. However, the transmitter power capabilities of portable and personal two-way radios are much less than those of base stations and also less than those of vehicle radios. As a result, the officer in the field using a personal radio might not be able to talk back to the base station if the system were designed conventionally. This is especially true when the officer is in a poor signal area such as a building, narrow walkway, or alley.

An arrangement which provides more reliable communications is one which employs several "satellite" receivers for each channel situated at scattered locations throughout the coverage area. The satellite receiver arrangement decreases the distance from the hand carried unit to the nearest receiver and thus compensates for the lower available transmitter power and also for operation in poor signal areas. Radio links or wire lines are usually employed to convey the receiver audio output signal to its proper destination, the base station or a mobile-repeater.

It is highly probable for several satellite receivers to pick up the same transmission. When this occurs, several audio output signals are produced and appear at the base station or repeater unit. In general, the audio output signals of the different receivers vary in signal-to-

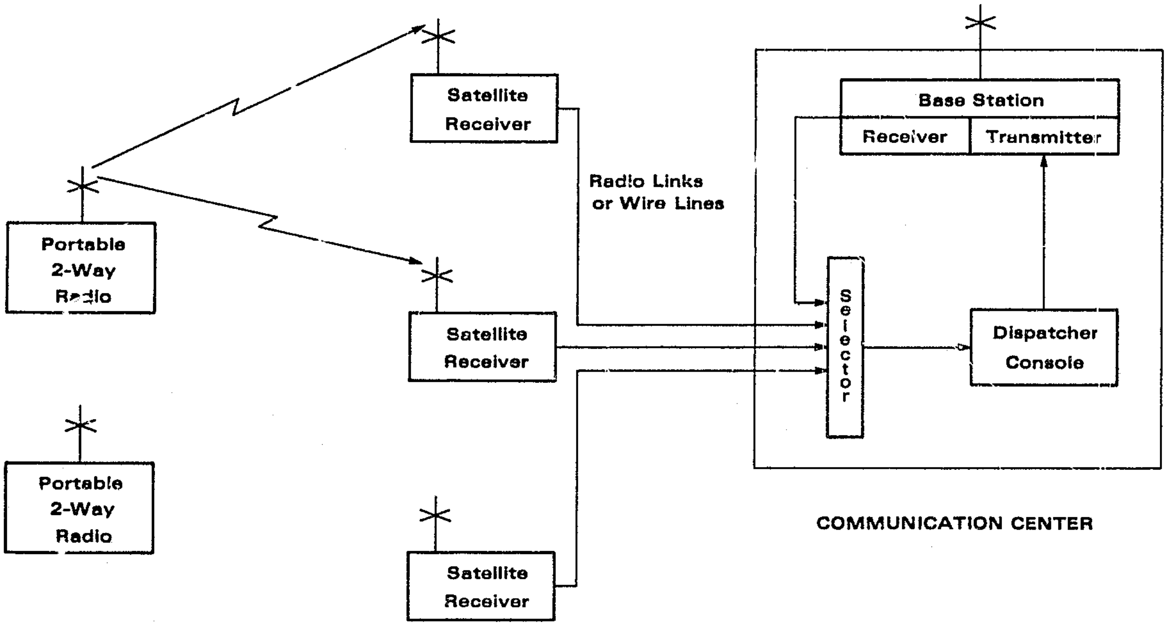

Fig. IV-8 Satellite Receiver Voting System

noise ratio, amount of distortion, and thus overall quality. If the several audio signals were simply added to produce a combined output, the resulting signal would generally be poor in quality and sometimes unintelligible. Rather than combine the signals, a better method is to select the one signal with the highest quality. This selection process is called "voting," and the unit which performs the voting operation is called a "selector" or a "comparator." A block diagram of a radio system which employs receiver voting is shown in Fig. IV-8.

There are three selection techniques used in available voting equipment which are suitable for police radio systems. The three techniques are *audio quality selection*, *RF signal level selection*, and *quieting level selection*.

> *In the first system, the audio signals from the satellite receivers are processed for certain characteristics by the selector to determine signal quality. Characteristics considered are level, frequency distribution, syllabic rate, and noise level during pauses in speech. In this system, the satellite receiver requires no additional special circuitry and all of the selection equipment may be located at a central position.*

In the RF signal level selection system, the selector compares the received radio frequency (RF) signal level from each receiver and chooses the receiver with the highest level. Since the audio signal to noise ratio at the output of the receiver is directly proportional to the received RF signal level, the highest quality audio signal is the one selected. Measurements of received RF signal level can only be performed at the receiver, however, and the measurement information must be conveyed to the selector. Consequently, each satellite receiver is equipped with encoder circuitry which generates coded tone combinations which correspond to various RF signal levels. The RF signal level is usually divided into four ranges and there is a code combination for each range. The coded tones are sent along with the receiver audio output to the selector, where the tones provide the information required to choose the best audio signal.

The third method is quieting level selection. In this method, the selector compares the quieting levels on the lines from the unsquelched receivers and chooses the receiver line with the least amount of noise. The best signal is the one chosen. It is necessary in this system that the squelch status of the receiver be known at the voting selector. This information is conveyed to the selector by means of a tone or DC signal generated at the satellite receiver when the receiver is squelched. Absence of the tone or DC signal indicates the unsquelched condition. Special circuitry is required at the receiver to generate the squelch status signal.

An advantage of RF *signal level selection* and *quieting level selection* over *audio quality selection* is that the first two systems can be made faster acting. Only the unmodulated RF carrier signal is required by the first two selection processes and selection can be completed before the operator even begins talking. The latter system requires an audio signal, however, and selection cannot begin until after the operator starts to speak. In any case, voting must occur fast enough in a practical system so that the loss of syllables at the start of a transmission is minimized or does not occur. The *audio quality selection* method has the advantage that special circuitry is not required at each satellite receiver.

Voting selectors are produced with various voting modes. The mode may be of the continuous, periodic, or lock-on type. In the continuous *mode, the highest quality audio signal always appears at the selector output. If the relative signal qualities from the different receivers change during a transmission, the selector will switch to the best signal as soon as the change occurs. In the periodic mode, selection occurs only at preset intervals of several seconds duration, and in the lock-on mode, selection occurs just once, at the beginning of a transmission. The selector output for these last two modes will not always be the highest quality signal, since the relative signal qualities might change after the start of a transmission.*

Voting selectors are generally supplied in the form of a rack which accepts a number of plug-in modules, one for each satellite receiver. Depending on the manufacturer, one rack may handle enough modules for as many as six to eleven receivers. The rack usually comes with an audio amplifier module and power supply section but may or may not have a built-in speaker. Also, several racks may be connected in parallel to accommodate more receivers than possible with one rack.

IV.5 Personnel—Qualification and Training

The operating staff of the telecommunication system includes, but is not limited to, supervisor or commanding officer of the communications unit, dispatchers and complaint operators. Often the latter two roles are combined. Although some knowledge of police procedures is required of persons assigned as complaint operators, no direct enforcement action is expected of them. There is nothing inherent in the task, therefore, that necessarily requires the assignment of sworn personnel to processing complaints.

The trend toward greater utilization of civilian personnel in law enforcement agencies results in a proportionate increase of civilians in communications work.[16]

The greatest concern of police administrators in contemplating use of civilian employees in communications work is that "non-police" personnel will fail to understand the complexities of police work, and will make unsatisfactory decisions even in routine processing of complaints. The experience of police agencies which have assigned civilian employees to this type of work shows general acceptance and satisfaction, particularly where careful selection and training are provided.[17]

In a 1960 survey of state law enforcement agencies, five of the 48 respondents indicated exclusive use of sworn radio dispatchers, and eleven a combination of both sworn and civilian employees. The balance, 32 agencies, relied entirely on civilians.[18]

In municipal agencies, a practice sometimes followed is to assign civilians to complaint taking, and sworn personnel to actual dispatching of field units, although the reverse arrangement is also found. This approach is applicable to agencies which experience a volume of work justifying separate complaint operator and dispatcher positions, of course. In the smaller agencies, civilian employees who have been well trained in police records work, departmental regulations, and who have been indoctrinated in and observed field patrol practices, are entirely capable of acting as combination complaint operator-dispatchers.

It is important to realize that effective dispatchers and complaint operators can be either civilian or sworn, male or female personnel. Capable complaint operators and dispatchers are obtained through careful selection as a first step, and adequate training as the next. The use of civilians, men and women, results in a larger number of individuals to choose from and increases the potential for obtaining high caliber employees. Experience of departments of all sizes in the U.S. indicates that success can be obtained with any of these categories of personnel.

Selection and training are the really important criteria for any phase of communication work, whether assigned to civilian or sworn, male or female personnel. The ability to remain calm and effective in times of stress is not readily measurable by any economical "paper and pencil" test, nor is the ability to evaluate the status and deployment of field units and make rapid—and correct—dispatching decisions.[19]

The selection responsibility is oftentimes out of the hands of the police administrator if civilian employees are contemplated, the positions involved falling under the jurisdiction of the local civil service agency. However, job descriptions should be developed and the personnel agency should welcome any suggested criteria which will help to define and classify the tasks at hand. (See examples in Section VI.1.3.2, in Chapter VI.) A prospective employee should be given the opportunity to view the communication center in action; the experience may save subsequent processing steps if the applicant cannot relate personal abilities with requirements.

The selection of supervisors for communication tasks requires the abilities which would be expected in any police supervisory position, with emphasis on analytical and decision-making abilities. The unexpected demands caused by an event requiring extensive headquarters direction must be met if the situation is to be controlled, and the services of command personnel may not always be available. Rotating field supervisors through the communication position increases their comprehension of the total police operation, and may serve as a screening device to select officers for regular assignment who demonstrate their potential in this capacity. Also, communication personnel should be given the opportunity to observe field operations in order to increase their overall comprehension.

There is an absence of widely accepted training standards for dispatchers and complaint operators. Most departments have developed their own procedures—ranging from a casual introduction to the system to highly structured exercises. Poor and inadequate training is false economy for any department regardless of its size.

The Associated Public-Safety Communications Officers, Inc. (APCO), in particular, are aware of the training problem. In fact, APCO chapters throughout the country have organized training seminars to alleviate this difficulty. Written material on the subject of training is becoming increasingly available.

The basis of a good training program is an operating manual which describes in detail the procedures of the communication system. One such manual is the APCO *Standard Operating Procedure Manual.*[20] The table of contents of another[21] is shown in Fig. IV-9. Review of the contents of this manual indicates the complexity of the duties of complaint operators and dispatchers, and thus the importance of comprehensive training.

To accompany this manual, an In-Service Training Guide has been developed. The purpose of this guide is:

- To instruct the new Communication Operators in the duties that they must perform in their daily activities as Communication Operators
- To give instructors a record of what the student has already learned and hence avoid duplication in instructions
- To show the progress of the student operator and to aid supervisors in giving assignments which can be adequately performed

Each student operator is issued an In-Service Training Guide. When supervisors are changed, the training guide follows the student on to the current supervisor. The chance to perform some procedures comes only infrequently and thus must be taught as the opportunity arises. The guide contains a record of when the subject matter was explained to the student and when the student performed the task. For the period of time deemed necessary, the trainee observes and listens to the business and emergency calls. The trainee is instructed in the miscellaneous duties that are necessarily performed each day, such as cleaning duties, files, attendance sheets, signing log sheets, etc. The supervisors utilizes spare time to set up hypothetical situations and allow the trainee to solve these problems, make mock dispatch cards, simulate dispatching, etc.

COMPLAINT OPERATOR/DISPATCHER OPERATING PROCEDURE MANUAL

TABLE OF CONTENTS

Fig. IV-9 Contents of Operating Procedure Manual

The selection and training of the police telecommunication system personnel directly affect the performance of the system. The staff forms an element of the system whose selection and training requires as much care as does the purchase and maintenance of equipment.

CHAPTER V

DESCRIPTION OF POLICE TELECOMMUNICATION SYSTEMS

The objective of this chapter will be to explain the important features of police radio communications that create and have an impact on the communication *system*. The reader will thus become aware of the way in which the basic elements—equipment, procedures, organization—together form a system that has attributes and requirements not necessarily inherent in its individual components. In particular, this chapter will contain a detailed description of the various types of municipal and county radio systems and the requirements which these systems must meet.

First of all, the various functions which a system may perform will be described, including communication within and between departments and with other public safety agencies. The most common types of radio communication systems currently used by municipal departments will be described both for the general reader and in greater detail for the more technically knowledgeable reader. The equipment configurations and organizational configurations will be treated separately, with particular mention of the consequences each has for the other. Finally, the requirements on a system will be discussed.

Requirements fall generally into two categories—performance requirements and externally imposed requirements. Among the former are the allowable amount of delay in gaining access to a channel, the quality and effectiveness of the messages, the reliability of the system (both operational and equipment reliability) and the degree of flexibility in altering operational procedures, equipment utilization or organizational configurations. The externally imposed requirements include the FCC regulations, licensing, spectrum availability, legal constraints, economic limitations, and the general need to fulfill certain expected community services.

V.1 Functions of a System

A police telecommunication system performs a number of functions in the necessary transfer of information to support required police services. These functions are responsive to the elementary needs found in most communication systems; namely,

- The need to transfer information in messages between prescribed individuals, groups and organizatons leading to conceptual "paths" of information flow

- The need to store information for various intervals of time and to retrieve the information in a timely manner
- The need to assess, as a function of time, the state of affairs in the information flow in order to schedule and utilize the system resources

Before examining the way these needs are satisfied, we shall first define just what a police telecommunication system *function* is.

By a *function* of a police telecommunication system we shall mean the process* which must be carried out by a system to fulfill an information handling need of the department. A function, therefore, is identified by the first two, or all three of the following items:

- Information to be conveyed
- The communication path to be furnished
- The information to be stored and the means to do so

A communication path includes the two terminals of the path as well as the means and direction of message flow. The terminals include the calling party and called party, which are often designated the originator and the destination of information. Thus the communication path consists of all equipment, radio channels, telephone, teletypewriter, data circuits and personnel required to convey information from an originator to a destination. As applied to police telecommunication systems, functions associated with the first need are divided into the following main categories:

- Communication between the public and the police department
- Communication within the police department
- Communication among police departments
- Communication between the police department and other agencies

Each of these functions is discussed separately with examples given of the information exchanged. In each case, common methods for carrying out the information transfer are discussed.

The second need, to store information, exists in each of the above four categories. It involves the range of activities from the note-taking of an individual officer to centralized storage of records in files or digital computers. The telecommunication system aids in the transfer of information to and from storage in each category, but most notably in association with centralized data banks and information retrieval systems. These are discussed in this section. The interaction between information storage systems and a police telecommunica-

*In other words, the process is simply the things the system must do.

tion system is both significant and of considerable scope. This subject is treated in Chapters VI and VII because of its influence on the system evaluation, modification and design. Finally, the third need is discussed in association with the latter three categories, particularly for communication within the police department.

V.1.1 Communication Between the Public and the Police Department

Most of the information reaching a police department from the public passes through the public telephone system, when the telecommunication system is involved. (Person-to-person contact or the mails do not, of course, involve the telecommunication system.) Telephone calls to the police emergency telephone number may be routed directly or indirectly to a complaint operator, who must obtain enough information from the caller to decide on the next step to take. The majority of calls involve:

- A request for assistance
- A request for information
- An offer of information to the department

In addition, calls for members of a department other than the complaint operator must be routed to the proper person.

V.1.1.1 Request for Assistance

A request for assistance from a citizen may require immediate action, as when the caller reports a crime in progress or an injured person. Many calls from citizens are clearly of an emergency nature. In such cases, the complaint operator conveys the necessary information to the radio dispatcher. (Often, the complaint operator and the radio dispatcher are the same person, eliminating this step in the process.) The dispatcher, using the two-way radio system, will then assign the appropriate personnel, such as a patrol unit to respond.

Some calls to a department are not of an emergency nature, reducing the need for priority handling. When the dispatcher receives the information he may, for instance, decide to assign the call to a patrol unit which is currently unavailable. Thus, the message waits until the unit has returned to service. Examples of requests in this category are the complaint about a neighbor's dog, or the report of an apparently abandoned automobile.

Most complaint calls are not clearly in either the emergency or non-emergency category, however. An operator must avoid the assumption that a complaint is not urgent, for the cost of an error in judgment may be high. He must therefore treat all such doubtful calls as if they were urgent, representing true emergencies. Every experienced police communicator knows of instances in which a routine request was found to be a serious emergency by the investigating officer. A complaint about a noisy party or quarreling neighbors may be a situation bordering on or erupting into violence. A loose, stray dog may have bitten a child, a report of a ransacked house may uncover the burglars still in the building and a man staggering or falling in the street may be having a heart attack. Each such call for aid may, of course, turn out to be a routine matter that was not particularly urgent. A small percentage, however, require immediate response. Since they cannot be predicted, all such doubtful requests must be handled without delay.

V.1.1.2 Request for Information

Many calls to the police emergency telephone number are merely requests for information. When is the parade due to start? What are the parking regulations on such-and-such a street? Is it legal to water the lawn after 9 pm? How long after purchase can a car be driven without license plates? Many other requests for information are made of police—often less appropriate to a law enforcement agency than these examples. The complaint operator generally must handle all such routine questions himself, transferring the caller to another member of the department only if he cannot answer the question, or if the answer can only be given by a person with responsibility to make the judgment or decision involved. In many small communities (and even some not so small) the only agency the public can easily turn to for general information about community affairs is its police department. After the normal business day, and on weekends, the police department may be the only municipal agency that is open to the public. Police departments, even in large cities, must consequently be a source of all types of information.

V.1.1.3 Offer of Information

Citizens frequently supply information to their police department. Such an offer may not require assistance to the caller, or even an immediate answer. Some examples are: A report of a traffic light out or a sign knocked down; notification that the residents will be away from their home on vacation; tips on the commission of crimes or the activities of suspected criminals; and a host of others. The complaint operator who receives this information must decide whether to merely record it, to respond with a specific patrol assignment, to transfer the callers to another member of the department, or other public service agency. If he chooses to record the information himself he must then make sure it eventually reaches those members of the department who will utilize it.

Other types of communication between the public and the department pass from the police to the public. The telephone system is often used for this purpose. These include requests for victims of a crime to appear at the police station to identify suspects or recovered property, or reports on the progress of an investigation involving the citizen. To reach an individual citizen, the telephone is the only element of the telecommunication system that can be used directly. There is, in some departments, another communication path to the general public. This is an arrangement by which the press and broadcasting media receive information from the police. While this normally may involve the telephone system, radio is sometimes used.

Specifically, the department may install police radio receivers or special intercom units in the newsrooms of local newspapers, radio and television stations. A signal from the dispatcher turns the receivers on when messages of public interest are broadcast. This becomes useful during major emergencies or disasters involving the entire community. By "tuning in" the press on the police radio, the department may forestall a deluge of telephone calls inquiring about the emergency, both from the press and from the public.

V.1.2 Communication Within the Police Department

Information received from the public must eventually be transferred to police officers in the field to enable them to act on it. This involves communication within the police department, and is usually accomplished by the two-way radio system. The radio system must provide:

- Dispatch instructions to the field forces
- Tactical communication between supervisory personnel and field forces
- Status communication among the members of a department
- Dissemination of information among members of a department

The radio system is used primarily to transfer information between the communication center and police officers in the field. The speed with which a modern system operates allows the police department to respond quickly to a plea for help. A police officer on duty always has a general assignment to patrol a beat, direct traffic, or carry out an investigation. The radio system is used to change that assignment or to assign him to carry out a specific task within the general instructions.

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V.1.2.1 Dispatch Communication

The bulk of the dispatch messages are in the form of definite assignments given to individual patrols. For example, "412, report of prowler at 749 High Street," is an instruction assigning the patrol unit No. 412 to proceed to a specific location. It also states the purpose and urgency of the assignment. In practice, many departments use the APCO ten-code,[1] (in this case, 10-14) instead of the phrase "report of prowler" to shorten the message and make it as clear as possible.

Several different types of assignment instructions pass over the telecommunication system. Some are assignments to provide assistance to a complainant, similar to the example above. Others are instructions to take on a routine assignment; directing traffic, for example. Still others are administrative instructions, such as to report to the station or to meet another officer at a specific location.

V.1.2.2 Tactical Communication

Another main use of the radio system is the direction of tactical forces in the field. Sealing off an area and searching it for suspects can be effectively coordinated by radio. Crowd control and civil disturbances also frequently require field commanders to direct their forces from minute to minute. Control over a sizeable police force in one area may be required. The command level personnel cannot make intelligent decisions about deployment unless they obtain constantly updated information from their forces on the situation from moment to moment. The contact with radio equipped members of those forces enables the information to be gathered and acted upon at the command level.

Some dispatch and command communication also takes place over the telephone, especially if the instructions are lengthy or must be kept confidential. If the department is large enough to have a fair amount of this type of communication it may have special telephone circuits, using unpublished numbers. Some departments also have a call-box system which is, in effect, a private telephone system. Periodic call-in allows instructions to reach patrolmen over this system as do calls in response to radio transmitted instructions.

V.1.2.3 Status Communication

The status of most of the members of a police department is kept current by use of the radio system. Status reports from field personnel, such as "72 out of service for lunch at Joe's Diner", "412 arrived at 749 High Street", or "35 out of car for check of Shopping Center", are just some of the messages which inform the dispatcher and all other listeners of the location and activity of a particular unit. It is most essential for the dispatcher to know the status of every patrol unit under his control, so that he knows which are available for assignment.

The use of the radio system to convey messages of this nature addresses the third need described previously in Section V.1. It is the most common example of collecting supervisory information related to police operations and resources.

The knowledge which supervisors and other officers on patrol have by monitoring the radio messages is important in the performance of their duties. The radio communication system makes the immediate, widespread dissemination of this information possible. Some status reporting takes place by telephone and call box systems, also. In these cases the information is obtained only by the person called and those he may inform directly. In certain kinds of investigative work this method rather than wide dissemination by radio may be desired.

It should be pointed out that the knowledge of the status of a large part of a department's on-duty force by all of that force extends beyond the formal status reports of "in-service", "out-of-service" and so on. By means of the radio communication system almost every officer monitoring a given channel can know the whereabouts and assignment of almost every other officer operating on the same radio channel. In terms of mutual support and readiness to respond to emergencies, such knowledge is invaluable to a department.

V.1.2.4 Dissemination of Information

The police telecommunication system, especially the radio system, is used for distributing important information quickly among the members of a department. Such information as descriptions of suspects or missing persons, time announcements and many others are broadcast over police radio. Some go from the dispatcher to mobile units, others go from a particular squad to the dispatcher, and then usually to all others monitoring that radio channel. The information disseminated this way helps supply the members of a department with the overall picture of police activity and the specific information they need to do an effective job.

On police radio channels that suffer from congestion due to a high volume of message traffic, care must be exercised regarding transmission of information. It is possible to consume a large amount of air time broadcasting routine information or long lists (such as stolen auto lists, for example). If the channel is crowded, information that has less time urgency than status and dispatch messages should be postponed until a less busy time, or perhaps disseminated by other means. In short, since the radio channel is not an unlimited resource, it must be wisely used. It must fulfill its most important functions before it gets "used up" (during some particular time period) performing some lower priority function.

V.1.3 Communication Among Police Departments

An important function of the total police telecommunication system is maintaining communication between police departments that have common information needs. This exchange may be divided into two kinds of communication—directed and incidental. Directed communication is the conveying of information from one department to one or more specifically selected departments. Incidental communication is the exchange of information among departments that is a by-product of the primary purpose of the communication.

An example of directed communication among departments is the exchange of stolen auto or missing person information between two particular departments. This may be accomplished by telephone, teletypewriter or radio. If teletypewriter or radio are the means of transmission, the information may be directed to more than one specific department. It is common practice to disseminate such information to departments in the surrounding communities. Directed communication also consists of inquiries and replies on vehicle registration, driver licenses, warrants and stolen articles. Such information may pass between small departments and a larger one that serves as a clearinghouse for such information for a particular region. A major use of directed communication among police departments involves a central information retrieval system operated by a police department. However, many of these systems are operated by governmental agencies other than police departments, so that the communication involved falls into the category discussed in the next section—Communication with Other Agencies.

Incidental or non-directed communication among departments occurs whenever one department monitors the transmissions of another, although the information is not specifically intended for interdepartment distribution. Most of this kind of communication takes place by radio, especially among departments that share a radio channel. This kind of communication is no less important than directed communication, for it allows one department to be aware of situations in another community that may "spill over" or involve it directly in a short time. This kind of monitoring of nearby departments' transmissions helps the listening department anticipate the need for mutual aid and enables it to be aware of the level of police activity in an area larger than its own community boundaries. If two communities anticipate a need for mutual aid or cooperation they frequently monitor each other's calls even when they are not on the same channel. In that case, monitor receivers at the dispatcher positions are generally used.

Two other aspects of this type of information exchange must not be overlooked. The first is an advantage of mutual monitoring on the same channel. Not only the dispatchers, but also the individual patrolmen are aware of the police activity in the surrounding area because of such mutual monitoring. Especially in small departments with only a few units on the street, the security of the officer patrolling an isolated beat is increased by the incidental communication with nearby squads from other departments. A second aspect is a disadvantage that results when several departments operate on the same radio channel. The greater the number of users that occupy the same channel, the more likely it is that there will be some delay in getting messages on the air. Channels with many departments on them may be so crowded with message traffic that delays are normally expected during every busy period. Thus, when departments have a choice of channels on which to operate, they must weigh the advantages of mutual monitoring by all system users against the disadvantages of greater message traffic and the resulting problems of channel crowding. This judgment will be greatly influenced by the alternative modes of communication that exist between the departments involved. These may consist of ordinary or special telephone links, teletype circuits or additional radio channels. In some areas of the country, particular channels are dedicated to point-to-point use, and link together many police radio base stations on one single-frequency, simplex channel. In other areas a microwave network serves this purpose. The effectiveness of such point-to-point channels depends on the number of users and the type of message traffic on them. If too many departments are on the same channel, or if it is used for lengthy messages, it may become quite useless for urgent communication between departments.

In several states, a special radio channel for mobile use only has been licensed so that police officers from adjacent jurisdictions can communicate directly with each other. Administered by the State and using a separate radio in each patrol vehicle, such a channel can serve both normal interjurisdictional communication needs—for instance, for use during prisoner transport—and emergency communication during widespread disasters—as in case of storms, earthquakes, floods, etc.

V.1.4 Communication Between Police Departments and Other Agencies

Police departments exchange information with other, non-police agencies in a variety of ways. Perhaps the one most closely associated with law enforcement functions is the submission of inquiries to central information retrieval systems. These may be for vehicle registration, driver license, warrant or stolen property checks. They are usually transmitted over teletypewriter networks, although leased telephone lines with data terminals or microwave links are also used. Many centralized information storage and retrieval systems are administered by agencies such as a state highway department, a department of motor vehicles, or other state, regional or county agencies with either criminal justice responsibilities or data processing facilities. The prime requisite of this type of information exchange is that it be rapid and accurate. With the increasingly wide use of computerized data retrieval systems it is possible for inquiries to be answered in a few minutes or even seconds. If the data retrieval system is itself capable of such speed and has the capacity to handle the demands made on it, then a reliable data link with sufficient capacity can insure rapid access to the stored information by every police department in the network.

Another major category of communication between police and other agencies is that class of information which the police passes on to other municipal county or state agencies. Reports of traffic light failures, flooding, road damage, fallen trees, and the like are often made to the police and must then be passed on to the appropriate agency. This may be a public works, street, sanitation, forestry or animal welfare department. The police must also maintain adequate communication with fire departments in their area, since many fires require police assistance for traffic and crowd control. Additional communication must also be maintained with hospitals, ambulance services, towing companies and public utilities.

Much of this communication is carried on by telephone, sometimes with leased lines. Some is achieved by installing monitor receivers in the agency involved. If these can be activated by the police dispatcher, the other agency does not have to be bothered by the police radio traffic not directed at them. Most of the communication with other agencies goes through the complaint operators and dispatchers. Therefore, the amount of traffic, and the means for handling it, should be periodically checked to make sure that the primary functions of complaint processing and of dispatching are not impaired.

A third type of communication with other agencies occurs during major catastrophes or emergencies. Such situations may be occasioned by plane wrecks, violent storms, widespread fires, civil disturbances or a host of other events. They have in common the need for fast, continuing communication between one or more police departments in an area and many other governmental and public or quasi-public agencies. Some are also accompanied by the likelihood that normal means of communication, such as the telephone system and those means relying solely on commercial power, have themselves been damaged or disabled. Three aspects of those communication requirements are appropriate to note here.

- *Prior planning:* Under emergency conditions there is no time to set up new communication links. They must have been planned beforehand. Thus, the telecommunication system of a police department is not complete unless contingency plans have been made for the emergency situations likely to arise.
- *Message volume:* The second aspect to note is that the volume of messages that must be handled during such an emergency is likely to exceed most estimates. Therefore, plans for such occasions must include means for handling the volume of message traffic so as to prevent system breakdown merely due to overloading.
- *Language barrier*: During certain types of emergencies, communication with National Guard and U.S. Army units is required. The standard language of police radio is not used by the military. The APCO ten-code and phonetic alphabet are cases in point. Therefore, liaison personnel familiar with radio language of the police and the assisting organizations is needed to maintain effective communication.

The portion of the communications with other agencies that can be handled by telephone in emergency situations can usually be planned for in conjunction with local telephone companies. Presuming that the telephone system facilities have themselves not been damaged in the emergency, the flexibility and capacity of the telephone switching system is such that prearranged emergency facilities can be made available. In widespread disasters or emergency situations they may well be damaged or destroyed, however. Then radio communication remains the only means of rapid communication with other agencies. During emergencies liaison with military organizations, public works departments, fire departments and others may be necessary. These agencies ordinarily operate on different radio channels than the police. To achieve communication with them requires that prior arrangements for such events be made. It may be achieved by mutual monitoring of transmissions, loan of equipment, setting up of joint communication posts, or the use of specially reserved emergency channels. In any case, the method to be used must be planned beforehand and periodically tested.

V.1.5 Centralized Data Banks and Information Retrieval Systems

Large communication networks involving all aspects of communication (mail, telephone, teletypewriter, microwave, mobile radio, facsimile, etc.) which support criminal justice information systems are presently operational on a federal, state and local level. In conjunction with these networks, information retrieval systems and data files have been implemented using digital computers (electronic data processing) for storage of law enforcement related information. The digital computer offers the advantages of rapid access to stored information, rapid access memories whose capacities are sufficiently large for many current law enforcement applications, and access from both local and remote terminals. Further, more than one terminal can simultaneously request information from a number of appropriately designed computer systems.

A computer system may be used entirely within a single department if the department size and needs are large enough to allow use of a commercially available computer. A telecommunication system then involves only the interconnection of the computer input/output devices with local and remote terminals, usually within a single building. Computer systems which are used by a number of law enforcement agencies are more common and consequently are given more attention in the discussion presented in this section. A brief introduction of major computer functions as they relate to law enforcement agency applications is given. Planning guidelines are set forth so that the reader can ascertain where to begin when he tries to match department or agency needs with available systems.

It is appropriate to point out that a department may often obtain the use of existing computer systems and data files simply by acquiring the required data terminal. This situation differs from the application of a new computer system to a department or group of departments and agencies. In the latter case, the needs and requirements must be specified not only for purchase or lease of the computer system equipment, but also for the development and operation of the associated computer programs. Finally, the data to be stored initially in the computer must be key punched or suitably processed. A number of these observations become apparent from use of the methods given in Chapters VI and VII.

V.1.5.1 Role of the Computer

The computer may serve in three basic capacities:

- A data storage and retrieval device
- A logic device serving as the hub of a complex message transmission network
- A computational device performing certain operations on stored data

As a storage and retrieval device, it can supply pertinent information within seconds to field personnel. In its message switching capacity, the computer can serve as the exchange center for a network of terminals, that is, for the sources and recipients of the messages in the system. It may direct messages from one terminal to one or several others as directed by the sending terminal. The computer may maintain records of messages, store messages when they cannot be delivered, generate reports of message traffic, and in addition, may connect the message network to another network, or to another computer. As a computational device, the computer can perform such administrative tasks as processing payrolls, maintaining personnel files, controlling inventory and equipment maintenance. It may also be used for such tasks as the compilation of crime report statistics, the analysis of traffic accidents, and optimum manpower utilization forecasts.

In its first two capacities, the computer functions directly as a law enforcement tool, while in the third, it is utilized as an aid in management, administration, and operations analysis and planning.

The data stored in a computer are kept in what is commonly known as a data "file". Typical examples of data files are given in Table V-1. This listing includes data of the type which when required must generally be retrieved in a matter of seconds. Requests for such data are usually made directly by field law enforcement personnel. The listing in the second half of the table is broader in nature, encompassing data of use to law enforcement agencies, management and administrative personnel, courts, prosecutors, parole and other agencies.

The lists are indicative of the types of data presently being utilized by law enforcement agencies. The listing is not all inclusive, and in addition, not all these data would be entered into any one computer storage. In any particular case, the specific data stored is dependent both upon the needs of the agency and the capacity of the computer.

Instructions to the computer constitute a program whether they are in the form of key-punched cards, magnetic tape or other forms. The program may be simple, consisting of no more than instructions for the retrieval of some information stored in the machine. More complex programs may call for manipulation and analysis of all or parts of the stored data, possibly with logical decisions being made by the computer at intermediate steps. In order to illustrate the flexibility of the computer, typical examples of the applications which have been used by various agencies are given below. The observation must be made that in small departments, all of these activities are performed manually. This has also been true in the largest departments prior to the introduction of digital computer technology. The computer becomes attractive in support of police operations and management when it performs these manual tasks more rapidly and with fewer errors. Cost is always a factor, but not always the only major factor to be considered.

TABLE V-1
TYPICAL COMPUTER DATA FILES

- Vehicle File
    - stolen, impounded, or repossessed
    - stolen license plates or identifiable parts
- Operator License File
    - personal identification
    - court convictions, revocations, or suspensions
- Vehicle Registration
    - vehicle type, year and identification number
    - license number and owner
- Wanted-Warrant File
    - wanted notifications and arrest warrants
- Stolen Identifiable Property
- Firearms
    - registration, permits, or stolen
- Criminal History (& Profile) File
    - names, personal appearance, or convictions
    - social history, finger prints, hand writing
- Modus Operandi—Criminal Pattern Recognition
- Organized Crime Intelligence Data
- Missing Persons
- Sex Offenders
- Narcotic Offenders
- Stolen Securities
- Pawnbroker Files
- Taxicab Operator Files
- Miscellaneous Permits
- Crime Statistics and Arrest Information
- Accident Records
- Field Interview Information
- Data for Administrative & Planning Purposes
    - inventory and personnel
    - maintenance and manpower utilization

(1) *Information Retrieval*

The simplest examples of information retrieval are instances where it is desired to check if certain license plates are stolen or a specific person is wanted on a warrant. It is assumed that the complete plate number and name are, respectively, known. A more complex situation exists when only partial descriptors are available. For example, to identify an automobile with make and model, but only part of the license plate number known requires special computer programs. An example of a more complex retrieval problem is the identification of a criminal by means of *modus operandi.*

(2) *Command and Control*

Computers often are elements of systems which obtain and display location and status of patrol cars. In turn, optimum car assignment can be made through use of appropriate computer programs.

(3) *Criminal Activity Evaluation*

The identification of high crime rate areas is aided by computers. In turn, predictions as to the location and time of expected criminal activity can be obtained.

(4) *Resource Allocation Programming*

Manpower needs and workload levels can be predicted. Beat structures can be redesigned so as to reflect changes in crime density patterns.

(5) *Case Reporting*

Case reporting can be made on a real time basis in such a way that computer files are updated automatically without a clerical intermediary.

(6) *Administrative Procedures*

Computers may be used to maintain and update personnel, payroll, training, motor transport, inventory and other records.

(7) *Message Switching Terminal*

The computer can serve as a central exchange center for a number of terminals. It is capable of directing messages from one terminal to another, maintaining records of messages, storing undeliverable messages, and generating reports of message traffic. It is also capable of interconnecting message networks and tying a network in with other computers.

V.1.5.2 Computer Systems

The use of computers for record keeping, statistical data processing, accounting, etc., by private businesses and governmental agencies has been a common practice for many years. These types of computers are basically computing systems, not generally tied in with other computers (although exceptions do occur), and are commonly referred to as off-line systems. Data processing is generally not done in real time. For example, a time lapse occurs between the time that it is recognized that a solution to a problem is desired, and instructions are given to the computer for solving the problem. On-line systems, however, do operate in real time. With on-line computer systems, it is possible to query the computer from a remote terminal, e.g., a teletypewriter, and have data processed and/or retrieved in seconds. Furthermore, access to data files in other computers is possible through the interconnection of networks, computers and terminals.

Computer and related facilities are owned and maintained by agencies at all governmental levels, e.g., Federal, state, county, and municipality. Generally, access to certain data files is granted to other qualified agencies, which may include not only law enforcement agencies, but courts, prosecutors, and probation, correction and parole agencies as well. In many instances, computer facilities and data transmission networks have been generated along regional and geographical lines, thus providing lower costs to individual participating agencies, and more effective utilization of the computer as a law enforcement tool due to rapid interchange of data between agencies.

Some general planning guidelines are available. These coupled with the material of this section should enable the reader at least to begin to evaluate his needs relative to existing systems and practices. These guidelines may be formulated in terms of questions, for example:

- Are any of the applications of on-line computers suitable for the solution of my problems?
- How should the computer be coordinated with other available computer and data processing facilities?
- How should the system be designed to yield the greatest benefits?
- Is the cost of the desired system consistent with available funds?

In terms of system components, the replies to these questions should enable the following decisions to be made.

- Is a terminal (e.g. teletypewriter) alone sufficient to meet the needs of the agency?
- Is an "in-house" computer required?
- What types of data files will be stored in-house versus retrieval from other computer facilities?

The major factor, by far, is cost per hour of usage, which in turn is largely determined by the size of the community (agency) served and its proximity to existing facilities. For example, a small community located on the outskirts of a large metropolitan area may be most effectively and economically served by a terminal facility only. Manual record keeping methods may be completely adequate due to the low incidence of crime in the community. Meanwhile, the data terminal allows access to outside data files, both nearby urban and national, as required. For several small communities that are in close proximity, a common centralized computer may provide an optimum arrangement, especially if they are not near any large cities. A central clearing house for data is available with the advantage that costs may be pro rated.

For a large metropolitan area, the acquisition of a computer appears potentially attractive. High crime rates and a heavy administrative work load make manual operation inefficient. The question to be answered here is what size is adequate to efficiently perform the required operations and store the necessary data files.

With regard to data file storage, provision must be made to incorporate data of a localized nature in a computer serving a metropolitan area. Such data will simply not be available elsewhere. For other types of data such as motor vehicle registration, the decision to incorporate this into the computer storage is dependent upon the frequency of need and the increase in operational efficiency versus the cost of providing for increased machine capacity.

Computers are currently being used or planned by many departments serving communities of 100,000 population or larger. It would seem that communities smaller than this must enter into cooperative arrangements to make a computer installation economically practical. The size of the police forces in the cities with computer installation varies considerably. However, among cities replying to a survey of computer use by police, conducted under the auspicies of the International Association of Chiefs of Police, the smallest departments with computer installations had forces of approximately 200. This can be used as a rough indication of the size of the police forces needed to justify operation of a computer system.

V.1.5.3 Representative Computerized Information Retrieval Systems

Table V-2 is a compilation of a number of representative information retrieval systems in use throughout the country. It is presented for information purposes to give the reader an insight into how the computer is utilized.

The table is divided into four parts, considering separately systems at the federal, regional, state and local levels. Each listing is divided into three parts; a tabulation of the files kept in the computer, functions performed by the computer in addition to data retrieved, and computer interface and/or data availability to other agencies. This particular breakdown allows the essential characteristics of the system to be portrayed without unduly lengthening the table. It should be recognized that some omissions may have occurred, and it is possible that some reported systems are not fully operational in all respects.

In the last column, "Interface with other agencies and systems", an attempt has been made to indicate the direction of information flow, e.g., "1" indicates information (other than requests) flow from the computer system being described to the agency listed in the third column; "2" indicates the reverse flow of information.

V.2 Types of Systems Which are Used

V.2.1 General

One police telecommunication system differs from another by its equipment characteristics, the way the equipment is arranged to form the system, and the operational and administrative organization of the system users. Different combinations of these factors have produced different systems in response to the historical development in an area and the peculiar requirements of a community and its police department.

Groups of departments may share facilities, spectrum space, or administrative structures and thus form a telecommunication *network*. Common forms of networks will be discussed and illustrated below.

A basic distinction is made in terms of the first two functions of a system—communication between the public and the department, and communication within the department. These functions are performed either independently of other police departments or they involve sharing of facilities, spectrum or administration with other departments.

If a department performs these two functions independently, it can utilize any organization of people and equipment which best suits its own requirements. If it shares with other departments, however, the best organization must be determined by the combined requirements of all departments involved. This may result in compromise to find an organization which is best suited to satisfy the combined requirements.

Table V-2

Representative Law Enforcement Information Retrieval Systems

Data File Contents	Functions in addition to information retrieval	Interface with other agencies and systems
	FEDERAL LEVEL	
	National Crime Information Center (NCIC)	
1. Stolen vehicles 2. Stolen license plates 3. Wanted persons 4. Stolen firearms 5. Stolen property 6. Criminal profiles & histories 7. Stolen securities		1. States (1,)* 2. Washington, D. C. (1) 3. Canada (1)
	System for Electronic Analysis and Retrieval of Criminal Histories (SEARCH) **	
1. Criminal histories	Develop statistical and analytic base of criminal justice information	1. Participating states (1, 2) 2. Government justice agencies (1)
	REGIONAL PROGRAMS	
	New England State Police Administrator's Conference (NESPAC)	
1. Criminal information files		1. Police agencies in six New England states (1)
	Washington Area Law Enforcement System (WALES)	
1. Vehicle information 2. Personnel information		1. Police agencies in Washington, D. C. (1) five adjoining counties 2. NCIC (2)
	STATE NETWORKS	
	California Highway Patrol Automatic Statewide Auto Theft Inquiry System (AUTOSTATIS)	
1. Stolen & wanted vehicles 2. Stolen license plates 3. Stolen auto parts 4. Repossession reports		1. Police agencies throughout California, Airzona and Nevada (1) 2. Police Information Network (PIN) (1, 2)

* "1" indicates information (other than requests) flow from the system to the agency listed. "2" indicates the reverse flow of information.

** Scheduled to be operational in the summer of 1971.

Table V-2 (continued)

Data File Contents	Functions in addition to information retrieval	Interface with other agencies and systems
California Law Enforcement Telecommunications System (CLETS)		
NONE	Centralized computer for message switching	1. Alameda County, (PIN) (1, 2) 2. Los Angeles, (SPIN) (1, 2) 3. California Highway Patrol (1, 2) 4. California Dept. of Motor Vehicles (1, 2) 5. Criminal Identification & Intelligence Agency (1, 2) 6. NCIC (2) 7. Nevada
California Department of Motor Vehicles Automated Motor Information System (AMIS)		
1. Vehicle registration 2. Driver registration		1. CLETS (1) 2. NCIC (1) 3. Western Area Network Telecommunications System (WANTS) (1) 4. National Law Enforcement Telecommunications Systems (NETS) (1)
California Department of Justice (DOJ)		
1. Criminal justice information stored in various participating agency computers	1. Message switching	1. Police (1, 2) 2. Prosecutors (1) 3. Courts (1) 4. Probation (1) 5. Correction agencies (1) 6. Parole agencies (1)

Table V-2 (continued)

Data File Contents	Functions in addition to information retrieval	Interface with other agencies and systems
California Bureau of Criminal Identification and Investigation (CII)		
1. Firearms file		1. Department of Justice (Calif.) (1)
2. Arrest statistics		
3. Narcotic prescriptions		
4. Charitable trust reports		
5. Misc. property files		
6. Modus operandi data		
7. Statistical reports		
8. Sex registrant file		
9. Narcotic registrant file		
10. Criminal history file		
11. Finger print file		
12. Master cross reference name file		
New York State Identification & Intelligence System (NYSIIS)		
1. Vehicle registration	1. Message switching	1. Police throughout New York State (1, 2)
2. Operator's license	2. Automatic license plate scanning	2. Prosecutors (1)
3. Firearms	3. Facsimile network for graphic data transmission	3. Criminal courts (1)
4. Criminal histories	4. Closed circuit television	4. Probation (1)
5. Finger prints		5. Correction (1)
6. Fraudulent checks		6. Parole (1)
7. Personal appearance		
8. Names		
9. Warrants		
10. Wanted Notifications		
11. Organized crime intelligence		
12. Stolen vehicles and parts		
13. Social history		
14. Modus operandi		
15. Missing persons		
16. Permits		
17. Stolen property		
18. Property marks		
19. Handwriting		
20. Voice prints		

439-911 O - 71 - 9

Table V-2 (continued)

Data File Contents	Functions in addition to information retrieval	Interface with other agencies and systems
New York State Police		
1. License plate file registration—stolen	1. Switching-messages 2. Message traffic reports	1. Various state police agencies (1)
Pennsylvania State Police		
1. Stolen vehicle file 2. Stolen other property	1. Message switching 2. Facsimile transmission	1. State police terminals (1, 2)
Louisiana State Police		
1. Vehicle registration 2. Stolen vehicles 3. Operator licenses 4. Accident Information	1. Message switching	1. NCIC (2) 2. National Law Enforcement Teletype Service (1) 3. Other state agencies (1)
Michigan State Police (Law Enforcement Information Network—LIEN)		
1. Vehicle file 2. Stolen vehicles 3. Stolen license plates 4. Repossessions 5. Wanted vehicles 6. Recovered vehicles 7. Warrant file 8. Operator license file 9. Criminal histories 10. Stolen property 11. Fraudulent checks 12. Finger prints 13. Sexual deviate records 14. Modus operandi 15. Gun and permit file 16. Accident and resource records 17. Administrative records	1. Message switching 2. Resource allocation	1. Various state police agencies (1) 2. Judges (1) 3. Prosecutors (1) 4. Certain state departments (1)

Table V-2 (continued)

Data File Contents	Functions in addition to information retrieval	Interface with other agencies and systems
Ohio State Law Enforcement Automated Data System (LEADS)		
1. Stolen vehicles and parts 2. Vehicle registration 3. Operators licenses 4. Stolen property 5. Wanted persons 6. Wanted guns		1. State highway patrol (1) 2. Local sheriffs (1) 3. Local police departments (1) 4. NCIC (2)
LOCAL LEVEL SYSTEMS		
Alameda County (California), Police Information Network (PIN)		
1. Warrant files 2. Modus operandi	1. Message switching 2. Traffic control	1. Police agencies in nine counties (1)
Chicago Police		
1. Stolen vehicles and parts 2. Warrants 3. Missing persons 4. Suspended & revoked licenses 5. Vehicle driven by unknown criminals	1. Message switching 2. Analysis of police operations 3. Criminal statistics information analysis 4. Business processing	1. NCIC (2)
St. Louis Police		
1. Wanted vehicles 2. Unserved arrest warrants 3. Criminal history 4. Vehicle registration 5. Field interview information	1. Message switching 2. Statistical data processing 3. Resource allocation	1. Other metropolitan agencies (1) 2. Missouri Highway Patrol (1) 3. NCIC (2)
New York City Police		
1. Finger prints 2. Criminal justice data bank 3. Crime statistics 4. Traffic accident information 5. Other	1. Administrative studies 2. Command & control system (SPRINT)	1. NYSIIS (1)

Table V-2 (continued)

Data File Contents	Functions in addition to information retrieval	Interface with other agencies and systems
San Diego, California		
1. Vehicle information file 2. Warrants 3. Stolen property 4. Modus operandi		1. NCIC (2)
Los Angeles (Southern Police Information Network (SPIN))		
1. Crime reporting 2. Warrant information 3. Field interview information 4. Finger prints 5. Stolen property 6. Pawnbroker records	1. Command and control system 2. Administrative procedures	1. Local police (1) 2. Department of Motor Vehicles (2) 3. NCIC (2) 4. AUTOSTATIS (2) 5. PIN (2)
Los Angeles County Sheriff Optimum Record Automation for Court and Law Enforcement (ORACLE)		
1. Law enforcement records 2. Finger prints 3. Photographic 4. Traffic violations 5. Arrests and breakings 6. Jail populations 7. Prisoner movements		1. Statewide criminal justice systems (1)

V.2.2 Telephone System Configurations

V.2.2.1 One-or Two-Number Systems

Police departments require three distinct types of telephone service for:

- Incoming complaint calls
- Incoming administrative or business calls
- Outgoing calls of all types

There must always be enough trunk lines available so that incoming administrative and outgoing calls do not use all the lines for incoming emergency and complaint calls. A department should lease enough trunk lines to handle the anticipated loads. It may use one or more trunk lines on the "emergency number" for all police calls or it may also establish a separate group of trunk lines on a second, so-called "administrative" number for callers who do not want emergency service. The lines on the "administrative" number can be used for outgoing calls without tying up any of the "emergency number" trunk lines.[2]

Several different types of lines are available and in use by police departments. These are described in Section IV.2.6 of Chapter IV. These lines terminate at the department in one of the following types of equipment, also described more fully in Section IV.2.6:

- Push-button or "key" telephone set for a small number of incoming lines
- CALL-DIRECTOR*, a push-button telephone set for a larger number of incoming lines
- Private Branch Exchange (PBX) for larger police telephone systems. This may be a manual switchboard (manual for both incoming and outgoing calls), or may provide automatic dialing for only outgoing calls. It may be provided with a Centrex system, which in addition, allows direct inward dialing to an extension. A PBX with Centrex capability must usually be implemented for all departments and agencies of a municipal government.

V.2.2.2 Complaint Processing Procedures

Incoming complaint calls from citizens which require dispatching police personnel to a particular location may be handled in several different ways. However, no matter which way is chosen, the steps in any process are basically the same. The difference between any one process and another depends on the way the individual steps are performed. They may

*Registered Service mark of the Bell System.

all be done by a single operator or distributed among as many as three operators as well as automatic telephone switching equipment. The steps in processing a complaint call are:

1. Receive the call on telephone equipment terminating incoming trunk lines
2. Switch caller to complaint operator
3. Record the complaint
4. Transfer the complaint information to radio dispatcher
5. Dispatch the appropriate police personnel

A complaint that does not result in the eventual dispatch of a patrol may be directed to the appropriate department personnel at any one of these steps. The caller may be switched to another extension to talk to a particular member of the department, the complaint may be recorded and referred to a member of the department other than the radio dispatcher, or it may be recorded for future action or information storage. In the first case the complaint call is handled the same as a business or administrative call—it is routed through the department telephone system to the proper extension. In the other cases, a voice recording or a written record may be made and stored, or it may be passed on to the appropriate personnel in the department for immediate or future action.

The simplest means for carrying out the above steps is to have a single person be the switchboard operator, complaint operator, and radio dispatcher. Because no message switching or physical transfer of information is required for the complaint to reach the dispatcher, this method is very efficient and, in fact, is the method used by many smaller departments.

When the work load becomes too great for one operator/dispatcher, the calls can be divided among two or more operator/dispatchers who each have the same duties. The process could also be divided by giving different duties to each operator. The latter, two-stage process, for example, would have a switchboard operator execute Steps 1 and 2, and a separate complaint operator/dispatcher carry out Steps 3, 4, and 5. With this arrangement, the first operator only switches the caller to the complaint operator/dispatcher and is not required to transfer any information. The main advantage is that callers who do not wish to talk to a complaint operator can be routed to another member of the department or handled by the switchboard operator without taking up the time of a complaint operator/dispatcher.

Another way to make this a two-stage process is to combine the switchboard and complaint operator functions in one person, while using separate radio dispatchers. In this case the switchboard operator/complaint operator records the pertinent complaint information and sends this to the radio dispatchers. The transfer may be made by messenger, conveyor belt, pneumatic tube, other mechanical devices or by manual transfer of complaint memos to the dispatcher. Many calls to a police department do not result in the dispatch of a patrol; these take the dispatcher's time away from the operation of the radio system. The advantage of this arrangement is that the dispatcher is not distracted by complainants. The disadvantage of this arrangement is that some time elapses between the recording of the complaint and its receipt by the dispatcher. Since the information is second hand, there is also a possibility for error. Oftentimes departments using this arrangement make provision for switching urgent calls directly to the radio dispatcher in order to reduce the time lapse and the possibility for error.

Finally, the process may be divided into three stages by assigning switchboard operation, complaint taking and dispatching to three separate individuals. In this case, complaint operators are not burdened with business and administrative calls, while radio dispatchers are again insulated from handling matters not requiring the radio system. The main drawback is the possibility of increasing the time delay between arrival of a complaint call and action by the dispatcher to radio information to the field forces.

In each of these arrangements, some of the message switching functions can be performed automatically rather than by an operator, especially if a Centrex system is used. This will reduce the switchboard-operator load compared to that for a manual system. However, it shifts some of the responsibility for finding the correct extension number from the switchboard operator to the public.

Only the most obvious features of these various arrangements have been discussed. The choice among them depends on other factors, including the volume of complaints and other calls to the department, the volume of radio messages, the size of the population and area being served, the size of the police department, the nature of the demands made on the department by the community, the organization of the department, its record system, and the boundaries of the telephone exchanges in the community. No single rule-of-thumb can be stated to make the choice an automatic one. Departments of a wide range of sizes in different areas of the country successfully use every one of these arrangements for handling complaint calls. Nevertheless, general experience indicates that communities with populations below about 40,000 to 50,000 normally use one person for all five steps. Communities with populations between about 50,000 and 100,000 generally use two. The addition of the second person is made only during the busiest shift for the departments near the lower end of this range. When the population is near or beyond 100,000, a third person is usually added to the busy shift, and as community size increases, more personnel is added to the other shifts. The more people are employed in the communication center the more likely it is that the complement on each shift will differ according to the system's needs. There are, of course, many exceptions to these guidelines, caused by particular local conditions.

The decision to give additional personnel all the same duties or to divide the five step process into two or three stages is less dependent on population size than on some of the other factors mentioned above. The procedures outlined in Chapter VII, combined with knowledge of a system's specific requirements and features, will aid in making this choice.

V.2.3 Radio System Network Configurations

The base-mobile radio system of a police department is, for most departments, part of a *network* in which frequencies, physical facilities or personnel functions are shared. The types of systems that we are considering are treated in terms of networks that generally include more than one department. In this presentation, therefore, a system with only one department becomes a particular example of the more general case. The basic factors which characterize a base-mobile radio network have been presented in Section IV.1.3 of Chapter IV. The five trade-offs that the basic factors give rise to are listed as:

1. Dispersed or central location of dispatching points
2. Dispersed or central location of base station equipment
3. Single-frequency or multi-frequency channels
4. Single-channel or multi-channel networks
5. Simplex or duplex operation of channels

All possible combinations of these five parts result in 32 unique network configurations. A cursory examination of the resulting configurations shows that eight of the thirty-two can be immediately eliminated because they specify a one-channel duplex link, which is impossible with commercially available equipment. The remaining 24 network configurations are listed in Table V-2, in which a network number is assigned to each unique combination. The 24 networks are shown in diagrammatic form in Figs. V-2 through V-25. Figure V-1 is the legend of the symbols and notations used in the diagrams. It is assumed that the dispatching centers are either in the same building as the base transmitting and receiving equipment or connected to them by land lines or the like. It is also assumed that there are at least two mobile units operating on each channel.

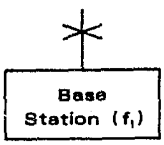
The network configurations are generated by choosing either one or the other of the alternatives in the five areas. While it is possible to have networks with both alternatives—e.g., inclusion of both simplex and duplex channels—what is learned from the study of each of the 24 networks separately is extendable to these other possibilities.

Table V-2
Possible Network Configurations for Five Trade-Offs

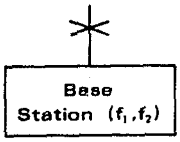
	Dispatching Personnel		Radio Equipment		Channel		Network		Operation	
Network Number	Central	Dispersed	Central	Dispersed	One-Frequency	Multi-Frequency	One-Channel	Multi-Channel	Simplex	Duplex
1		X		X		X		X		X
2		X		X		X		X	X	
3		X		X		X	X			X
4		X		X		X	X		X	
5		X		X	X			X	X	
6		X		X	X		X		X	
7		X	X			X		X		X
8		X	X			X		X	X	
9		X	X			X	X			X
10		X	X			X	X		X	
11		X	X		X			X	X	
12		X	X		X		X		X	
13	X			X		X		X		X
14	X			X		X		X	X	
15	X			X		X	X			X
16	X			X		X	X		X	
17	X			X	X			X	X	
18	X			X	X		X		X	
19	X		X			X		X		X
20	X		X			X		X	X	
21	X		X			X	X			X
22	X		X			X	X	X	X	
23	X		X		X				X	
24	X		X		X		X		X	

The most commonly encountered network configurations are those described in Chapter III. A single-frequency simplex system may be Network Type No. 6, 12, 18 or 24, depending on whether dispatching personnel and base station radio equipment are centrally located or dispersed. By far the largest number fall into the Network No. 6 category, in which each department has its own dispatching point and radio equipment located apart from other departments on the network.

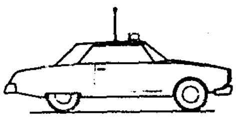
A significant feature of this configuration is that with no special arrangement, the same transmission can be heard by every receiver within range of the unit sending it. An example



Base station transmitting and receiving equipment.

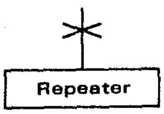


Base station transmitting and receiving equipment, transmitting on frequencies f_1 and f_2.

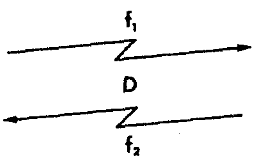


Mobile unit transmitting and receiving equipment.

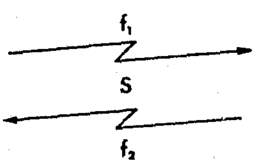
Dispatching location with personnel and communication center equipment other than transmitters and receivers.



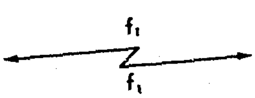
Repeater station transmitting and receiving equipment.



Duplex radio channel using two frequencies, f_1 and f_2.

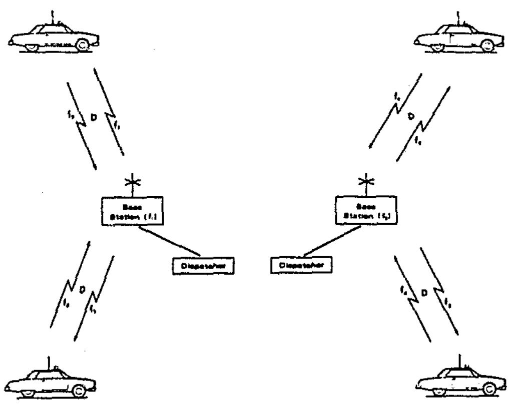


Simplex channel using two frequencies, f_1 and f_2.



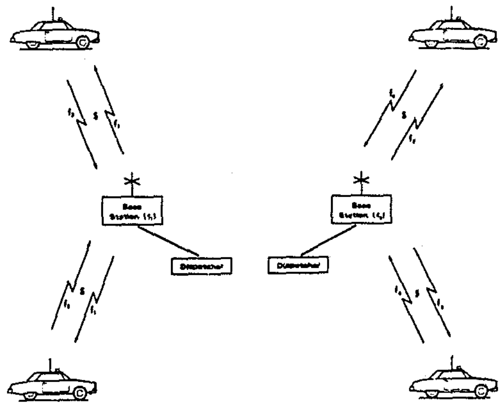
Simplex channel using one frequency, f_1.

Fig. V-1 Legend to Network Diagrams



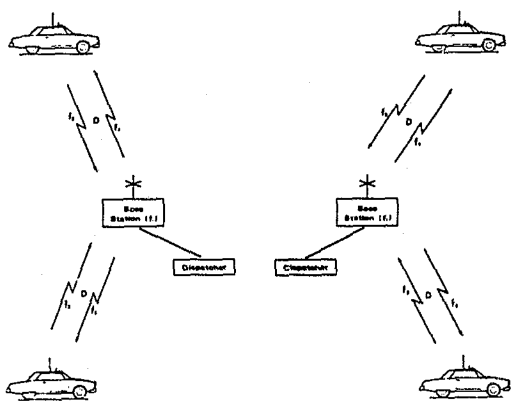
Dispersed Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
Multi-Channel Network
Duplex

Fig. V-2 Network No. 1



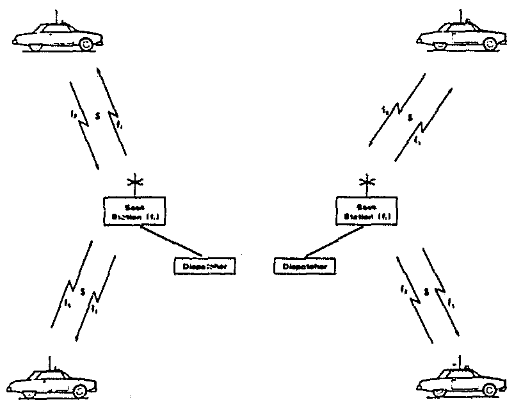
Dispersed Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
Multi-Channel Network
Simplex

Fig. V-3 Network No. 2



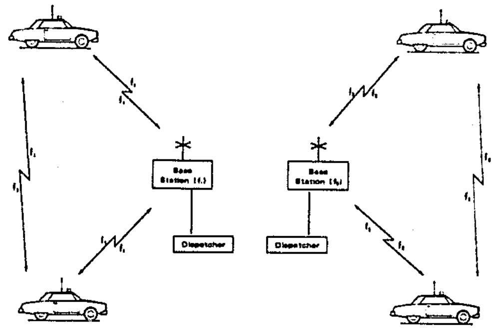
Dispersed Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
One-Channel Network
Duplex

Fig. V-4 Network No. 3



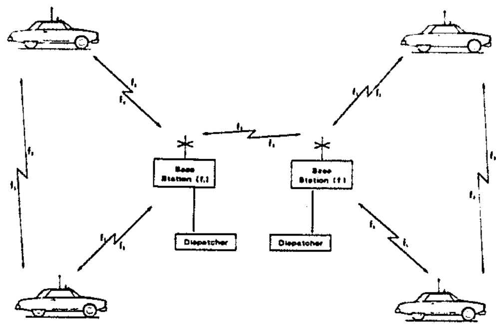
Dispersed Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
One-Channel Network
Simplex

Fig. V-5 Network No. 4



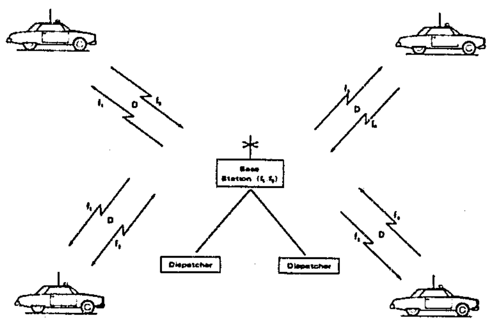
Dispersed Dispatching Personnel
Dispersed Radio Equipment
One-Frequency Channel
Multi-Channel Network
Simplex

Fig. V-6 Network No. 5



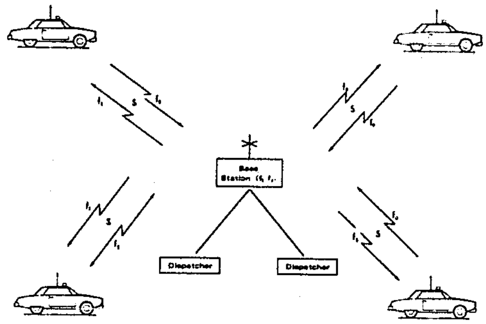
Dispersed Dispatching Personnel
Dispersed Radio Equipment
One-Frequency Channel
One-Channel Network
Simplex

Fig. V-7 Network No. 6



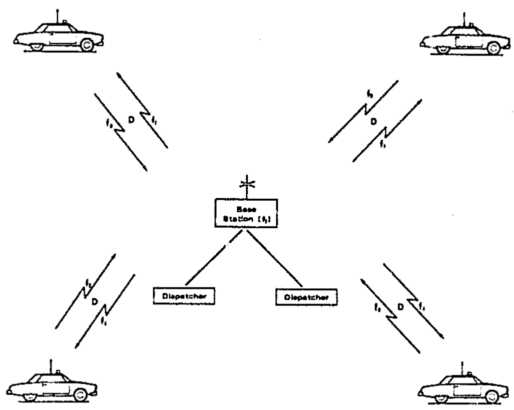
Dispersed Dispatching Personnel
Central Radio Equipment
Multi-Frequency Channel
Multi-Channel Network
Duplex

Fig. V-8 Network No. 7



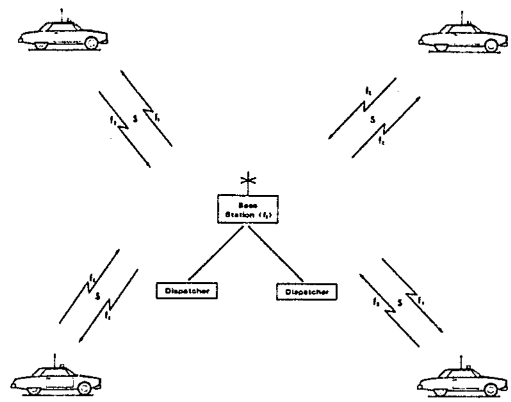
Dispersed Dispatching Personnel
Central Radio Equipment
Multi-Frequency Channel
Multi-Channel Network
Simplex

Fig. V-9 Network No. 8



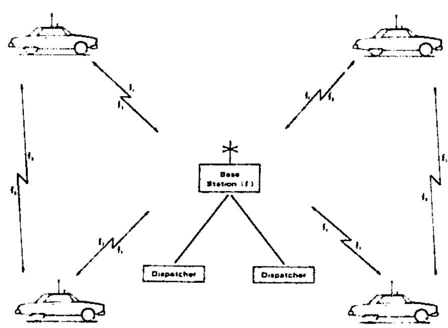
Dispersed Dispatching Personnel
Central Radio Equipment
Multi-Frequency Channel
One-Channel Network
Duplex

Fig. V-10 Network No. 9



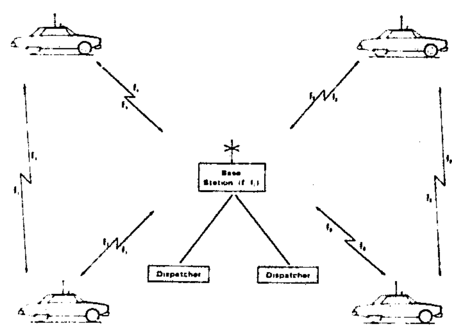
Dispersed Dispatching Personnel
Central Radio Equipment
Multi-Frequency Channel
One-Channel Network
Simplex

Fig. V-11 Network No. 10



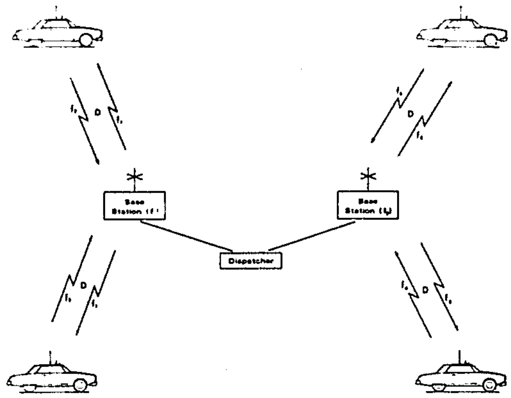
Dispersed Dispatching Personnel
Central Radio Equipment
One-Frequency Channel
Multi-Channel Network
Simplex

Fig. V-12 Network No. 11



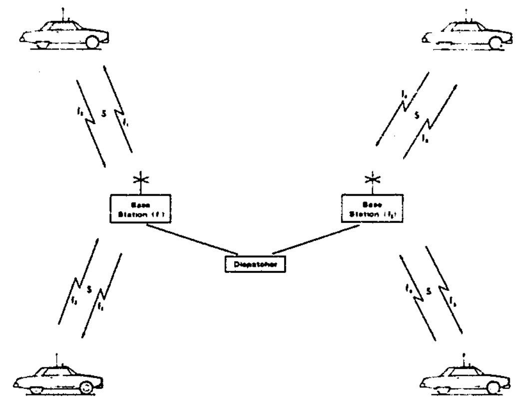
Dispersed Dispatching Personnel
Central Radio Equipment
One-Frequency Channel
One-Channel Network
Simplex

Fig. V-13 Network No. 12



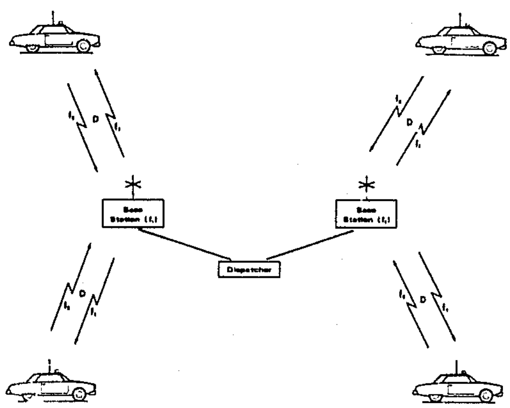
Central Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
Multi-Channel Network
Duplex

Fig. V-14 Network No. 13



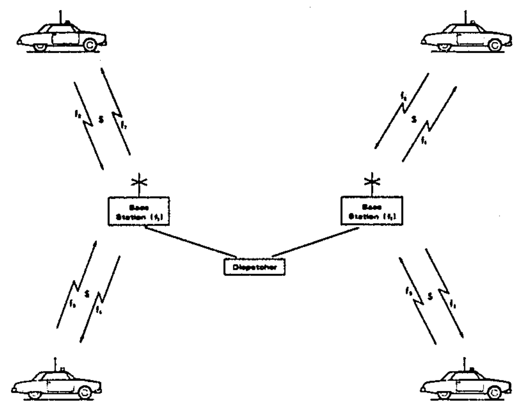
Central Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
Multi-Channel Network
Simplex

Fig. V-15 Network No. 14



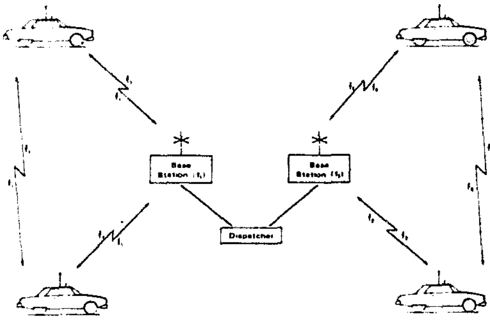
Central Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
One-Channel Network
Duplex

Fig. V-16 Network No. 15



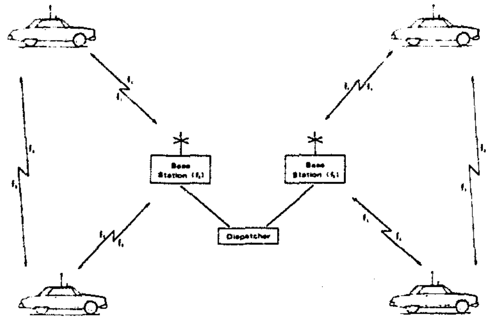
Central Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
One-Channel Network
Simplex

Fig. V-17 Network No. 16



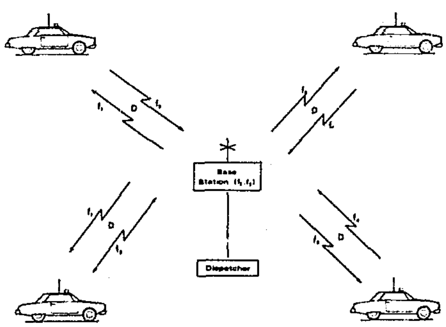
Central Dispatching Personnel
Dispersed Radio Equipment
One-Frequency Channel
Multi-Channel Network
Simplex

Fig. V-18 Network No. 17



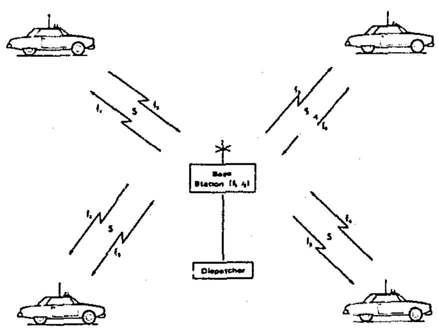
Central Dispatching Personnel
Dispersed Radio Equipment
One-Frequency Channel
One-Channel Network
Simplex

Fig. V-19 Network No. 18



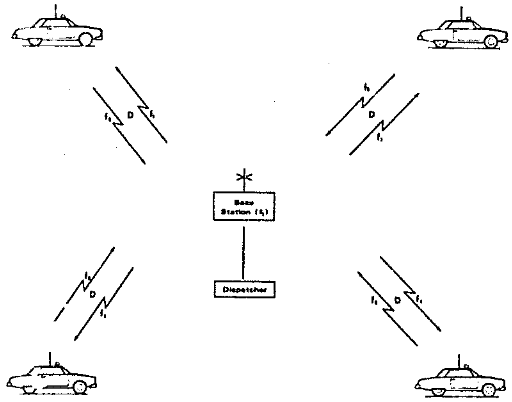
Central Dispatching Personnel
Central Radio Equipment
Multi-Frequency Channel
Multi-Channel Network
Duplex

Fig. V-20 Network No. 19



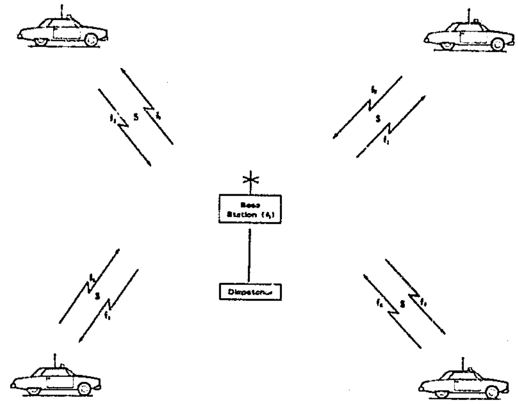
Central Dispatching Personnel
Central Radio Equipment
Multi-Frequency Channel
Multi-Channel Network
Simplex

Fig. V-21 Network No. 20



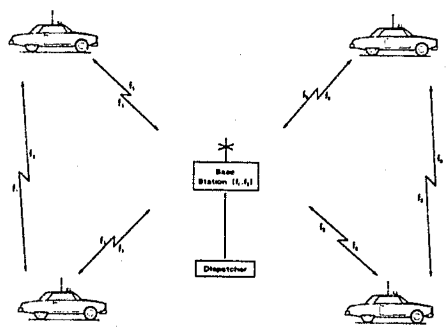
Central Dispatching Personnel
Central Radio Equipment
Multi-Frequency Channel
One-Channel Network
Duplex

Fig. V-22 Network No. 21



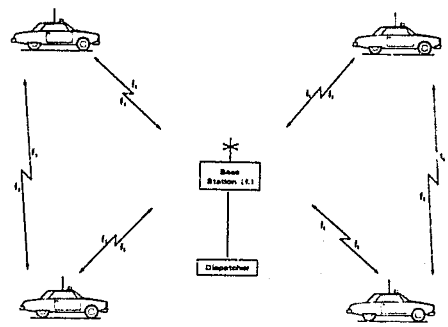
Central Dispatching Personnel
Central Radio Equipment
Multi-Frequency Channel
One-Channel Network
Simplex

Fig. V-23 Network No. 22



Central Dispatching Personnel
Central Radio Equipment
One-Frequency Channel
Multi-Channel Network
Simplex

Fig. V-24 Network No. 23



Central Dispatching Personnel
Central Radio Equipment
One-Frequency Channel
One-Channel Network
Simplex

Fig. V-25 Network No. 24

of how this configuration works is shown in Fig. V-26. If Officer Smith calls his base station, not only does the base station hear his call, but Officers Jackson and Jones may hear it too. Of course, they also hear the base station when it answers Smith's call. This listening arrangement is important for two reasons:

- Officers Jones and Jackson know what Smith is doing and where he is, which is tactically and psychologically important
- Officers Jones and Jackson know that Smith is talking to the base station and that they cannot use their radios to transmit while Smith and the base station are talking

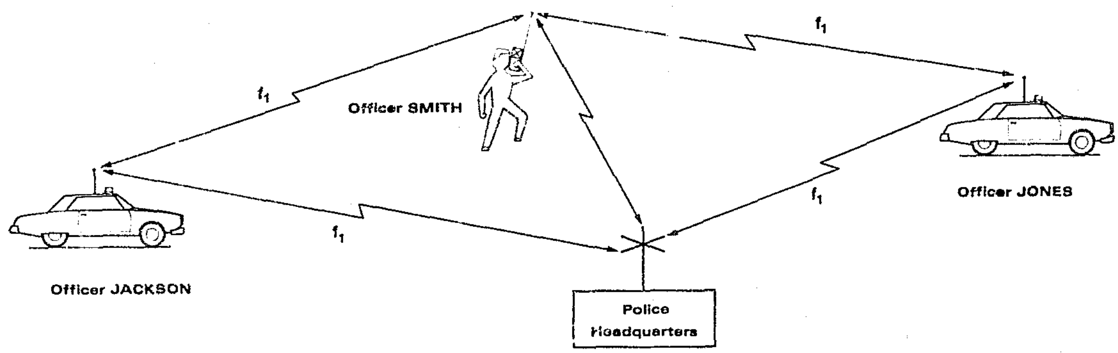


Fig. V-26 Single-Frequency Simplex Operation

The second point is crucial in preventing radio interference from Jones and Jackson. In any single-frequency simplex network which must be shared (as practically all are), each user must know when someone else is sending a message.

A two-frequency simplex system may be Network Type No. 4, 10, 16 or 22. Network No. 4, with dispersed dispatching and base radio equipment is again the most frequently used configuration. To see why this system is popular* in some cases, look at the example in Fig. V-27. Suppose we have two nearby police departments with radio systems in the cities of Jamestown and Elmville.

Both cities use a two-frequency simplex radio system and both base stations broadcast on frequency f_1 and their cars broadcast on f_2. The transmitters at both base stations are considerably more powerful than the cars' transmitters and the antennas are higher. Suppose

*FCC Regulations require that all systems in the UHF-band be two-frequency systems.

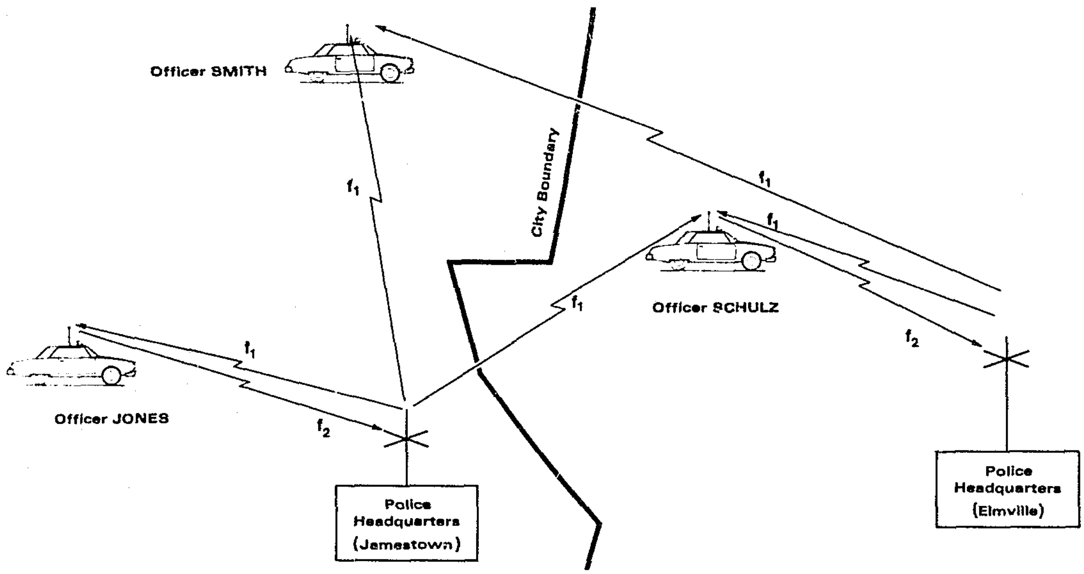
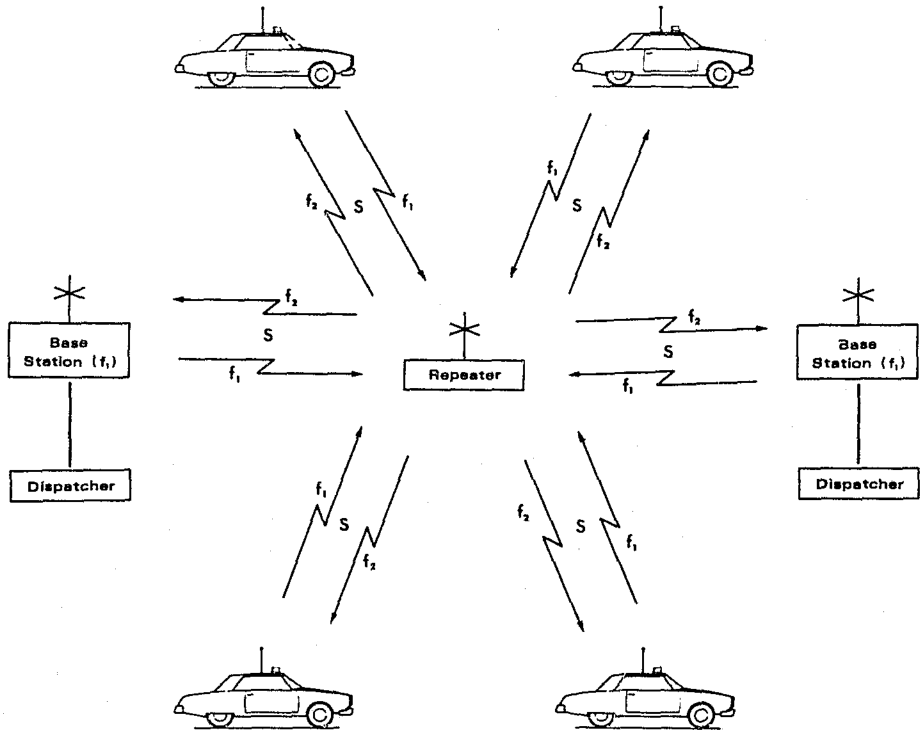


Fig. V-27 Two-Frequency Simplex Operation

that the two cities were using the single-frequency simplex system. If the Jamestown dispatcher were listening to Officer Jones on f_1, and the Elmville dispatcher were talking to Officer Schulz of their department at the same time—also on f_1 —then, most likely, all that the Jamestown dispatcher would hear would be the Elmville dispatcher talking to Schulz. (Radio waves know no city boundaries and the transmitter at the Elmville headquarters is more powerful than that in Jones' mobile unit.) This is an undesirable situation. To avoid this, the two-frequency simplex system shown in Fig. V-27 was adopted by Jamestown and Elmville. With this system it is impossible for the Elmville dispatcher to interfere with the Jamestown dispatcher's reception (and vice versa), because they transmit and receive on separate frequencies. For this reason, this system is desirable in densely populated areas with many police departments.

This system has some drawbacks, though. For example, if Officer Jones transmits to the Jamestown base station, Officer Smith cannot hear him unless he has an additional radio receiver in his car to listen to frequency f_2. Another way of avoiding this problem is to have the base station rebroadcast on its frequency f_1 everything it receives on the mobile frequency f_2 so that Officer Smith can hear what Jones is saying. This requires the system to be half-duplex. The base station is then operating as a mobile relay.

A system using a two-frequency remote repeater is a special case of a two-frequency simplex system. The most common arrangement is that shown in Fig. V-28. The repeater station operates in the duplex mode, but the base and mobile stations may be simplex. The base stations in such a network do not need to transmit a more powerful signal than the mobile units, since the repeater is used to cover the entire service area. The only transmission on frequency f_2 is that of the repeater station. All base station and mobile unit receivers are tuned to f_2. Therefore, only one transmission between mobile and base or between mobiles can be completed at any given moment. This is an important limitation. For example, in Networks No. 4 and 6 simultaneous use of the channel by two units is possible, if there is sufficient separation for the FM capture effect to play a role. However, it is not possible in the repeater system of Fig. V-28. For full duplex operation through a repeater station, four frequencies would be required for the channel. In this case, the base station would transmit on f_1, which is then repeated on f_2 to be received by the mobiles. The mobiles would transmit on f_3, which is repeated on f_4 to be received by the base.



Dispersed Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
One-Channel Network
Simplex

Fig. V-28 Remote Repeater Network

Two separate base stations are shown in this system. The same arrangement may, however, be used by a single department having just one base station, as well as by many departments with separate base stations. Other configurations are also possible, depending on the particular needs of the system. If two distant service areas are to be covered, the base station and repeater may transmit on the same frequency, f_1, and both receive on f_2. This may be desirable where a mountain ridge separates two areas and acts to shield one from radio transmissions in the other. The repeater may then be linked to the base station by wire lines or a microwave system (see Section IV.2.4 and Appendix B).

A multi-channel system is illustrated in Fig. V-29. Each channel in the network may be either a single-frequency channel (as in Networks No. 5, 11, 17 and 23) or a multi-frequency channel (as in Networks No. 1, 2, 7, 8, 13, 14, 19 and 20). Some of these networks (such as Nos. 1 and 2) look like two independent networks, with separate equipment, channels and dispatching. If they share an administrative structure, however, they are in fact a single network.

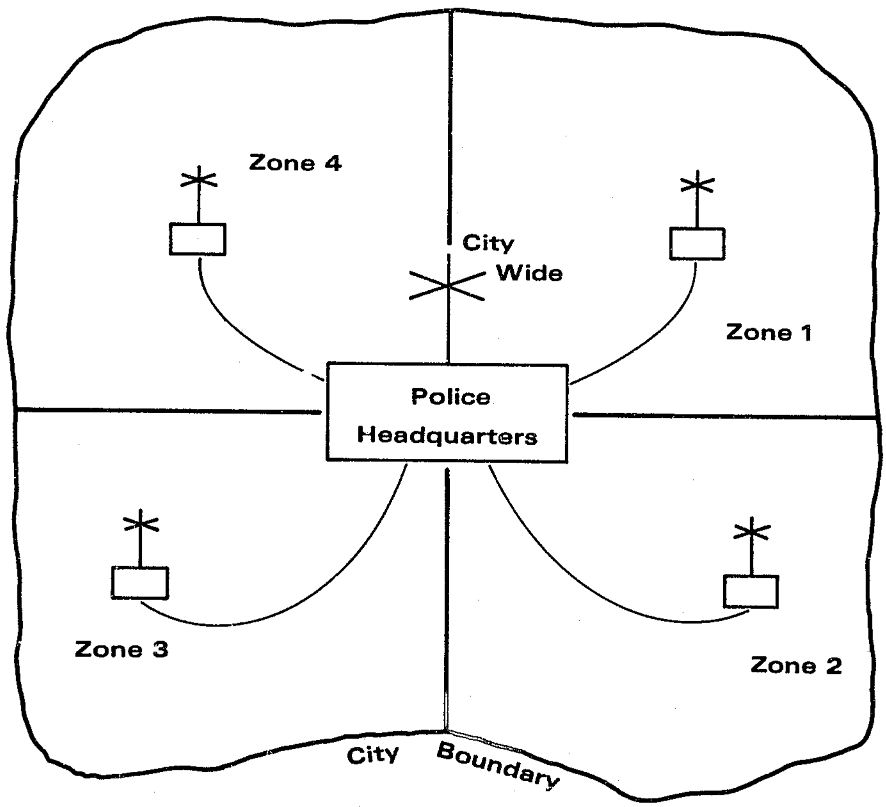


Fig. V-29 Multi-Channel Operation

There are two basic ways of organizing a multi-channel system:

- The various frequencies can be used for different types of police details, such as detective squad, traffic control, and routine beat patrols
- The various frequencies can be used in geographically separate parts of the city and each can be operated separately

In reality, most systems are a combination of both. In Fig. V-29, the city is divided into four zones, each with its own transmitter and frequency. In some cases, radio coverage of the entire city is desirable, so the police have installed a city-wide channel located atop the police headquarters in the heart of the city. This system corresponds to Network No. 17 if each channel is single-frequency simplex. If the zone channels are two-frequency duplex or simplex channels, the diagrams, respectively, of Networks No. 13 or 14 describe the configuration.

V.2.3.1 Network Co-Channel Interference Characteristics*

Any network that has more than one transmitter on a given frequency is susceptible to co-channel interference from one of the other transmitters. We shall call this a failure. The extent to which this occurs depends on the structure of the network. Within a network there are four possible modes of failure due to co-channel interference:[3]

B1 Failure of a base station to receive a transmission intended for it due to interference from another base station.

B2 Failure of a base station to receive a transmission intended for it due to interference from a mobile unit.

M1 Failure of a mobile unit to receive a transmission intended for it due to interference from another base station.

M2 Failure of a mobile unit to receive a transmission intended for it due to interference from another mobile unit.

The failure modes to which each network is susceptible are presented in Table V-3. From this table, it can be seen that all of the networks are susceptible to B2 failure because all have at least two mobile units on each frequency, meaning that there will always be at least one free mobile which is capable of producing interference by coming on the air. Two networks,

*Interference which is not co-channel, such as intermodulation, adjacent channel, etc., is discussed in Appendix C.

Nos. 6 and 18, are susceptible to all four modes of failure because all bases and mobiles share the same frequency. In those networks containing two-frequency channels, mobile-to-mobile communications by mobile use of the base frequency leads to possible M2 failure. The use of two-channel receivers in the mobile for this purpose does not lead to this failure mode.

The co-channel interference failure modes can be eliminated by separating the interfering transmitters geographically from the receivers. The separation required depends on the equipment and terrain characteristics peculiar to each situation. A general indication of the approximate distances required may be obtained by assuming typical characteristics. Suppose the coverage area for two networks is a 20 mile radius from each base station over lossy, curved earth with no obstructions or terrain irregularities. Assume receiver sensitivities of -143 dBW (that is, 0.5 microvolts across 50 ohms) in the mobile units and base stations, transmitter powers of 30 watts into the antennas at the base station, and 7.5 watts into the antennas for the mobile units. Base station antenna heights are assumed to be 150 feet with 6dB antenna gain, and six feet for the mobile units with 2dB gain. Then the minimum separations required between base stations (or mobile units) to eliminate the indicated co-channel failure mode are:[4]*

These are approximate distances for a typical set of conditions. They depend on antenna heights and gains, transmitter RF power, receiver sensitivity and capture ratio, and terrain. The distances will vary for particular systems. They must either be calculated using the specifications of each system, or obtained by actual field-strength measurements.

*The powers given are the RF power output of the transmitters, not the DC input to the final stage.

Table V-3
Co-Channel Interference Failure Modes

Network	Possible Failure Modes B1	B2	M1	M2
1		X		
2		X		
3		X	X	
4		X	X	
5		X		X
6	X	X	X	X
7		X		
8		X		
9		X		
10		X		
11		X		X
12		X	X	X
13		X		
14		X		
15		X	X	
16		X	X	
17		X		X
18	X	X	X	X
19		X		
20		X		
21		X		
22		X		
23		X		X
24		X	X	X

Table V-4
Minimum Separation Distances for Eliminating Co-Channel Interference

Failure Mode	SEPARATION 150 MHz Band (miles)	450 MHz Band (miles)
B 1	72	58
B 2	30	26
M1	50	46
M2	8*	8*

*This is the minimum distance between two mobile units to eliminate co-channel interference between them.

V.2.3.2 Network Co-Channel Interference Prevention

Co-channel interference among users of a network is affected by the network structure. Interference from signals at nearby frequencies, resulting in adjacent channel, intermodulation or other such interference is more closely related to equipment and environmental characteristics than to network structure. Therefore, that kind of interference is discussed in Appendix C.

Co-channel interference may be prevented by separating the interfering signals in frequency, time or space.

We will consider the possible methods for minimizing interference in the most commonly employed networks. We shall talk in terms of the *base channel*, that frequency on which the base transmits to the mobiles; and the *mobile channel,* that frequency on which the mobiles transmit to the base. The two frequencies are, of course, the same in a single-frequency system.

> *Frequency isolation in the base channel is possible in those networks which have only one base station on the same transmitting frequency and also have no mobiles transmitting on that frequency. In these networks, the base stations have clear channels for transmission, and the mobiles are separated in frequency from the base station. Since it is assumed that there are at least two mobiles on each mobile transmitting frequency in each network, frequency separation of the mobiles from each other is impossible in any of the networks. Frequency separation between mobiles assigned to base stations belonging to different departments is potentially more important, however, than isolation between mobiles within a department. This kind of separation is possible if enough frequencies are available in an area. For example, in Network No. 3, the mobiles from two base stations use the same frequency; this is not as desirable from an interference viewpoint as Network No. 1, in which the mobiles attached to the two bases use separate frequencies (see Figs. V-2 and V-4).*
>
> *Time separation is possible in all of the networks on the base channel. However, in networks with one-frequency channels, synchronization or cooperation of all dispatchers and mobiles on the channel is necessary; otherwise interference will occur. Time*

separation on the mobile channel is impossible in all of the networks (assuming that more than one mobile is on the mobile channel), unless some sort of synchronization or cooperation between mobiles takes place. Of course, this often happens in present systems where one mobile waits for another to end his transmission before beginning his own transmission. However, this type of cooperation is limited in networks which have mobiles from more than one department sharing the same frequency; the cooperation within a single department is more easily controlled and structured.

Another limiting factor in the use of time separation is that in many networks the mobile operators cannot hear each other. In that case, they have to guess by listening to the base channel and deducing when a mobile is transmitting. Understandably, this method of time sharing a channel is only partially successful.

Space separation on the base channel is possible in only one way: geographic separation of base stations on the same frequency. Separation must be great enough to eliminate interference between stations in any desired reception area. The required separation distances depend primarily on transmitter powers, antenna height and antenna gain. Thus, reducing each of these to cover only the actual desired reception area is important.

Space separation on the mobile channel is not possible in a system with more than one mobile unit, since some units will always be closer to the base station receiver than others.

Preventing interference on the mobile channel is difficult. In all of the networks, frequency separation is impossible because there are several mobiles on the same channel and sometimes the base station is also on that channel. Time separation is possible only through the cooperation of other mobiles and bases on the channel. Space isolation is possible only when all other mobiles and bases are beyond the interference range, which will rarely occur. The conclusion to be drawn is that for the mobile channel, time separation is the only feasible way of preventing interference.

Time separation on the mobile channel depends exclusively on the operating procedures of personnel in the field. No circuit arrangements can be used by mobile units to supplement the radio channel itself—a possibility that does exist for the base channel. Therefore, the rules and courtesies governing the use of the mobile channel are of prime importance.

The rules themselves will not be given here, since the Public Safety Communications Standard Operating Procedures Manual[5] *discusses these in detail. We stress, however, the need for observing these rules and observing them uniformly. If some users of a channel do not follow the agreed procedures the ability to efficiently time-share the channel will be seriously impaired, with the result that there will be increased competition for air time. This increases the interference experienced by users and causes them to repeat transmissions in order to complete an entire message. Thus an already heavy volume of message traffic increases just to maintain the same amount of information flow. The process escalates on busy channels and can lead to a communication breakdown. These are usually short in duration, for if no one is communicating successfully, the natural reaction is to stop and then try again. However, even a short breakdown is serious in police communication, where rapid response is essential and seconds of communication delay can have serious consequences (see Section V.3.2 on Communication System Response Time).*

Time separation on the base channel can be aided by utilizing an additional communication path between base stations. If dispatching is centralized each dispatcher can easily be informed that the base channel is occupied. The audio (and visual) communication between dispatchers in the same room may be sufficient, or it can be aided by indicator lights at each position.

If dispatchers are physically dispersed in different rooms, in different buildings, or even different departments, the audio and indicator light information can be transmitted over land line circuits between base stations. With this scheme, each department involved would operate its own complete base station. Thus each dispatcher can be informed that the base channel is in use without depending on monitoring of the channel itself. Further, the identity of the base station user can be displayed. This reduces the *unnecessary competition that frequently results in destructive interference to transmissions in progress during busy periods. In short, the competition takes place on the supplementary audio circuit between base stations rather than on the air in order that they may agree on who should be the next user of the base station channel. This arrangement can also be equipped with an interlock-with-override feature that prevents any dispatcher from operating his transmitter if one of the others is in use. If such interlocks are employed each dispatcher can also be equipped with an override capability which allows him, in effect, to defeat the interlock if he has reason to do so.*

If dispatching is dispersed, but a common base station transmitter is used, such an interlock feature is mandatory. In its simplest form an override capability is not included. However, various schemes to provide it could be implemented if the need warrants the increased cost and complexity.

Co-channel interference prevention is most difficult in Network No. 6, the most commonly used configuration. Here, all the users operate independently on the same frequency. Thus, time separation is the only means of preventing interference. This requires the cooperation of the users. In practice this often depends on the effectiveness of the administrative organization of the network, the operating procedures, rules and regulations, and the quality of training given the dispatchers and patrolmen.

In a two-frequency simplex network configuration, such as Network No. 4, interference can be prevented by time separation and by space separation of base stations. Because base-to-base interference (B1 failure mode) is not possible in this configuration, base stations need not be as far apart as in a single-frequency system (Network No. 6). In the example given in Table V-4, the minimum base station separation distance for Network No. 4 is 50 miles in the 150 MHz band, while for Network No. 6 it is 72 miles.

In a remote repeater system of the type shown in Fig. V-28, the main interference failure mode between separate systems is when a mobile receiver in one system is interfered with by the repeater station *transmitter of the other. The problem is solved if the mobile and base station receivers within interference range of the repeater station are tuned to a different frequency than the repeater station transmitter. Thus, either frequency or space separation can prevent interference between two networks where one is a remote repeater system. Within the system, however, time separation is required. Signals from base stations transmitting to the repeater station compete equally with the mobile transmissions. (The base station transmitters can be made more powerful, however, to give them an advantage in capturing the repeater station receiver.) If the base stations are connected to the repeater station by wire line or microwave link, they can be given priority over mobiles.*

A multi-channel network such as No. 13, 14 or 17 eliminates interference between zones by frequency separation. Each zone uses a different frequency (or pair of frequencies). Municipal multi-channel networks which use central dispatching do not, ordinarily, cover a wide enough area to permit the same frequency to be used in two zones that are geographically separated. However, county-wide or state wide systems may permit this, especially if terrain features provide some radio isolation between the zones.

V.2.3.3 Miscellaneous Network Characteristics

Among the important attributes of police radio networks are their performance under heavy message loads, their area coverage characteristics, and the possibility of direct mobile-to-mobile and base-to-base communication.

Performance under Heavy Load is a measure of how well a network can handle the communications load caused by regular peak periods and special emergencies. This performance is largely dependent on the configuration of the channels within the network and also the organization of the network itself. A network with several channels operated in a duplex mode is judged to have the best performance. Single-channel, single-frequency simplex networks are the most widely used. However, the "spiralling" effect discussed in Section V.2.4, which may occur under heavy load, is an undesirable characteristic which degrades its heavy load performance.

In general, those networks with dispersed transmitting and receiving equipment are judged to have the best coverage characteristics. Central grouping of transmitters forces coverage of larger areas than needed in many cases. Use of dispersed transmitters, on the other hand, can allow efficient coverage of small or odd-shaped areas. Reliable radio coverage of an area from several transmitter sites may enable each to employ less power and lower antenna heights than if a single transmitter were to cover the entire area. Thus, the potential of interference to other networks using the same frequencies is reduced.

In all of the networks, a direct mobile-to-mobile link exists only when the channels are single-frequency. In those networks with two-frequency channels, mobiles can be linked with each other by rebroadcast of the incoming mobile transmissions over the base channel. This capability can be added to a two-frequency system by making the base end of the channel duplex, thus allowing broadcast simultaneously with reception. This rebroadcast has the disadvantage, especially during peak hours, of loading the base channel. During those hours, dispatchers may find it necessary to delete the rebroadcast mode. Another way to achieve the mobile-mobile link, if required, is to have monitoring receivers in the mobiles for the required channel or channels. Yet another way to achieve this link is to use two-frequency transmitters in the mobiles, the second frequency being the same as the mobile receiver frequency.

The base-to-base link is necessary only in networks with dispersed placement of dispatching points. In those networks the links can be established (if desired) by installation of monitoring receivers on the appropriate channels, providing the separation of the bases is not too great. Telephone and teletypewriter systems provide alternatives to radio links between bases. A separate point-to-point or microwave channel also provides a base-to-base link for a certain class of messages in many areas of the country.

V.2.4 Considerations in the Design of Radio Networks

V.2.4.1 Type of Channel

In any network, the types of channels which are used greatly affect its suitability to the needs of its users. Therefore, it is worthwhile to consider the characteristics of channels by themselves apart from any network, in an effort to define their influence within a network.

The two basic tradeoffs which one must consider in selection of a radio channel for police telecommunication are:

1. Should the channel contain one, two or more frequencies?
2. Should the operation of the channel be one-way, simplex or duplex?

While there are some special situations in which more than two frequencies are used in one channel, these seem to be unusual cases requiring individual consideration. Therefore, channels with more than two frequencies will not be discussed. The combinations of the remaining tradeoffs yield the following six possibilities:

1. A single-frequency one-way channel
2. A single-frequency simplex channel
3. A single-frequency duplex channel
4. A two-frequency one-way channel
5. A two-frequency simplex channel
6. A two-frequency duplex channel

Of these combinations, number three is impossible, and number four is uneconomical, since it uses two frequencies for a one-way channel which could just as well use one frequency. Number six includes the possibility of either half-duplex (duplex at the base station only) or full duplex. The latter is rarely used in police radio systems. Therefore, only the half-duplex channel will be discussed. The four possibilities considered individually for their applicability to police telecommunication requirements are therefore:

> *Single-frequency simplex channel* in which the mobiles time-share the same frequency. At any given time, communication in only one direction is possible.
>
> *Two-frequency simplex channel* in which the base transmits on one frequency and the mobiles another. At any given time communication in only one direction is possible.
>
> *Two-frequency half-duplex channel* in which two transmitting frequencies are used, one by the base and one by the mobiles. At any given time the base can both transmit and receive.
>
> *Single-frequency one-way channel* in which one frequency is used in a broadcast mode and communication is in one direction only.

In general, a *single-frequency simplex channel* is suited to the needs of users whose mobile units must communicate with each other at locations which are out of range of the base station,[6] because it is the only type which offers direct mobile-to-mobile communications. However, this capability can be obtained with the other types by addition of a two-frequency transmitter or receiver to the mobiles for mobile-base or mobile-mobile operation. This type of channel requires the least possible spectrum space since it uses only one frequency. However, as was noted in Table V-3, this type of channel is prone to all four co-channel interference failure modes.

> *In addition, the channel can suffer "spiralling" to a greater extent than the other types. Spiralling is the effect which occurs when the failure rate in the channel increases, causing more messages to be repeated, causing more failures, more repeats, etc. Channel loading becomes unstable due to this effect if user demand is not reduced.[7] Usually this effect does not last long, however, due to changes in operation of the link by the users, e.g., shortening of message lengths, elimination of messages, etc. Under heavy loading, a network comprised of one-frequency simplex channels tends to become a network in which communication is dominated by the base channel. This is because the B1 failure mode produces severe limiting of reception on the mobile channel.[8]*

A *two-frequency simplex channel* is operationally better suited if a base station is in near-constant communication with a fleet of mobile units and shares the channel with other similar users suitably separated geographically.[9] This channel type is susceptible to the B2 failure mode (as are all types) and also to the M1 failure mode if more than one base station broadcasts on the same frequency within interference range. From the spectrum usage standpoint, although the channel uses two frequencies, it is good for areas requiring densely packed stations. This follows because it is not subject to the B1 failure mode, and the large space separation of bases in order to avoid B1 failure is not necessary.

> *There is no direct mobile-to-mobile link with the two-frequency simplex channel, but if it is needed it can be obtained by addition of receivers in the mobiles to receive mobile transmissions or by addition of a second mobile transmitting frequency. Due to the absence of the B1 failure mode, this channel type holds up well under heavy loading and does not tend to become one-way as does a single-frequency simplex channel.*

In a *two-frequency half-duplex system,* the two frequencies are spaced far enough apart to permit simultaneous reception and transmission by the base station. This type of system is susceptible to B2 and M1 failure modes, as is the two-frequency simplex system. Mobile-to-mobile communication is possible by operating the base station as a mobile relay and re-transmitting mobile messages. The B1 failure mode does not exist, so that separation of bases can be reduced from that required for one-frequency simplex.

> *It is likely that duplex can offer some savings in channel usage time compared to a two-frequency simplex channel, but simultaneous transmission and reception by the base probably occurs only a small percentage of the time. Thus, half-duplex does not substantially decrease channel congestion when compared to two-frequency simplex operation.*
>
> *An important asset of half-duplex is that the dispatcher maintains absolute control of the network at all times, with the result that the system stands up well under heavy loading. If a mobile unit and base station transmit simultaneously, neither call is completely lost with half-duplex operation. There is a human feedback effect that tends to tie the two users more closely together, as in face-to-face conversation; this does not exist so distinctly in simplex systems.*
>
> *The half-duplex system lends itself well to the use of mobile relays, which simply retransmit any signal received. This can lead to excellent base and mobile coverage. With mobile relays, monitoring ability is excellent, since mobile transmissions are repeated and can be heard by all users; this leads to good cooperation. An additional receiver or transmitter can be installed in the mobiles as another means to provide mobile-to-mobile communication.*

The *one-frequency one-way channel* is suited only to specialized purposes within a police network. Such a channel can best be used for broadcast of information to which no reply is necessary. An example might be broadcasts to mobile teleprinters, provided no replies are required. A separate voice channel might supply this requirement. Since fast access time to such a channel is generally not necessary, channel occupancy can be high.

V.2.4.2 Location of Base Station Transmitters and Receivers

An important aspect of network design is the geographic location of the base station transmitting and receiving equipment. The choice of placement of the equipment is usually between centralized or dispersed location within the area which the network must serve.

Networks with dispersed location of the radio equipment are very common in present police communications. The dispersed stations offer the advantage of good geographic coverage and the possibility of setting up zones. One frequency can be used more than once if adequate space isolation is possible. Dispersed stations are also less vulnerable as a group to disasters than a central complex—they offer a certain back-up capability.

In networks serving more than one department with centralized transmitting and receiving equipment, a major consideration is achieving adequate coverage. This may be more difficult than in a system which has dispersed transmitters, especially where topographical features such as hills or mountains are present. A central location requires each channel to cover the entire area served by the network, which may be unnecessary. The forced coverage of a large, essentially circular area makes the common spectrum-conserving practice of repeating frequencies by means of geographic separation of bases more difficult. With central receiving equipment the mobile units must have high power transmitters in order for their signal to reach the central receiving point. However, "satellite" receivers can be placed throughout the area to eliminate this problem. Such a system is characterized as hybrid, with centralized transmission and dispersed reception.

Central transmission is useful for cases where all points coverage is required, such as for network-wide emergency channels and possibly for a teleprinter system shared by all departments within the network.

V.2.4.3 Location and Organization of Dispatchers

The basic choice with regard to organization of the dispatching function in a network is whether the dispatchers are to be located at a central point or whether they are to be dispersed geographically throughout the area—usually at the headquarters of their respective police departments or zone or district stations.

Central dispatching enables the functions of several dispatchers to be well organized without the use of the radio system to bring it about. This can improve the communication effectiveness and economic efficiency of dispatching in the network. Each dispatcher may be responsible for his own zone, which in many cases will cover an entire community, or all may handle calls for the entire area. Residents of the area covered by the network call the police at a central number. The message is routed automatically or by a switchboard operator to the next available dispatcher, or to the one who covers the zone in which the call originates. The dispatching load can thus be equally distributed among several dispatchers. The number required is usually smaller than if the dispatchers are dispersed.

439-911 O - 71 - 11

Central dispatching can eliminate B1 and M1 failure modes in the system by proper coordination between dispatchers who have voice and sight contacts with each other. It also eliminates base station-to-base station communication needs within the network, since this will be handled internally.

Dispersed dispatching has the advantage of physically placing the dispatching personnel in or near the area for which they are responsible. It also keeps the personnel under the supervision of the department or district they serve. A further advantage of dispersed dispatching is that the widespread location of the dispatchers enables the system to avoid catastrophic failure of the dispatching system such as might be caused by destruction of a central location by fire, flood or other disaster.

For departments below a certain size, contribution of personnel or funds to a central dispatching system may not be economical. This critical size has been found to be when the population served is between approximately 20,000 and 25,000 in suburban communities in large metropolitan areas. Central dispatching generally reduces the total number of dispatchers required by the network, but it may not reduce the number of personnel required by small departments belonging to the network. A dispatcher in such departments may also be record clerk, receptionist and secretary. Supplying dispatchers or funds to a central system may then actually be an addition to the budget, and not a reduction. However, even for small departments, the improvement in communication effectiveness and the benefits of access to data terminals may outweigh the economic factors related to personnel.

On the other hand, the dispersed dispatched network generally cannot respond in as organized a manner as a centrally dispatched system to area-wide emergencies because of its less highly organized structure. It is more prone to B1 and M1 interference than a central dispatching network because dispatchers must rely on the radio system itself for contact with each other.

The best dispatching arrangement for a group of departments in one network, or a large department covering an extensive area depends on population size and distribution, the geographic distribution of the radio service areas, as well as economic and political considerations. A network may find one or the other mode of dispatching, or a combination of both to be most suitable.

V.2.5 Administrative Organization of Police Telecommunication Systems[10]

The place of the communication unit in the police department, or in some cases outside it, and the organization of the unit itself are discussed in this section.

V.2.5.1 Organizational Placement

Considerable variation occurs in the placement of communication responsibilities in police organizations. Typically, communication is thought of as a supporting service to all line units, and therefore the persons fulfilling communication duties are assigned to a staff section.[11] Occasionally, a line unit such as the patrol division also operates the communication system, on the basis that it is the largest "user" of the service. In smaller departments, overall communications responsibility may be found assigned to a knowledgeable individual who performs this duty in addition to his primary task in some other function.

The expanded use in larger jurisdictions of radio communications by other municipal departments has led in some cases to the creation of a centralized agency providing communications services to its users. The centralized agency obviously relieves the police department of many of the administrative details involved, particularly in the technical phases. There remains, however, even in this kind of organizational approach, the need for establishing department control of the communications concerning police operations.

A step taken by many local governments, short of an autonomous communications agency, is to assign to the police department responsibility for communications services in *all* city agencies. This approach is usually an outgrowth of the police department's having the first and largest system in the local government, and therefore seemingly in the best position to provide a comprehensive service.

The police agency in smaller jurisdictions may find itself providing at least dispatching services for these other city departments. The other departments may operate their own control points for the radio system during normal business hours, then turn over "off-hour" dispatching tasks to the police department because it is frequently the only agency operating around the clock.

V.2.5.2 Unit Organization

The organization of the communications unit itself presents some problems due to the nature of the personnel requirements for the routine complaint processing-dispatching function contrasted with the engineering-maintenance activity. If the department is responsible for its own maintenance of equipment the chief engineer or technician may be under the direction of the commanding officer of the communications unit or he may occupy a comparatively independent position in recognition of his professional training. Alternately, the complaint processing function may be assigned to the "chief engineer."

Viewed from the standpoint of the "communication system", organizational principles require that responsibility for both the technical and non-technical phases be identified and assigned beyond a simple designation of "staff" activities or individual recognition. The degree of specialization which appears inherent in the technical phase may justify separating this unit from other communications functions within the same division, but coordination and direction must still be afforded at a level below the chief administrator.[12]

The organizational patterns which seem to have enjoyed success in various-sized departments are depicted in Fig. V-30 to illustrate the considerations mentioned. The smallest departments, represented in "A," must rely on the desk officer to carry out communication tasks in addition to many other duties which arise during his tour of duty. As the size of the organization increases, the importance of proper handling of the complaint dispatching process is reflected in the number of personnel assigned to "specialties" and the concomitant degree of supervision which must be afforded. Illustrations "B," "C" and "D" in Fig. V-30 reflect this growth.

It will be noted that in each of the partial structures shown the complaint processing is centralized within a single department. This phase of communications must be so treated if control is to be achieved.[13] One exception, of course, is in a jurisdiction such as a state police agency where operations are conducted from substations. In this case, functional control still remains at headquarters, with what amounts to staff supervision performed in the field. The advent of private microwave or other "tie lines", however, enables even a centralized statewide communications system to function much in the same manner as a municipal system.

Another exception shown in "E" of Fig. V-30, is in an agency that administers the telecommunication system for an entire community or for the police departments of several communities. Such a centralized agency relieves the individual departments of many of the administrative details and particularly the technical aspects of a system. In this kind of organizational approach care must be exercised to maintain the proper degree of department control of the communication operation. This may well be achieved through adequate representation of each department on the agency's policy making body.

V.3 Requirements on a System

Numerous requirements and constraints are placed on a police telecommunication system. Some are internally generated performance requirements; others are externally imposed requirements. Examples of internal performance requirements are the time allowed

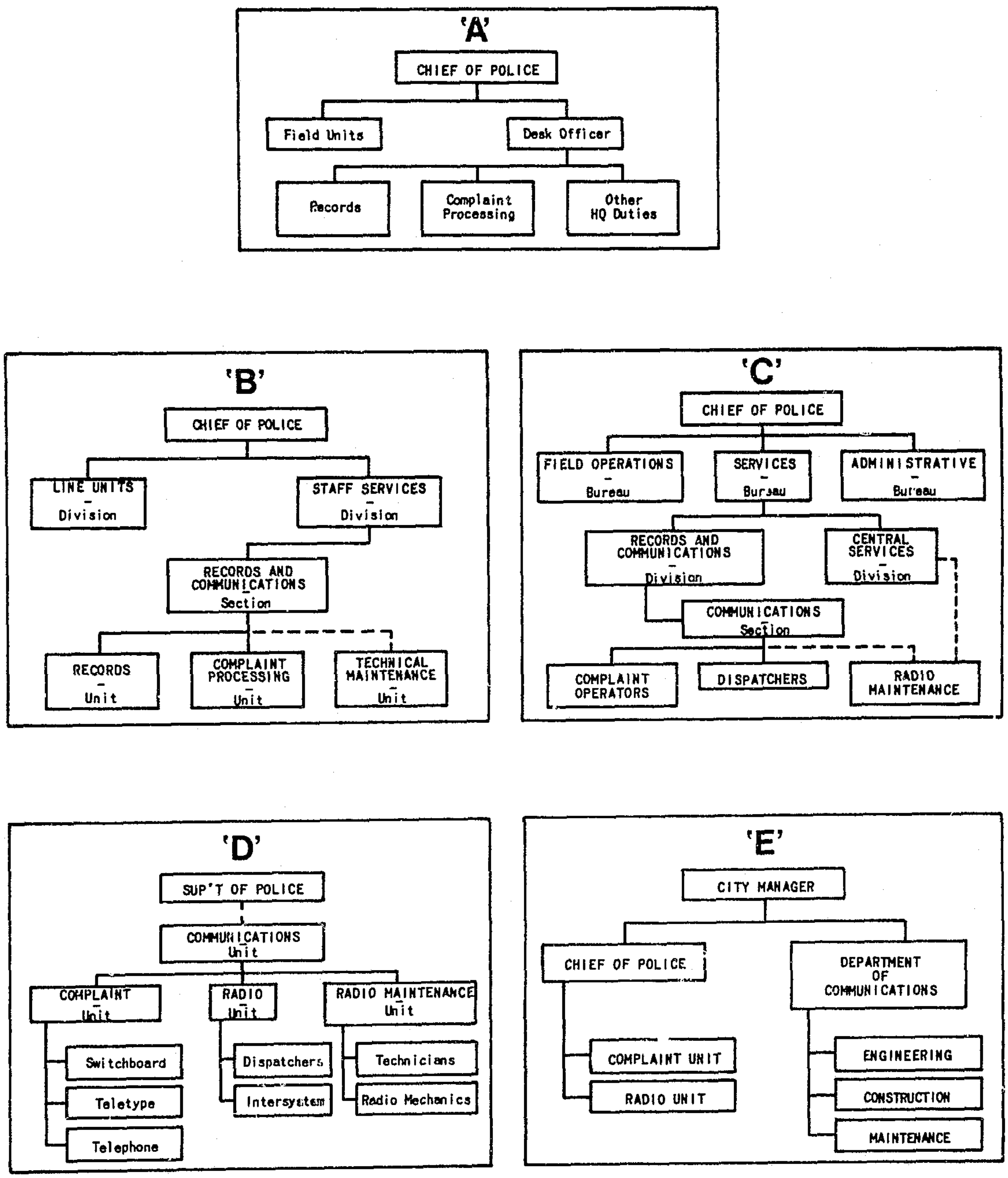


Fig. V-30 Representative Organization

for responding to a complaint, the reliability during continuous operation, and the system flexibility with changing demands. The externally imposed requirements include the FCC Rules and Regulations, spectrum availability, legal constraints, and economic limitations.

V.3.1 Sources of Communication Requirements

The police department's communication functions are generated by communication needs of the department's activities. These activities are responses to criminal offenses and non-criminal complaints; performance of miscellaneous services (such as requests for ambulances, reports of missing persons, fire department assistance, traffic control, etc.); traffic law enforcement and traffic accident-related assistance. A survey of 50 midwestern police departments[14] showed that in 85 percent of the departments, over half of the department's activity concerned non-criminal complaints and miscellaneous services. Thus, more communication activities are likely to be generated by non-criminal-related activities than by criminal offenses.

One of the main factors determining the demands on a system are the large fluctuations in complaint and message traffic over hourly, daily, weekly, monthly and yearly periods.

The number of radio and telephone messages changes from minute-to-minute. There are five basic reasons for this fluctuation. They are:

- Chance occurrence of individual events requiring police services
- Daily and weekly patterns of human activity
- Changes in those patterns due to seasonal and weather conditions
- Special events which require police services
- Catastrophe and emergency situations with related events requiring police services

The normal events which require police services are not equally spaced in time of occurrence throughout the day, week, or year. Over a year, a community may average one traffic accident a day, but there may, at times, be three accidents within one hour. These events occur randomly. The random nature of events requiring police services results in uneven loading on the communication system.

The police telecommunication system is, of course, busier during certain hours of each day and certain days of each week than it is during other time periods. For example, weekday morning and evening traffic rush hours are busier times for the communication system than the predawn hours. Since the activities of the people in the community change according to fairly predictable patterns throughout the day and week, the communication system's busy time periods can also be fairly well predicted.

Figure V-31 graphically shows how a communication system's radio usage varies throughout the day. The data used to construct this figure were taken from the records of a suburban police department which serves a population of about 30,000 people. The department uses a single-frequency simplex system. It broadcasts to its own mobile units and can listen to 35 other base-station transmitters. Thus, the transmitter "On" times reflect the amount of one department's activities while the receiver "On" times indicate the amount of 36 departments' activities (the receivers are equipped with carrier squelch so they are only "On" when there is a transmission to be heard). From the figure you can see that most radio usage per hour, that is, the peak occupancy of the channel, occurred between midnight and 1:00 AM, reaching 86 percent. This is the sum of the transmitter and receiver "On" times during that hour. The transmitter was on 4 percent or 2.4 minutes of the hour, while the receiver squelch was broken 82 percent or 49.2 minutes of the hour. This was almost four times the channel occupancy of the lightest hour from 0100 to 0200.

The patterns of activity also change over the year. For example, school vacations and, in some communities, seasonal tourist attractions influence the police department's activities. Also related to seasonal variations are weather conditions. Special events such as parades and athletic events create special demands on the communication system. For example, the communications are needed to coordinate police activities for directing and controlling traffic. For larger events more than one police agency may be involved in those activities. Since, the people attending the event increase the population which the department serves, the likelihood that incidents requiring police services will occur also increases. Unlike emergency situations, which will be discussed next, special events are known to the department in advance. The communication staff can plan for the additional load in that case.

Defining what is meant by an emergency situation creates some difficulty. Many of the situations police normally deal with are considered to be emergencies by the persons involved—whether it is a traffic accident, a missing child or a prowler. Here, however, we are speaking of situations which are emergencies in the eyes of the departments involved, because of their extraordinary nature, the wide area they cover, the number of persons involved, or their seriousness. Many catastrophies fall into this emergency category, such as storms, floods, airplane crashes, explosions or power failures. Still others are large scale demonstrations, civil disturbances, or riots.

Features common to many such situations are the strain placed on a department's resources and procedures, the large proportion of the police force directly involved, the large geographical area involved (often encompassing several communities or jurisdictions)

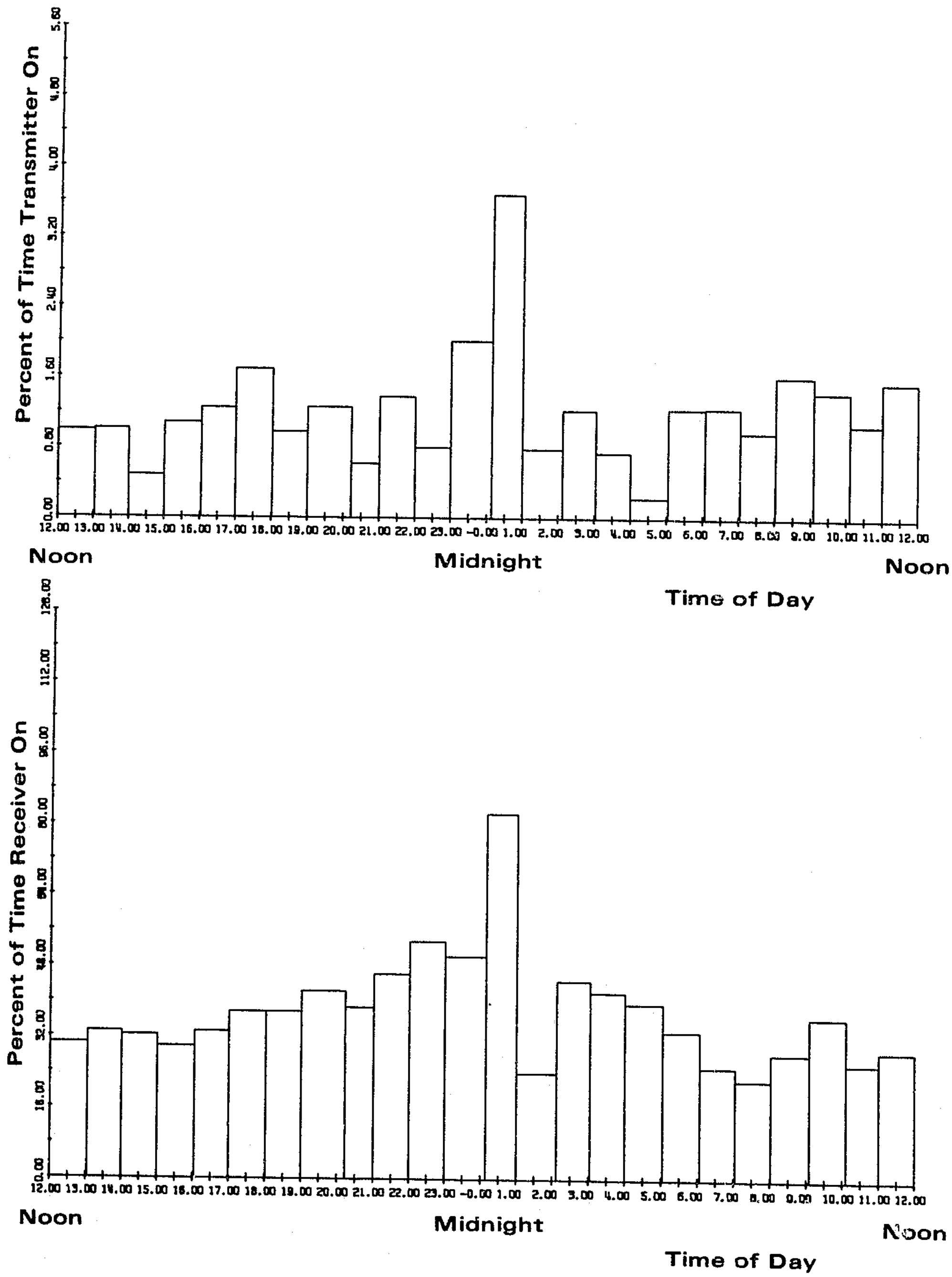


Fig. V-31 Percent Transmitter and Receiver "On" Time and the extreme seriousness of the incident to many citizens. Many emergencies also require tactical police operations over an extensive area. Effective coordination of tactical police units over a wide area requires field command capability, using a radio channel over which commands can go from a field commander to his men directly or by relay via a dispatcher or mobile relay. Such radio channels must be readily available to the large numbers of police personnel in several jurisdictions who may become involved in an emergency situation, and they must be channels whose use and availability is thoroughly familiar to these personnel. They must also incorporate provisions for field-located and unit-oriented tactical command and control.

The variation in demand on a police telecommunication system is one of its most important characteristics, one that distinguishes it from some of the other communication systems that use land-mobile radio. The system must be capable of handling the peak demand because of the emergency, life-and-death nature of some police service. The average demand or load over a period of time (hourly, daily, etc.) on the system is not an adequate measure of the necessary capacity. Demand variation thus becomes one of the primary sources for the requirements placed on a system.

V.3.2 Communication System Response Time

In police communication it is not enough to transfer information from its source to its destination accurately. The transfer must be made in as short a time as feasible. The governing factor is the total response time for a complaint; that is, the time between receipt of a call for service at the police comunication center and arrival of a police unit at the scene. Studies[15] by the President's Commission on Law Enforcement and Administration of Justice have indicated that the probability of apprehension of criminals is correlated with response time. In complaints considered by the police operator to have emergency priority, a six-minute response time was associated with a 49 percent arrest rate. A two minute response time was correlated with a 57 percent arrest rate, while a one minute response time resulted in a 63 percent arrest rate. Thus, if response time is reduced from six to one or two minutes, the net improvement in apprehensions might be thirty or fifty percent respectively. Even in non-criminal situations the effect of a four or five minute difference in response time may be critical. This is especially true when the calls for service involve crime-in-progress, traffic accidents, sickness or injury.

Response time consists of two major components: Communication-center response time (the time required in the communication center from receipt of a telephone call to transmission of a radio message) and field response time (the time between receipt of the message by the patrol unit and arrival at the scene). An analysis of response time resulted in the conclusion[16] that the best dollar investment to decrease overall response time is in the police communication center.

V.3.2.1 Communication Center Delay

To achieve one- or two-minute overall response times, seconds become important in the communication process. The communication center delay consists of the time required to complete the five-step process discussed in Section V.2.2.2 and shown in Fig. V-32. Some of these steps are not performed separately if any two, or all three of the functions of switchboard operator, complaint operator or dispatcher are carried out by one person. The study cited above found that for all calls analyzed, average communication-center delay time was about the same as average field response time, slightly more than five minutes for each.[17] Differences were significant, however, between emergency and non-emergency calls—average overall response times differed by as much as a factor of about five.[18] Average

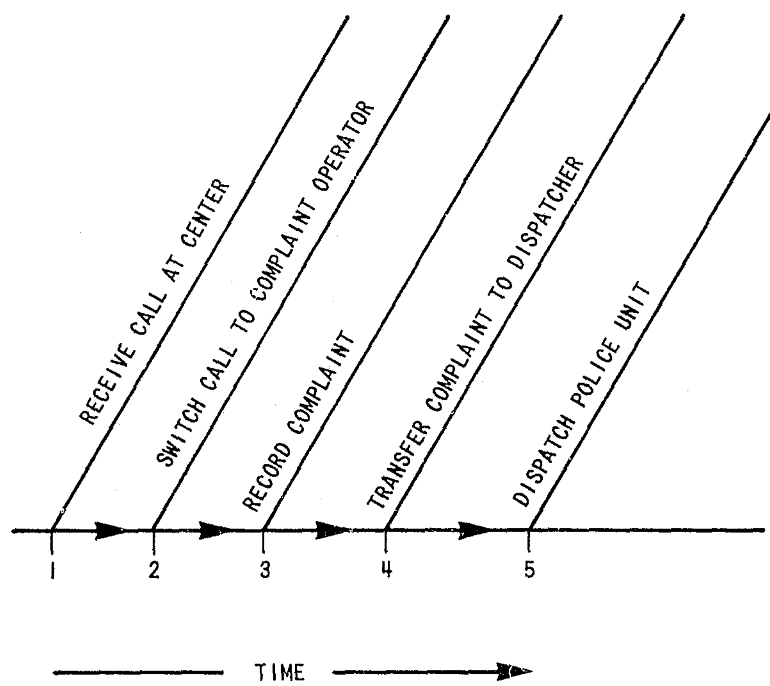


Fig. V-32 Communication Center Delay

communication center delays varied from 1.11 minutes for an emergency call in which an arrest was made to 7.25 minutes for non-emergency calls in which no arrest was made. The range of field response times was much less than for communication center delays, however. This bears out the intuitive expectation that field response times have a fairly definite minimum value on the average. Because of distance, street patterns and traffic, average field response times cannot be easily reduced without large increases in the number of patrol units on the street.

If the complaint processing procedure is a one-stage process, the time interval between Steps 1 and 4 consists of obtaining the complaint from the caller and recording the necessary information (such as the address, nature of complaint, etc.) on a complaint form, radio log or scratch pad. If the procedure is a two-stage or three-stage process, this time interval may include some additional fixed delays. These may consist of the time it takes to transfer the call to an extension, ring it and pick up the receiver. It may also include the time it takes to send the complaint form to the dispatcher by conveyer belt or other means. The total time to carry out these four steps will vary, depending primarily on the judgments of the operators receiving the complaint. The urgency they attach to the complaint will affect the speed with which they process it and the procedure they follow. If means are available for skipping some of these four steps, considerable time can be saved. In a two- or three-stage process, the option of connecting the caller directly with the dispatcher can make the time for Steps 1 through 4 comparable to that for a one-stage process.

If an average overall response time of three minutes is desired,* and average field response time is approximately half this time, the average communication-center delay must be less than 90 seconds. If calls are assigned priorities, the response time criteria must, of course, be assigned individually for each one. In that case, one- to two-minute response times appear possible for emergency calls. The communication center delay must then be correspondingly less. If calls are not formally assigned priorities (most departments do not), the *minimum* possible delay for these four steps is more significant than the *average* delay. The other component of the communication center delay, Step 5, is not completely under the dispatcher's control and will be discussed separately.

Since field response time cannot be changed for an individual emergency call as communication center procedures can, it is reasonable to establish these procedures to have communication-center delays at least less than one minute for emergency calls. To achieve

*This is the standard set, for example, by the Chicago Police Department.

one-minute overall response time requires that the communication-center delay be of the order of 20 to 30 seconds.

V.3.2.2 Radio System Delay

The component of the communication center delay represented by Step 5 depends on the required message lengths and the delay time in gaining access to the radio channel. Police radio messages have been found to have an average duration of approximately ten seconds.[19] If an operator must wait to place a message on the air, a delay of only a few seconds thus becomes a significant portion of the time required to complete the entire dispatch. The average waiting or delay time in placing a message on the air during a normal busy period has been judged to be reasonable if it does not exceed five seconds.[20,21,22] This standard was developed in cooperation with a number of police administrators from all over the nation. This criterion is for the *average* delay time, which is an important observation. Based on observed characteristics of police voice radio traffic, about one percent of the messages will wait more than one minute and five percent will wait more than thirty seconds, if the average delay time on a radio system is five seconds.

The "waiting line" or queue in a radio system is somewhat similar to the ticket line at a movie theater. Only one person can be served at a time. However, there is a crucial difference. Unlike the ticket line at a theater, no one in the radio system waiting line knows where they are in line or who is immediately in front of them. No one is aware of other users who are waiting, until one of them has seized control of the channel and is thus no longer waiting in line. Therefore, everyone must assume at some time that he is now at the front of the line, otherwise he will never get on the air.

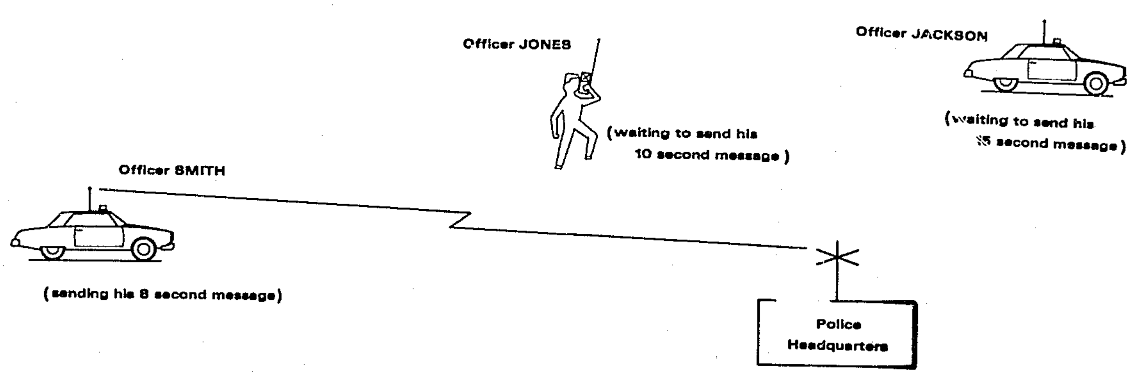


Fig. V-33 Radio System Delay Times

As an example, suppose we have a situation as shown in Fig. V-33. Officer Smith has just started sending an 8-second message from his patrol car to headquarters. Officers Jones and Jackson, using the same channel, are waiting to send messages which will be 10 seconds and 15 seconds long, respectively. We can see, then, that Officer Jones will have an 8-second delay and Officer Jackson will have an 18-second delay.*

By most standards in police communications, 18 seconds is a long time to wait to get on the air. If such delays happen often, the police department may restrict the length of messages which can be sent over the radio, or regulate the times when messages of certain types can be sent.

> *Several models have been developed which can predict queueing or delay time, if the time between units arriving have an exponential distribution. (See Section VI.1.4.1 in Chapter VI.) Since there is some evidence that the time between arrivals does have an exponential distribution (and there are not many useful techniques for describing queue behavior if the interarrival times do not have an exponential distribution), such a distribution is generally assumed. Furthermore, it can be shown that if the time between the messages for each department are exponential, the time between messages on a channel are also exponential. The total times required to complete a radio message were then computed, assuming that message lengths had an exponential distribution. The lengths of messages actually observed had a greater variance than if their distribution were exponential. Therefore, the actual delay times would be greater than the computed values. Assuming that the average message length is ten seconds and exponentially distributed, the total times required to complete a radio message have the distribution shown in Table V-5. The five second average delay time criterion is thus not an unduly high standard. Using this standard for average delay time, and assuming that average message length is ten seconds, the total times required to complete a radio message have the distribution shown in Table V-5. Even though the average waiting time is five seconds and the average message length is ten seconds, seven percent of the calls will require more than 40 seconds to be completed, and more*

*Actually, Officer Jackson might send his message before Officer Jones if he is quicker in getting on the air.

Table V-5
Distribution of Message Length Plus Waiting Time

Average message length = 10 seconds
Average waiting time = 5 seconds

Message Length* Plus Waiting Time t	Expected Percentage of Calls Taking More Than t Seconds
(seconds)	(percent)
10	51
15	37
20	26
30	13
40	7
50	4
60	2
70	1

* Message lengths are assumed to have an exponential distribution.[23]

than two percent will take over one minute, even though less than 0.2 percent of the messages are themselves longer than one minute. Only 14 percent of the message lengths exceed 20 seconds, but 26 percent of the calls will require more than 20 seconds to be completed because of the waiting time.

The waiting times are the result of some users occupying the radio channel at the time another operator wants to transmit a message. This occurs in any system with more than two users, and becomes increasingly serious as the number of users on the same channel increases. The growth—past and future—in police radio communication thus requires that more channels, that is, more radio spectrum, become available to the Police Radio Service. In many metropolitan areas not enough spectrum space is available to meet reasonable delay time criteria as stated here.[24] The requirement established for the duration of Step 5 is therefore closely related to the availability of frequencies in the department's immediate geographical area. The response time requirement for a department must be established on the basis of physical community characteristics, radio spectrum availability, the size of the department's field forces, and the community's police requirements. No single criterion can serve all departments. The considerations outlined above will, however, aid a department in setting its own response-time requirements.

V.3.3 Telecommunication System Reliability and Flexibility

The basic requirement for reliability of a police telecommunication system is simply that it operate with no system failure at any time, every day around the clock. The particular requirements that result in such reliability are sufficient system redundancy and equipment back-up, physical security, proper equipment standards and specifications, and adequate equipment maintenance. Interwoven with the need for system reliability is the requirement that it be flexible enough to meet unexpected and changing demands.

V.3.3.1 System Redundancy and Equipment Back-up

Major components of a communication system can be expected to fail despite the best maintenance program. This need not, however, produce a *system* failure, if proper preparations are made for such events. The standard techniques to prevent system failure are to provide back-up equipment and system redundancy. Both can be provided in police telecommunication systems at reasonable costs.

Back-up equipment should be available to substitute for a defective unit when breakdown occurs. In addition, it must be possible to make the substitution quickly, so that system operation is not significantly interrupted.

Telephone equipment back-up is ordinarily the responsibility of the public telephone system, since most telephone equipment is leased and not purchased. However, redundancy of important leased circuits can be obtained by paralleling lines. An additional safety factor is provided by obtaining alternate routing, through a second central office, for the second circuit.

Base radio stations may be supplied with back-up transmitters and receivers that are kept on a standby basis and can be readily switched into operation. Auxiliary (or emergency) power sources for base and repeater stations are also necessary. They are fully discussed in Section IV.2.7.2 of Chapter IV. Back-up radios for vehicle-mounted mobile units may consist of spare units that can quickly replace defective units in vehicles, allowing repairs to be made at the convenience of the maintenance shop. Another approach is to have a sufficient number of spare vehicles to enable the entire vehicle to remain out of service until the radio repair has been completed. Both methods allow the police personnel to stay on duty without losing radio communication. Portable and personal two-way radio back-up equipment usually consists of extra units that are not normally in use.

Sometimes back-up equipment is too costly or inconvenient to have available in standby condition. Then system redundancy can supply the same back-up capability. Departments that share a radio channel with nearby communities (or that have several base stations) can arrange for that community's police communication center (or its other base stations) to handle their complaint processing and/or dispatching functions in case of failure. If the entire complaint processing procedure is shifted to another location, arrangements for telephone calls to be shifted to that communication center must be made. This switching can usually be done at the telephone exchange. Notification procedures and command personnel communication must also be arranged and planned. A less convenient but still effective technique is to use a vehicle-mounted mobile unit as the base station transmitter and receiver. Because of the difficulty in conveying telephone messages to an operator in a vehicle and the difficulty in maintaining reliable coverage, this method is recommended only if the others suggested have failed. A further discussion of these techniques is found in Section IV.2.7.3 of Chapter IV.

V.3.3.2 Physical Security

To ensure reliable system operation, communication equipment and personnel must be protected from damage and harm. Threats to security come from severe weather, earthquakes, floods, fires, and intentional sabotage. The specific steps necessary to improve physical security are given in Section IV.2.7.1.

V.3.3.3 Standards and Specifications

The reliability of a system is primarily determined by the quality of the equipment of which it consists. In order to ensure that every component of a system is of sufficient quality to operate reliably over a long period of time (as is required by police telecommunication systems), the standards and specifications according to which it is manufactured and purchased must be well written.

The quality standards for equipment should serve to minimize requirements for maintenance. This results from good design, use of high quality components in manufacture, and operation that is normally below the unit's peak performance capability. The latter is especially important, for it not only reduces maintenance requirements and increases the equipment's life, but it also increases its reliability when subjected to extraordinary operational stresses.

Specifications should result in standardization of system components that increases flexibility. If parts, component units, or subsystems are interchangeable through standardization, fewer spare units and parts are required, and servicing of equipment is easier and faster. System flexibility results from standardization if system configurations can be changed in response to new requirements.

Complete specifications should include:

- An overall system description, to indicate how the new equipment will fit into an existing system or become a new one
- Factors on which the specifications are based—these include the system requirements the equipment has to meet, the qualifications of the operating personnel, and the performance criteria by which the system will be evaluated
- The life and reliability requirements of the equipment
- The mechanical characteristics of the equipment—its size, weight, connections, controls, etc.
- The electrical characteristics of the equipment—its frequency, power output, sensitivity, stability, power input, etc.
- The environmental conditions under which the equipment must operate and the electrical characteristics that correspond to them
- Test requirements—the type, number, and performance limits that are desired
- Standardization requirements—which component parts are to be standardized and which units are to be interchangeable
- The documentation requirements—reports of test results, and operating and maintenance manuals
- Maintenance requirements, parts replaceability, and contractual maintenance arrangements
- Guarantees and warranties on parts and workmanship
- Installation and system test demonstration requirements
- Delivery date and penalty clauses

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Particular specifications on equipment standards and measuring techniques are available from Electronic Industries Association (EIA).

A partial list of EIA specifications applicable to police radio systems follows. These should be consulted, and cited where applicable when writing a set of radio system specifications.

RS-152B	*Land Mobile Communications, FM or PM Transmitters (25 to 470 MC)*
RS-173	*Emergency Stand-By Power Generators and Accessories for Microwave Systems*
RS-195A	*Electrical and Mechanical Characteristics for Microwave Relay System Antennas and Passive Reflectors*
RS-203	*Microwave Transmission Systems*
RS-204A	*Minimum Standards for Land-Mobile Communication FM or PM Receivers*
RS-210	*Terminating and Signaling Equipment for Microwave Communication Systems—Part 1: Telephone Equipment*
RS-220	*Continuous Tone-Controlled Squelch Systems*
RS-222A	*Structural Standards for Steel Antenna Towers and Antenna Supporting Structures*
RS-232C	*Interface Between Data Processing Terminal Equipment and Data Communication Equipment*
RS-237	*Minimum Standards for Land-Mobile Communication Systems Using FM or PM in the 25 to 470 MC Frequency Spectrum*
RS-252	*Baseband Characteristics of the Microwave Radio and Multiplex Equipment*
RS-316	*Minimum Standard for Portable/Personal Land Mobile Communications FM or PM Equipment 25-470 MC*
RS-329A	*Minimum Standards for Land-Mobile Communication Antennas—Part I - Base or*

	Fixed Station Antennas
	*Part II - Mobile Antennas**
RS-334	*Signal Quality at Interface Between Data Processing Terminal Equipment and Synchronous Data Communication Equipment for Serial Data Transmission*
RS-368	*Frequency Division Multiplex Equipment Standard for Nominal 4 kHz Channel Bandwidths (Non-Compandored) and Wideband Channels (Greater Than 4kHz)*
REC-141	*VHF Receiving Antenna Performance, Presentation and Measurement*
TR-120	*Minimum Standards for Land-Mobile Selective Signaling Equipment*
TR-141	*Microwave Relay Systems for Communications*

Procurement of equipment is frequently done by competitive bidding to a set of detailed procurement specifications. In order to maximize the competition in bidding, and to increase the likelihood that reliable products will be obtained for least cost, there is a sequence of steps that is commonly taken.

The first is to prepare a complete and well stated request for procurement (usually referred to as the bid package). It must contain the

- Objectives and scope of the procurement
- Specifications according to which the products will be designed and produced
- Applicable cost information
- Time schedules

These are only the major constituents of the bid package. Additional items will be needed for each particular situation. Departments which do not have the services of qualified specification writers available may find it necessary to have competitive bidders help prepare the specifications.

Next, the buyers advertise the procurement with a short, general description of the work and products desired, inviting prospective bidders to submit their qualifications. From

*Part II will be issued during mid-1971.

the replies received, a bidder's list is selected and those companies chosen are sent the bid package for return of a bid by a specified date.

Before taking these steps, however, it is important for the purchasing agency to consult with appropriate counsel to determine the legality of this procedure and its conformity to existing local and state law. It is also desirable to check with the purchasing departments (or their equivalents) of the municipality, county and state. It may be possible to obtain aid, the benefit of experience and perhaps the benefit of greater purchasing power from one of these agencies.

The procurement cycle has only begun when the bids have been received. The process of evaluating bids is one that should be carried out according to previously agreed on procedures, so that each bid is completely and fairly evaluated. Organizations with great experience in this field have prepared guidelines for bid evaluation.[25] Their suggestions should be adapted to the buyer's situation and then carefully followed. One should expect that the effort of evaluating bids is comparable to that spent preparing and distributing the bid requests.

An agency which has had little experience in making major purchases through competitive bidding can be greatly helped by studying copies used by other agencies in previous procurements. This study should include the feedback from those agencies on how well their procurement turned out—to find the strong and weak points of these earlier procurements. A reasonable effort spent in this direction can make relatively sophisticated buyers out of previously inexperienced ones. The result will be to increase the likelihood that products of greater value will be obtained at lower cost.

V.3.3.4 Maintenance Requirements

A major factor in obtaining system reliability is proper equipment maintenance. The quality of the maintenance program bears direct relationship to the amount of time a system is partially or totally unavailable for use. A maintenance program begins in the planning stage of a system, and must be carried through to everyday usage. Proper system design attempts to accomplish a twofold task:

- To minimize the failure rate
- To minimize the time required to repair equipment

The total cost of operating a *system* is closely related to the reliability of its *equipment*. In practice, most electrical and electronic devices require some repair during their life. A balance can be found between the increased cost of more reliable equipment and the cost of maintenance. Further, availability affects the reliability of the total system, although its cost in dollars is hard to measure.

Ordinarily, one of three methods of maintaining telecommunication system equipment is used. The first method, generally used by larger departments, is for the department to operate its own service facilities. The second method, generally used by smaller departments, is to call upon one or more technical service companies to maintain its equipment. In some instances, a combination of department-operated and contracted maintenance service is used. The third method is for several departments, a municipality or a county to operate the service facilities. This may result from a compact among several police departments for a jointly operated maintenance department or may be part of more extensive joint operation of police communications facilities. A municipality or county may have a communications department that provides services for all of its governmental communication systems (see "E" in Fig. V-30). Two main ingredients are necessary for an adequate maintenance program: personnel and tools. The tools include mechanical and electronic equipment, spare parts, and means of transportation.

A police department generally requires that its communication system operate 24 hours a day. Telephone companies normally provide repair service for their equipment. With the changes in telephone system interconnection regulations, however, consideration must be given to "customer-owned" telephone facilities and their maintenance. If a base station fails it must be immediately restored to operation or provision made for a standby system. This produces a requirement for around-the-clock maintenance coverage by qualified technicians. Failure of a mobile radio unit, while not as serious, may still require immediate service.

The choice between the three methods for obtaining maintenance services is based on many factors. The cost of maintenance equipment, shop space, spare parts stocks, and qualified personnel must be measured against the cost of purchased services. Maintenance services can be contracted for through equipment manufacturers or independent maintenance organizations. The quality, convenience, speed and reliability of the service—whether performed "in-house" or purchased on the outside—are just as important factors in choosing between these alternatives as their relative cost.

V.3.3.5 System Flexibility

The flexibility of a police telecommunication system is an intangible attribute of the system. In general, flexibility consists of a system's ability to adapt rapidly to changes in demand and unforeseen events. Demands produced by individual events concern one aspect of flexibility. For instance, a flexible system will provide communication for a portion of the department or a segment of the service area that is involved in an extraordinary event, without seriously disrupting the communications for the rest of the department or area. This is related to having sufficient system capacity to absorb a sudden increase in the communication load.

Another aspect of flexibility involves adaptation to slower, but more permanent changes in demand. Growth of the community, of the demands for service, and of the department are changes of this form. Shifts in population within the system's service area, introduction or loss of industrial or business facilities, changes in political boundaries, and introduction of new communication technologies are all sources of permanent changes in communication system demands.

Both aspects of this flexibility requirement can be met if the system has enough capacity. If the system barely meets the current demands, flexible response to new or changing demands is difficult. If, however, some capacity is available for increased demands, system flexibility can be achieved by planning in three system areas—operating procedures, personnel resources, and system configuration.

The general characteristics of many unpredictable events are known. The operating procedures can identify the changes needed to deal adequately with these events whenever they occur. The operating procedures can include detailed instructions for dealing with localized catastrophies, such as an airplane crash or train wreck; with extraordinary criminal activity, such as a bank robbery; with increased demands for services, such as in response to severe weather conditions; and so on. If a radio network, for instance, utilizes three channels in three separate zones, it is possible to develop a plan for distributing normal radio traffic in the three zones on two of the channels when one is needed for a special purpose. This kind of planning implies both a set of procedures for such circumstances and the prior design of the network and its equipment to make such shifts in channel use possible.

The personnel resources of a communication system can be made flexible by training and using the personnel to give each employee a range of skills rather than a single, narrow specialty. If a communication center employs several people, it may be desirable to train some in the duties of others and on a scheduled basis give them experience in the different tasks. Dispatchers for different zones can rotate positions; switchboard operators, complaint clerks and dispatchers may learn each others jobs, or learn them sequentially. The more specialized tasks such as operating teletypewriters and computer terminals can be taught to personnel who ordinarily have other duties. The result of this kind of approach is to enable a communication system to operate effectively when heavy demands are placed on its personnel during emergencies.

For a system to be able to respond to growth, it must be able to increase its staff. This requires that the space and positions for additional dispatchers, telephone operators, technicians, etc. are anticipated when the system is first designed.

One example of flexible system configuration has already been mentioned—the shifting of channels among different zones. Another is the planned shift of communication load among communication centers (when one is disabled) that was discussed in Section V.3.3.1 in relation to system redundancy. A response to slower changes in demand is also possible if the system operates on several channels assigned to different zones. Changes in demand due to shifts in population or political boundaries can be accommodated by changing the zone boundary served by each channel.

A conclusion that emerges from these considerations and examples is that flexibility is easier to achieve in a communication system that encompasses several entities with respect to its network configuration of administrative organization. For instance, if two radio channels serve two zones in the same network, the zone boundaries can be shifted by administrative action. If the two channels constitute the frequency resources of two separate networks, a desired change in boundary may involve negotiations between differing interests, political considerations or governmental approval. Agreement may then be much more difficult to achieve than in the first case. Similarly, a system employing a number of persons can achieve the sort of flexibility discussed above. A one- or two-man staff does not have sufficient capacity to overcome the limitation of its size.

Size may be detrimental to flexibility if resistance to change is encountered in the system structure. There is no optimum size, however, because this resistance can be successfully avoided in large systems on the one hand, or be an inhibiting influence in relatively small ones on the other.

V.:4 Intersystem Communication

The need for intersystem communication arises from overlapping state, county, and municipal law enforcement jurisdictions, and events requiring police action which cross political boundaries. In addition, information about stolen items and wanted and missing persons must be readily exchanged among police departments. If centralized data banks and information retrieval systems are available, means for getting out needed data as well as means for supplying data to such banks or systems are required.

Law enforcement agencies can communicate with each other by utilizing

- Point-to-point radio
- Mobile intersystem radio
- Teletypewriter, telegraph, and data transmission systems
- Telephone
- Mail

There are advantages and disadvantages to each of these modes, and appropriate times to use them. The mail is, of course, not part of a department's telecommunication system in the sense defined here. A brief description of the requirements for intersystem communication follows. A more complete discussion may be found in Reference 26.

A common intersystem message is a request for a record check—primarily stolen automobiles and vehicle registration information, but also warrant and missing person checks. Another type of message supplies information to many departments—all those on a radio network or in a particular region covered by a teletypewriter system. These messages include information about wanted and missing persons and stolen articles of all kinds. Departments with adjacent or overlapping jurisdictions may communicate requests for assistance or direct police action. These range from traffic accident reports to requests for emergency assistance. In addition, miscellaneous messages from reports of serious crimes to weather and road-condition reports are exchanged. A separate class of intersystem messages are those directed to and received from centralized data banks and retrieval systems. These have been discussed in detail in Section V.1.5. When police vehicles must cross jurisdictional boundaries on official business, there is a need to maintain continuous communication, which can be met by a mobile intersystem radio network.

V.3.5 Emergency Communication

The way that emergency and catastrophe situations give rise to communication requirements was described in Section V.3.1.

Such requirements imply the existence of standby emergency radio communication capacity which is otherwise unused or has only low priority normal use. In general, such standby capacity can be provided in two ways, or in combinations of these two. One way is to establish special standby emergency channels whose regular, low priority traffic is easily displaced during emergencies. The other is to build enough reserve capacity into the regularly used channels to ensure that they can absorb the extra traffic generated during emergencies. An important attribute of any channel designated for emergency use is its immediate availability to the police departments involved. This requires that either standby or regular channels with sufficient reserve capacity be under the complete control of the law enforcement agencies who are to use them. Thereby ruled out (with a qualification explained below) is the sharing of emergency channels with other services.

The reasons for this are not difficult to see. To handle emergency situations effectively, the channels must be available with no forewarning, at any time of day or night, every day of the year. The occurrence of a police emergency is usually not predictable. For the police to expect to be able to preempt arbitrarily the communication facility of another service, involving other agencies, is not realistic. Most agencies using land-mobile radio attach high priorities to much of their own radio traffic, and may not wish to be summarily preempted. Furthermore, many emergencies involve non-police agencies as well. Thus, the occasion for emergency police use of a channel may often coincide with a period of heavy, perhaps even emergency use by other agencies, particularly other public-safety agencies such as Highway Maintenance, Forestry Service, Sanitation Departments, Public Works, Civil Defense, and others.

Another reason why sharing of channels for emergency use is not advisable for law enforcement agencies is that it would be possible for someone with access to the equipment used on such a channel to purposely or accidentally disable it. So simple a matter as a stuck microphone switch can render a channel entirely useless. Since some emergencies may involve disruptive or criminal action by citizens, easy access to means for disabling or interfering with communications should be kept to a minimum.

The question of how much reserve capacity for emergency communication is reasonable, is difficult to determine. It is almost certain that no amount of capacity provided will ever be enough in all situations. The capacity sufficient to handle communication after a major airliner crash or railroad disaster, may not be enough to handle the aftermath of a series of tornadoes devastating several nearby communities. Capacity sufficient to deploy and direct police for an annual Fourth of July parade may not suffice to command tactical police units controlling huge crowds at a major rock music festival. Such examples can be multiplied many times over. Since no simple criterion exists, the capacity recommended should be great enough to be useful in a large proportion of the emergency situations that might arise.

This leads to a slight qualification of the previous recommendation that no emergency radio channels be shared with other services. Since there will always be some emergencies that require more communication capacity than is available to the police, arrangements for

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2 OF 5

POLICE TELECOMMUNICATION SYSTEMS NCJ 00341

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the police use of some other public-safety channels during emergencies should be considered. If such arrangements are made with enough different agencies, one or another of them may not be involved with many emergencies and thus their radio channels can then be available for use by police. Such shared channels cannot be considered the primary emergency communications capacity for police agencies. They can only serve as back-up for emergency channels directly under the control of police.

V.3.6 Federal Communications Commission Rules and Regulations

Both land line and radio communication in police service are subject to the rules and regulations of the Federal Communications Commission (FCC).*

The statutory authority that governs communication and provides the basis for the management of electromagnetic frequencies is the Communications Act of 1934, which established the FCC and delineated its primary functions. It is printed in Title 47 of the U.S. Code, beginning with Section 151. Revised pamphlet copies may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

The FCC is the governmental agency concerned with the administration of rules and regulations governing the operation of radio stations, including those in use for law enforcement activities. Its rules and regulations govern many areas of radio usage (called "services" by the FCC). Of primary concern to the police telecommunication systems user is the "Public Safety Radio Service", which provides for the use of radio communication systems by "governmental entities" having certain specifications. The needs of police communication fall primarily within this category of regulations.

The FCC must apportion frequencies among commercial broadcast uses and non-broadcast services, such as police radio. The Commission's prime resource, the radio spectrum, is not available without prior restrictions, since the Federal Government claims large portions of spectrum space for its military and other operational uses. The Inter-Agency Radio Advisory Committee (IRAC) under the Office of Telecommunications Policy (OTP) performs functions similar to the FCC's, but only for Federal agencies. The Office of Telecommunications Policy is charged with developing national spectrum utilization policy. Of further limiting effects are the many international treaties which apportion spectrum space world-wide.

*Excerpts from the FCC Rules and Regulations that are pertinent to the Police Radio Service are contained in Appendix F.

Most of the problems which beset system planners are attributable to the lack of usable frequencies.[27,28] Competition for frequencies is intense, not only between broadcast and non-broadcast users, but within the group—for example, between public-safety and business and industrial radio users. The Police Radio Service is only one part of the land-mobile group. The most recent FCC action to make additional frequency allocations for all land-mobile radio services was the granting of frequencies between 470 MHz and 512 MHz on a shared basis with UHF TV Channels 14-20 in the ten largest U.S. metropolitan areas, through approval of FCC Docket 18261. Also made available to land-mobile radio were the frequencies between 806MHz and 960 MHz, through approval of FCC Docket 18262.

The FCC has established certain basic technical requirements and specifications for radio equipment characteristics. The basis for most of these characteristics is the need for provisions to reduce or eliminate harmful interference and to conserve the use of the radio frequency spectrum as much as possible. When entering discussions with radio equipment manufacturers, the system planner must have a general knowledge of certain basic provisions of FCC regulations that deal with such factors as frequency stability, type of emission, power levels, and acceptable equipment. The full provisions are set forth in Part 89 of Volume V of the FCC Rules and Regulations. (See Appendix F for the most pertinent sections.) These may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Inquiries on specific matters pertaining to the Police Radio Service should be addressed to the Federal Communications Commission, Safety and Special Services Division, 1919 M Street, N.W., Washington, D.C. 20554.

In the interest of reducing or eliminating harmful interference, the FCC has established certain operating rules. These rules are basic to any station operation. Supervisory functions should ensure that these rules are constantly being observed. Violations of these rules could result in violation notices from the FCC and possible suspension of service. The basic operating rules are as follows:

- All communications, regardless of their nature, are restricted to the minimum practical transmission time.*
- Continuous radiation of an unmodulated carrier is prohibited except when required for test purposes.*
- The FCC expects each licensee to take reasonable precautions to prevent unnecessary interference. If harmful interference does result,

*This does not apply to microwave systems.

the FCC may require any or all stations to monitor the transmitting frequency before transmission.

- Tests may be conducted by any licensed station as required for proper station and system maintenance, but such tests are to be kept to the minimum. Precautions are to be taken to avoid interference to other stations.

Among the specific provisions that apply to the Police Radio Service are as follows:

Eligibility. Authorizations for stations in the Police Radio Service are issued only to States and to other governmental subdivisions (counties, cities, towns, etc.) that are authorized by law to provide their own police protection.

Permissible Communications. Stations in this service are authorized to transmit communications essential to the official police activities of the licensee.

Types of Communications. In addition to the intercommunications between police base stations and mobile stations and between mobile stations, stations authorized in the Police Radio Service may also intercommunicate with other stations in the Public Safety Radio Service if no harmful interference will result.

Communication units of a licensed police mobile station may normally be installed in any vehicle that may require cooperation or coordination with police activities in an emergency. This includes highway vehicles, fire department vehicles, ambulances, emergency units of public utilities, lifeguard emergency units, and rural school buses.

Frequencies Available for the Police Radio Service. The frequency bands available for the Police Radio Service are listed in Table IV-1 in Chapter IV. A complete list of the actual frequencies is given in Section 89.309 of the FCC Rules and Regulations, shown in Appendix F. Normally, only one base and one mobile station frequency is assigned to a licensee for mobile station operation. A licensee in the Police Radio Service may use, without specific authorization from the FCC, any frequency available to the Police Radio Service between 40 MHz and 952 MHz for communication in connection with surveillance, stakeouts, raids, and other such activities. Such use is on a secondary basis and may not cause harmful interference to other Public Safety Radio Service licensees. The maximum power that may be used for communication of this type is 2 watts.

V.3.7 Frequency Coordination

The responsibility for actual determination of how many and which frequencies shall be assigned to a police agency rests with the Federal Communications Commission.[29] It is, however, assisted in this task by voluntary APCO Frequency Advisory Committees.* These Committees perform a frequency coordination function for the applicant for a radio channel and the FCC. Frequency coordination is the process of selecting and recommending to the applicant and the FCC one or more radio frequencies for use by the applicant, which will cause the least amount of interference to other radio users, to the applicant himself, and yet provide serviceable channels.

Thus, the function of these committees is essentially to minimize the likelihood of harmful interference being caused to other systems by the operation of a proposed system. An application may require the committee to perform extensive research in determining matters such as physical separation, propagation paths and the existence of other systems licensed on adjacent channels but in another service (usually Local Government). If the application is favorably commented upon by the Frequency Advisory Committee, the statement of the committee accompanies the application to the FCC, where it is processed.

Seeking a letter of clearance from a Frequency Advisory Committee is generally considered the most satisfactory method for processing the application. If a dispute arises or other considerations merit the action, an application may be forwarded to the FCC without a clearance letter. It must then be accompanied by a statement that all licensees within 75 miles and operating within 30 kHz of the proposed system have been notified of the intended operation, and by a report based on a field study of the likelihood of interference.[30] Section 89.15(c) of the FCC Rules and Regulations limits the power of the Frequency Advisory Committees. It points out:

> The functions of Frequency Advisory Committees are purely advisory in character, their comments are not binding upon either the applicant or the Commission, and must not contain statements which would imply that . . . (they) have any authority to grant or deny applications.

A manual which spells out the functions and procedures of a Frequency Advisory Committee is in preparation by the Associated Public-Safety Communications Officers, Inc. (APCO) and should be consulted for detailed information on the subject.[31]

*In New England this service is provided by the Eastern States Public-Safety Radio League.

V.3.8 Legal and Economic Constraints

While most of the legal requirements for police telecommunication systems are those imposed by Federal regulations, there are generally some state-imposed legal constraints as well. These relate mainly to agreements among police agencies in different communities. Most states have enabling statutes for certain types of inter-local agreements. These should be consulted when cooperative agreements between departments to establish joint network administrative structures are being contemplated. If governmental bodies in more than one state are involved, special interstate compacts or other arrangements may be needed.[32]

The economic constraints on a system are, of course, a function of the agency's budget and the community's resources. Potential sources of outside funding and the requirements for budgeting were discussed in Chapter III. A final caution regarding the budget should be noted. It is generally understood that the telecommunication system budget must include equipment maintenance, and that this must be considered as part of the system cost when new equipment is purchased. It is sometimes overlooked, however, that equipment depreciation or replacement cost must also be included in an accurate budget. It was recommended in Section V.3.3.3 on Standards and Specifications that the anticipated life expectancy of equipment be contained in its specifications. Therefore, the time for replacement will be known. Budgets which contain for a number of years no provision for depreciation costs and are then followed by a budget in which all the replacement costs are included in one year are not realistic, nor do they reflect adequate planning. This procedure has the added disadvantage that the funds available for modifying a system and replacing its obsolete or worn out equipment depend strongly on the community's resources during that year. If funds are scarce the amount available for expenditure may not reflect the actual need. Depreciating a system's equipment over its life-span and concurrently establishing a depreciation fund ensures that a minimum amount is always available when needed.

CHAPTER VI

EVALUATION OF POLICE TELECOMMUNICATION SYSTEMS

The purpose of this chapter is to provide methods for evaluating police telecommunication systems. The methods are applicable both to existing systems and to those in the design stage. Evaluation of a system is necessary to determine whether the communication needs of the police department are adequately met. If the existing system does not meet the department's needs, then the evaluation should clearly point out the deficient areas so that they may be improved. In this chapter, a Police Telecommunication System will often be referred to simply as a communication system.

The communication system consists of the personnel of the communication unit and its organization, equipment, operating procedures, and radio channels. The types of equipment included are radio, telephone, teletypewriter, data transmission terminals, recording devices, and information display. Examples of communication personnel are the communication officer, dispatcher, complaint clerk, and maintenance technician. Effective operation of the system requires a set of comprehensive procedures, and these must be considered in the evaluation.

The evaluation procedure to be presented consists of two steps:

- Finding out what you have to know about the system in order to evaluate it
- Taking that information and deciding whether the system does what it is supposed to do

The things one has to know about the system, or the information one has to get, can be described in terms of four sets of questions:

1. Who needs to communicate with whom, and what information is conveyed and stored?
2. What is the priority of the information listed in Question 1, how much time is allowed to convey the message, how long can the message be, what are the FCC regulations governing the mode of transmission, and what are the communication system budget limitations?
3. What type of radio, telephone, and control equipments comprise the system, how is the communication division organized, what are the operating procedures, and what are the duties of the personnel? and

4. Which variables are appropriate indicators of the quality of service provided by the system, which variables can be used to measure the load on the system, and what is the numerical value of each variable?

An example of a variable is the time delay a dispatch operator experiences in transmitting a message to a mobile unit. This variable is an indicator of service quality and system load, and can be measured. Further, a performance standard of an average time delay of five seconds has been established, as discussed in Chapter V, Section V.3.2.2.

Each set of the above questions describes a type or category of information which must be obtained. These categories numbered in correspondence with the questions, are:

1. Functions of the system
2. Requirements and external constraints on the system
3. Physical and organizational configuration of the existing system
4. System performance data

Functions of the system are discussed in Chapter V, Section V.1, requirements and external constraints are discussed in Section V.3, physical configurations are discussed in Section V.2.1 and V.2.4, and organizational configurations are discussed in Section V.2.5.

In Section VI.1, methods for getting the four types of information are discussed. Information about the functions and the requirements is needed to evaluate a proposed system as well as an existing system. Methods for designing a new system are discussed in Chapter VII. Section VI.2 discusses methods for using the information which has been obtained to determine whether the system is performing as it should.

Evaluating a communication system should be a continuing process. Such evaluation assists the police department in making long-range plans for expanding and updating the system. By this means the department can recognize potential weaknesses before they become major problems and should be in a better position to make necessary improvements.

In order for the evaluation to be useful, the required information must be identified. The methods for collecting the information must be compatible with the operation of the system. The data collected should provide a clear indication of the system's performance. A definite commitment must be made to interpret the results. Collecting data which are not used is wasteful and can also lead to a false impression that the system's condition is being adequately monitored.

VI.1 Methods for Collecting Evaluation Information

Procedures for obtaining each of the four major types of information are discussed in this section. Section VI.1.1 tells how to determine the functions of the system, Section

VI.1.2 tells how to determine the requirements on the system, Section VI.1.3 describes how to identify the existing system, and Section VI.1.4 discusses methods for collecting system performance data. A summary of the procedures and guidelines for organizing the information-gathering activities is contained in Section VI.1.5.

Once the information is obtained initially, only a relatively small effort is required to keep the information current. In addition, much of the information needed to evaluate a system can be used for other purposes, such as selecting and training personnel, scheduling maintenance, and preparing budget requests.

VI.1.1 Determining the Functions of the System

The basic objective of a police telecommunication system is to satisfy the information handling needs of the police department. Identification of the objective comes about by answering the question—"What is the police telecommunication system supposed to do?"

Three methods to determine the functions of the communication system are discussed in the following sections. The three methods are:

1. Obtain communication system functions from the operating procedures of the communications unit
2. Obtain communication system functions from the overall functions of the police department
3. Obtain communication system functions from the information needs of police department personnel

The second and third methods both determine the communication system functions from the information needs of the department. Method 2 does this by examining the information needs associated with each department function, while Method 3 does it by examining the information needs associated with each department position.

A function, as discussed in Chapter V, Section 1, is identified by the first two, or all three of the following items:

- Information to be conveyed
- The communication path to be furnished
- The information to be stored and the means (collection system) to do so

The information to be conveyed may be a complaint or request for assistance from the public, or the information given a citizen in response to an inquiry. It may be the content of the message transmitted by the dispatcher to a patrol unit in the field, or it may be the data on a license check requested from a central information retrieval system.

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A communication path is defined by the two terminals of the path as well as the means and direction of message flow. For instance, a path from the dispatcher to a patrol officer might need the dispatcher, a microphone, a base-station transmitter and antenna, a radio channel, a mobile antenna, a mobile receiver, and a patrolman. Figure VI-1 shows such a path in schematic form, indicating the intended communication path and the fortuitous or incidental paths. The latter are a by-product of the radio network configuration because the channel is single-frequency simplex and receivers all receive every transmission within their operating range since they are not addressed in the same manner as, for example, a telephone.

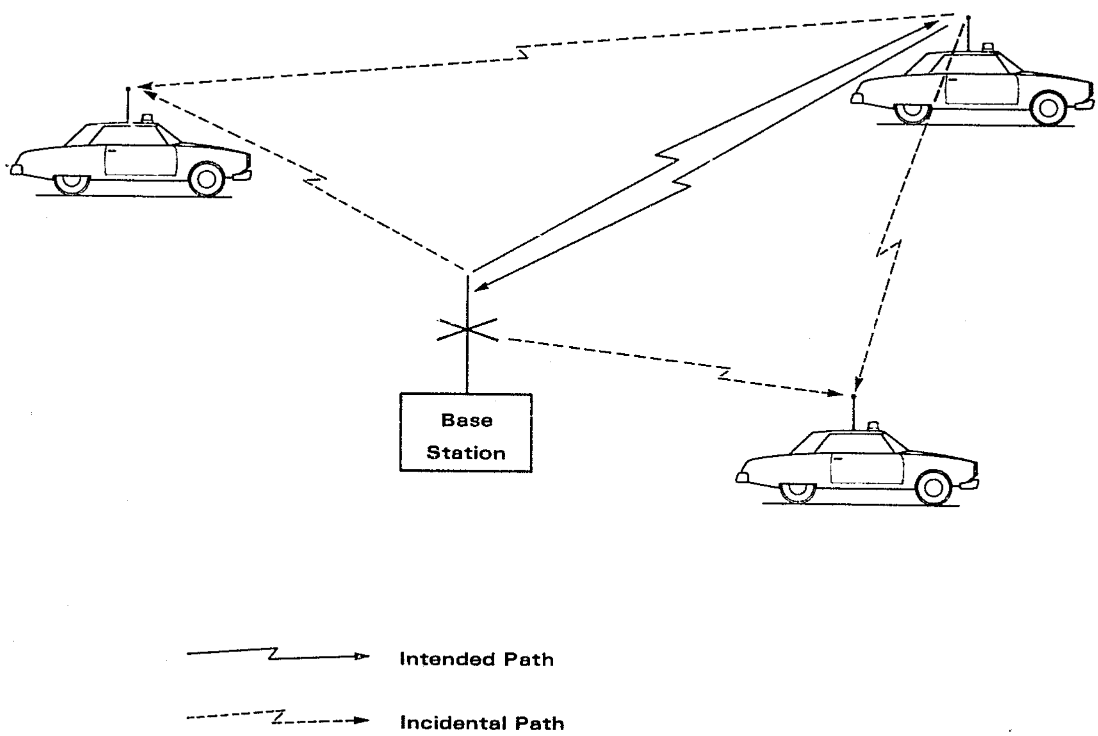

Fig. VI-1 Dispatcher - Patrol Unit Radio Communication Paths

Some types of information may be stored in a communication system for different lengths of time. One type of information is patrol-unit status. It may be stored by writing the status, for example, on a card and placing it in a file. Filing the card allows the information to be recovered quickly when it is needed. Another method is to use a status board containing switched lights which store and display the status information. The dispatcher need only glance at the board to determine whether a unit is in or out of service. Other types of information stored by some communication systems are taped telephone conversations between complaint clerks and the public and radio conversations between dispatchers and the mobile units. Magnetic tape or stylus-cutting recorders are often employed to store conversations. The basic complaint information may simply be written on paper, with time information stamped on by a time clock.

The three methods for recognizing the functions of a police telecommunication system which are described below result in a list of these functions. A form for recording them is shown in Fig. VI-2. The functions will be described by the entries in Columns 1, 2 and 3. Associated with each function are one or more function requirements, which will be listed in Column 4 next to the corresponding function. Function requirements are discussed in Section VI.1.2. Examples of entries in this form are shown in Section VI.1.1.2 (Fig. VI-5) and again in Section VI.1.2.1 (Fig. VI-11).

Communication System			
Information Conveyed	Communication Path Furnished	Information Storage	Function Requirements
____________	____________	____________	____________
____________	____________	____________	____________
____________	____________	____________	____________

Fig. VI-2 Form to Identify the Communication System Functions

Since determining the system's functions is the cornerstone of the evaluation process, the functions must be completely and precisely defined. Additional effort at this stage can have a big return in establishing the usefulness of the evaluation.

VI.1.1.1 Method 1: Obtain Communication System Functions from the Operating Procedures of the Communications Unit

One way to determine the functions of the communication system is to examine the operating procedures of the communications unit. The procedures may be documented in training or procedures manuals and job descriptions. A list of the functions may then be determined from these procedures. If such documentation is not available, interviews with the staff of the communications unit can be used to establish a list of functions. If interviews are used to get the information, a list of questions to be asked should be prepared in advance. This list includes what type of information do you supply, to whom do you give the information, what information do you store, how do you store it, and what else do you do.

A tape recorder is helpful in conducting interviews. Information can be lost if the interviewer is only taking notes. The person being interviewed should be advised in advance of the purpose of the interview. It is recommended that a department memo stating the objectives be sent out before the interviews begin.

A drawback to this method is that some functions can be overlooked. There are two major possibilities for this danger. One is that the documentation may not be complete. The other is that the system may not be performing all of the functions which it should be performing. This is a serious drawback because the evaluation would continue to overlook these deficiencies.

VI.1.1.2 Method 2: Obtain Communication System Functions from the Functions of the Police Department

Another way to determine the functions of the communications system is to derive them from the information needs associated with each police department function.

Examples of the functions of a police department are shown in Table VI-1.[1] In this list, the functions are placed in five major categories:

- Detection, control and reduction of crime
- Control of traffic movement
- Maintenance of public order
- Provision of public services
- Administration and support

The list in Table VI-1 is only an example of the functions of a department. A department using this method should prepare its own list. The department's annual summaries or reports can provide both a basis and a check for this list. An illustration is shown in Fig. VI-3. The services reported in this summary include reports of windows and doors found open, house checks, escorts, emergency messages, arrests for other jurisdictions, and many other department functions[2] which provide the basis for this method.

The steps required by this approach are:

1. Determine the functions of the total department
2. List department activities necessary to perform each function
3. List any support activities required to perform each function
4. List the information to be conveyed
5. List the communication paths needed for the activities
6. List the information to be collected and stored in the execution of each department function

Table VI-1

Szanton's Detailed Police Program Structure

I. CONTROL AND REDUCTION OF CRIME PROGRAM
- A. Prevention/Suppression
  - 1. General Purpose Patrol
  - 2. Special Purpose Patrol (by type of offense)
  - 3. Intelligence
  - 4. Community Relations
- B. Investigation/Apprehension
  - 1. Crimes Involving Major Risk of Personal Injury
    - a. Murder
    - b. Assault
    - c. Rape
    - d. Armed Robbery
    - e. Burglary—Homes
    - f. Arson
    - g. Etc.
  - 2. Crimes Not Involving Major Risk of Personal Injury
    - a. Theft
    - b. Unarmed Robbery
    - c. Auto Theft
    - d. Burglary—Commercial
    - e. Fraud
    - f. Forgery
    - g. Etc.
  - 3. Vice
    - a. Narcotics
    - b. Prostitution
    - c. Gambling
    - d. Etc.
- C. Prosecution
  - 1. Interrogation
  - 2. Preparation for Trial
  - 3. Trial
- D. Recovery of Property
  - 1. Autos
  - 2. Other Personal Property
  - 3. Commercial Property
- E. General Support
  - 1. Communications
  - 2. Records and Data Processing
  - 3. Technical Services
    - a. Fingerprint
    - b. Ballistics
    - c. Polygraph
    - d. Laboratory Analysis

II. MOVEMENT AND CONTROL OF TRAFFIC PROGRAM
- A. Traffic Movement
  - 1. Direction of Traffic
  - 2. Enforcement of Traffic-oriented Parking Rules
  - 3. Emergency Road Services
  - 4. Weather Emergency Procedures
  - 5. Identification and Reporting of Congestion Points
- B. Traffic Safety
  - 1. Enforcement of Regulations
    - a. Patrol/Apprehension of Moving Violations
    - b. Enforcement of Safety-oriented Parking Rules
  - 2. Driver Training
  - 3. Educational Programs
  - 4. Vehicle Inspections
- C. Accident Investigation

III. MAINTENANCE OF PUBLIC ORDER PROGRAM
- A. Public Events
  - 1. Sporting Events
  - 2. Public Ceremonies
    - a. Parades and Receptions
    - b. Public Meetings
    - c. Cornerstones, etc.
- B. Minor Disturbances
  - 1. Private Quarrels
  - 2. Parties
  - 3. Drunkenness
  - 4. Derelicts
  - 5. Miscellaneous Nuisances
- C. Civil Disorder
  - 1. Prevention
  - 2. Suppression

IV. PROVISION OF PUBLIC SERVICES PROGRAM
- A. Emergency Services
  - 1. Fire
  - 2. Medical
  - 3. Power Failure
  - 4. Flood
  - 5. Civil Defense
  - 6. Miscellaneous
- B. Missing Persons
- C. Lost Property
- D. Miscellaneous

V. ADMINISTRATION AND SUPPORT PROGRAM
- A. Direction and Control
  - 1. Direction
  - 2. Planning and Development
  - 3. Internal Inspection and Review
- B. Training and Personnel
  - 1. Recruitment
  - 2. Training
    - a. Basic
    - b. Advanced
  - 3. Testing, Evaluation, Promotion
- C. Public Relations
- D. Supporting Services
  - 1. Records (noncrime) and Data Processing
  - 2. Communications
  - 3. Budget
  - 4. Property

POLICE DEPARTMENT – 1968 ACTIVITY SHEET

Activity	1968	1967
Prisoners lodged for other agencies	129	51
Persons assisted	1,383	1,150
Doors/windows found open/reported	291	158
Fires discovered	4	3
Non-Criminal complaints	7,709	7,280
Escorts	679	772
Sudden deaths investigated	3	2
Arrests for other jurisdictions	34	21
Mental cases investigated	1	0
Suicide cases investigated	2	2
Non-vehicular accidents	63	74
Reports of conditions for other departments	473	378
Emergency messages	79	68
Houses checked	828	916
Stray and lost dogs	1,267	1,081
SUB-TOTAL	13,302	12,243
Automobile accidents investigated	395	371
Criminal complaints	1,320	1,246
Total traffic offenses	3,111	2,352
Miscellaneous arrests and citations	1,179	17
GRAND TOTAL	19,307	16,230

Fig. VI-3 Sample Activity Summary

Steps 4, 5 and 6 define the communication system functions in terms of the information needs associated with the department functions.

The basic outline for this method is a six column form as shown in Fig. VI-4. A list of the department functions is placed in Column 1. The communication system functions are the things that must be done by the system to fulfill department information handling needs. Thus, the lists in Columns 4, 5, and 6 define these functions.

Police Department			Communication System		
Functions of the Department	Activities to Perform those Functions	Support Activities	Information Conveyed	Communication Paths Furnished	Information Storage

Fig. VI-4 Form for Listing Department Functions and Related Data

An example of how to fill out the form is shown in Fig. VI-5. In the second column, the activities required to perform each function are listed. In the third column, support activities are listed. These support activities include those actions needed for the management and supervision of the department.

For each activity listed in Columns 2 and 3, the information conveyed is described in Column 4 while the necessary communication path is described in Column 5. Column 6 lists the information to be stored for each department activity. The department function considered in the example is the apprehension of a suspect.

From the basic function of the department, the activities and communication system functions can branch out much like a tree. Several department activities, communication paths, and types of information may be required to perform a single department function. For this reason, adequate space should be provided in the form.

After the form is filled out, the data in Columns 4, 5, and 6 should be transferred to Columns 1, 2, and 3 of the Communication System Function form, as shown in Fig. VI-6. The same communication system functions may be required for different department activities. However, each function should be listed only once.

The list of the communication system's functions should be reviewed for completeness. Preferably, the review should be performed by representatives from each bureau or division

Police Department			Communication System		
Functions of the Department	Activities to Perform those Functions	Support Activities	Information Conveyed	Communication Path Furnished	Information Storage
Apprehension of suspect	Receive complaint	Supervision	Complaint	Telephone: citizen — department	Complaint
	Select and assign patrol unit		Patrol unit assign	Two-way radio: base-mobile	Patrol unit status
	Meet complainant		Report arrival at scene	Two-way radio: base-mobile	
	Investigate complaint				
	Apprehend suspect	Notify watch commander	Report apprehension and intention to transport prisoner	Two-way radio: base-mobile	Time of apprehension
	Transport suspect	Prepare for arrival of prisoner			
	Deliver suspect		Report arrival at station	Two-way radio: base-mobile	Time of arrival Patrol unit status
	Prepare written reports				
	Submit report				

Fig. VI-5 Example of Department Functions and Related Data

Communication System		
Information Conveyed	Communication Path Furnished	Information Storage
Complaint	Telephone: citizen-department	Complaint
Dispatch patrol unit	Two-Way radio base-mobile	Patrol unit status
Report arrival at scene	Two-way radio base-mobile	--

Fig. VI-6 Example of Identification of Communication System Functions

and members of the communication staff. Any omissions should be added to the list, and an attempt made to explain why the omission occurred. If one knows why an omission was made, one can check to see if other functions were omitted for similar reasons.

Although this method may appear cumbersome, it has the advantages of:

- Providing a complete check list for functions the system could and/or should perform
- Relating communication functions to police activities
- Identifying restrictions or requirements imposed by department policy
- Identifying restrictions or requirements imposed by the communication system
- Isolating functions which are created internally by the communication system

An additional advantage to this approach is that Steps 1, 2, and 3 provide the basis for evaluation of not only the communication systems, but for all systems of the department.

VI.1.1.3 Method 3: Obtain Communication System Functions from the Information Needs of Police Department Personnel

Another way to determine the functions of the communication system is to consider the information needs of the department personnel and external information users. The steps required by this approach are:

- List each position (or entity) in the organization of the department
- List the information needs of each position
- Determine and list the source of the information
- Determine and list information supplied to organizations and individuals outside of the department

The basic framework for this approach is, first, a form listing each position and its information needs, and second, a matrix (that is, a listing arranged in rows and columns) which displays the sender and receiver of each type of information.

Department positions are listed in Column 1 of the first form (See Fig. VI-7). For example, the list of positions or entities for one department would consist of Chief, watch commanders, patrol units, division commanders, detectives, record clerk, and dispatchers.[3]

Entity or Position	Information Needs
1. Patrol Unit	Complaint assignments; Current Stolen, Wanted, Missing Persons Information, Traffic Control Information, etc.
2. Watch Commander	Status of Units, etc.
3. Detective	

Fig. VI-7 Form for Recording Position Information Requirements

After each position, the information needed by that position is listed. Once the form is prepared, it should be checked by each commander for accuracy and completeness. The commanders should be advised of the purpose for which the information is being collected. A department memo stating the objectives should be distributed.

After review and correction of the list, a matrix is formed with a row and a column for each entity in the initial list (See Fig. VI-8). The rows in the matrix represent the destination or user of the information. The columns represent the originator or supplier of the information. An additional row and column will be used to represent external originators or destinations of information. After the matrix is formed, the boxes are filled in by looking at the initial list of information requirements and deciding who supplies the needed information. For example, the patrol unit obtains the complaint assignments from the dispatcher. After filling in each row and exhausting the requirements of each recipient, a check should

Information Destination	INFORMATION ORIGINATOR							
	Patrol Unit	Watch Commander	Detective	Division Commander	Dispatcher	Record Clerk	Chief	External
Patrol Unit								
Watch Commander								
Detective								
Division Commander								
Dispatcher								
Record Clerk								
Chief								
External								

Fig. VI-8 Form for Communication Path Matrix be made of each column to see that each originator has the information to supply. The entity or position represented by the column may have to get the information from another entity. If this is the case, the originator's row should be checked to see that it does receive the information. For example, the dispatcher must get the complaint from the citizen (external).

Each box in the matrix represents a possible communication path. When a path is not needed, it should be noted or crossed out. To complete the identification of the communication system's functions, the external communication paths (the last row and the last column) must be examined. For each entry in the last column, the originator of information (citizen, state police, county police, information retrieval system,. . .) must be specifically identified. For example, the dispatcher receives stolen automobile information on a teletypewriter from a state computer file.

Entries have not been made, as yet, in the last row. First, each column should be examined to determine whether any entity or position supplies information to someone outside of the department. Consideration should be given to such things as departments of adjacent communities monitoring radio traffic.

A check of the entries made in the last row can be obtained by examining the last column (types of information supplied from outside the department).

Examples of the two forms, shown in Fig. VI-9, consider the information needs associated with apprehension of a suspect. The example in Fig. VI-10 identifies the communication needs for reporting hazardous driving conditions. The information to be conveyed and stored is listed in the box and the location of the box identifies the terminal points of the communication path.

The functions of the communication system are obtained from the completed matrix. Each matrix box utilized represents a necessary communication path which must be supplied by the communication system. The information to be conveyed and recorded by the system is obtained from the data in each box. The data contained in the finished matrix should be transferred to the Communication System Function form, as shown in Fig. VI-6 after being checked for accuracy and completeness. The advantage of the matrix structure is that it organizes the information needs so that items missed become apparent.

VI.1.1.4 Conclusion

This section describes three basic methods for obtaining a list of functions of a police telecommunication system. A department may use one of the basic methods or modify or

Entity	Information Requirements
1. Patrol Unit	Complaint assignment, ...
2. Watch Commander	Notification of suspect transport, ...
3. Dispatcher	Complaint, ...

Information Destination	Information Originator			
	Patrol Unit	Watch Commander	Distpatcher	External
Patrol Unit			Assignment	
Watch Commander			Notification of suspect transport	
Dispatcher	Status of unit Time of arrival Time of departure			Complaint

Fig. VI-9 **Examples of Information Requirements and Communication Paths**

Information Destination	Information Originator			
	Patrol Unit	Watch Commander	Dispatcher	
Patrol Unit				
Watch Commander				
Dispatcher	Report Icy Intersection			
External			Report Icy Intersection (Dept. of Public Works)	

Fig. VI-10 Example of Communication Paths combine the methods to suit the individual needs.[4] The factors which influence the choice are:

- The size and complexity of the department
- The size and complexity of the communication system
- The amount, detail, and accuracy of existing documentation

Each function of the communication system then listed on the Communication System Function form will be identified by the first two, or all three of the items: the information to be conveyed, the communication path to be supplied, and the information to be stored.

Regardless of the manner in which the functions of the communication system are determined, the list and descriptions of the functions should be checked by various members of the department. Particular attention should be given to the functions which are required during special or emergency situations and by mutual aid agreements. It is important not to overlook any areas.

After the functions have been determined, provisions should be made to update the list. Changes in department policy, availability of new services and information, and changes in the organizational structure can lead to additions or modifications to the functions of the communication system. In any case, periodic review of the list is desirable.

This task provides the information required for the first category of the four described at the beginning of Chapter VI. The next section discusses how to obtain the information in the second category.

VI.1.2 Determining the Requirements and the External Constraints on the System

The basic requirement on a police telecommunication system is that it be able to perform its functions (as described in the previous section) in a manner which meets the department's information-handling needs. It there were no external restraints imposed on the system, the requirements could be defined as the ability to transfer and record complete information instantaneously, at all times, without any errors, regardless of the workload placed on the system. Unfortunately, there are constraints with which to contend; examples of these constraints are limited spectrum availability, FCC rules and regulations, budget limitations, performance and characteristics of commercially available equipment, and human response times. Therefore, it is necessary to determine how well the functions can be performed and still fulfill the information-handling needs of the department.

Most, if not all, departments are aware of the congestion on police radio frequencies and of the difficulties of obtaining adequate funding. What this means is that there is not unlimited spectrum available, manpower, and equipment to perform the functions of the system. In fact, these resources may be quite limited. Therefore, it is not feasible to have zero delay whenever anyone wishes to use the channel, or to have every emergency telephone call answered on the first ring. The department makes a compromise between the desired perfect system and what the limited resources allow. It cannot, however, compromise severely the effectiveness of law enforcement and service to the public.

To avoid too severe a compromise of its service, the department must make maximum use of its resources. Unnecessary messages should not be allowed on the air. Messages should not be longer than necessary to convey the needed information. Transmitter power should be limited to cover only the necessary area. To achieve maximum use of the resources, requirements are placed on the functions and the system. These are intended to eliminate undue waste of the resources.

For the system to perform the functions, there are some basic general requirements which are common to all functions. For example, these general requirements include physical protection of equipment and personnel, provisions for continuous operation, adherence to FCC regulations, and adequate staffing and training.

This section contains a discussion of methods which can be used to determine the requirements on the system in view of the external constraints. The methods are employed to answer three types of questions—"How well can the system be expected to perform each function?", "How often must the system perform each function?", and "What general requirements are imposed on the system?" Methods for determining function requirements are discussed in Section VI.1.2.1; methods for getting the number of times a function is performed are discussed in Section VI.1.2.2; and a brief discussion of general system requirements is contained in Section VI.1.2.3.

VI.1.2.1 Function Requirements

Requirements are associated with functions. If these requirements are not met, the function cannot be adequately fulfilled. For example, a function of the communication system is to dispatch a patrol unit to apprehend an on-the-scene suspect. If the unit is not notified until thirty minues after the complaint has been received, the function is not being performed adequately. For each function, it is necessary to determine how much delay, error, and condensation of information can be tolerated without impairing law enforcement effectiveness. In establishing the requirements, it is necessary to consider effective use of resources such as radio transmission air time, money, and manpower.

Communication system response time is discussed in Chapter V, Section V.3.2. If an average overall response time of three minutes is desired, requirements on the communication system are that the average communication-center delay must be less than 90 seconds and the average delay in gaining access to the radio channel be less than 5 seconds. When determining requirements in terms of average desired performance, the variable nature of the load on the communication system is to be considered. The delay averaged over a peak period is longer than the delay averaged over a day or a week. Therefore, the requirements might be defined in terms of allowable limits for the busy periods.

The limits on communication-center delay and on gaining access to the radio channel are just two of many requirements which must be met to perform the functions adequately. The basic approach in determining function requirements is to ask and answer certain questions about the functions. This section will contain examples of questions which should be asked. The examples are not complete. They indicate the types of questions which should be asked. The examples should be used to aid the evaluator in thinking of additional questions.

For each function, there are several basic questions which can be asked. "What are the requirements in regard to accuracy, completeness, reliability, time delays, etc.?" In addition, "Are there any attributes of the function which give rise to special requirements?" For example,

- Are there any special legal considerations?
- Are there any special situations which would alter the requirements?

Examples of requirements are:

"A legal requirement on monitoring transport of a suspect is that the time the suspect is placed in the squad car and the time the suspect arrives at the station must be recorded."

"A requirement on reporting hazardous driving conditions is that Public Works should be notified of icy intersections before 0400 hours."

The function requirements are determined by answering questions about how well the function should be performed. In answering these questions, there are things the evaluator should avoid doing. The function requirements should not be confused with procedures for performing the functions. Defining current procedures as requirements may introduce biases of personal preferences or prejudices. The question at this point is not how is the function going to be implemented, but what results are expected of any procedure. Also, restrictions imposed by the communication system should not be confused with function requirements.

439-911 O - 71 - 14

For example, to reduce air time, missing person broadcasts are delayed during busy periods. This is a system restriction, not a function requirement. This restriction may impair the overall effectiveness of police service. However, such a compromise may be necessary in order to put higher priority messages on the air.

There are function requirements which consider the effective utilization of the resources. One question to be asked is "How can the length of messages be reduced and still convey the needed information?" A requirement is that APCO "Ten Signals" and other codes be used whenever possible.

The answers should be as specific as possible. Some of the questions can be answered in terms of numerical values. For example, "What is the allowable delay in making a complaint assignment?" Some requirements cannot be expressed in numerical terms. For example, "Is there a risk if the message is monitored by an unauthorized listener?" In other words, numerical standards can be defined for some requirements but not others.

In most cases, the requirement is either met or not met each time the function is performed. The complaint number is either recorded correctly or it is not. A citizen calling the police either gets a busy signal or does not get a busy signal. However, these are events which are repeated many times throughout the year; part of the time the requirement is met, part of the time it is not met. A standard could be defined as an acceptable percentage of time the requirement is not met.

Numerical standards can be defined for some requirements. It is up to the department to establish what the standards should be. Often the standards are quite arbitrary, but they represent the level of service that the department can reasonably expect to provide. Development of standards should consider the following questions:

- Do the standards provide for the desired level of service?
- Do the standards consider the good will and expectations of the citizens?
- Do the standards consider the needs and expectations of the police officers?
- Do the standards take into account efficient use of resources including manpower?

For example, in setting the standards for permissible delay in transmitting a record check, was it considered that the officer requesting the check would be idle while he waits for the check? What is the cummulative effect of that idle time? In other words, what would be the net reduction in effective patrol time? In setting standards for data reduction and summary preparation, was the importance of timely information considered? Will beat assignments be based upon obsolete information?

After the initial determination, requirements should be reviewed to see whether they are reasonable. Impossible or unnecessary demands should not be placed on the system. For example, if a department shares a radio channel with thirty neighboring departments, it might be impossible to meet the requirement that the average delay in gaining access to the radio channel is less than five seconds. Conversely, the requirements should be checked to see if they are too loose. One way to check if the requirements are tighter or looser than necessary, is to ask, "What are the consequences if the requirement is not met?" If the consequences are not serious, then the requirement may be too tight. If, however, a serious problem will arise, the requirement might even be too loose.

The methods for determining the requirements are discussed separately from the methods for determining the functions. However, in practice, the two activities are sometimes conducted in parallel. All function requirements should be listed in Column 4 of the Communication System Function form in Fig. VI-11.

COMMUNICATION SYSTEM			FUNCTION REQUIREMENTS
Information Conveyed	Communication Path Furnished	Information Storage	
Complaint	Telephone: Citizen — department	Complaint	Emergency number trunk line open—busy signal less than one per hundred.
Dispatch patrol unit	Two-way radio: base—mobile	Patrol unit status	Communication center delay less than 90 seconds (from receipt of complaint call to end of dispatch message).
Report arrival at scene	Two-way radio: base—mobile	— —	Communication center delay less than 25 seconds (from time patrol unit wants to send arrival message to end of message).

Fig. VI-11 Example of Communication System Functions and Requirements

VI.1.2.2 Function Demand

The communication system responds to the information handling needs of the department. These needs constitute a pressure toward action. This pressure is the demand made on the communication system. The size of the demand determines the response of the system, that is, the number and intensity of the activities undertaken (the things that are done) to meet the demand. Therefore, the size of the demand can be determined from data which measures the number and intensity of the system's activities. These data are called demand data. An example is the number (volume) of radio messages handled by a system in a given time period. Another is the proportion of these calls which are emergency in nature. Simply stated, the demand is the number of times each function must be performed.

COMPLAINT REPORT 1.2

NATURE OF INCIDENT ☐ BELOW ☐ IN PROGRESS | COMPLAINT NO. | TIME

LOCATION OF INCIDENT | CORNER ☐ NW ☐ NE ☐ SW ☐ SE | BEAT | REVERSE USED ☐ | REC'D.

COMPLAINANT'S NAME ☐ REFUSED | ADDRESS ☐ SAME AS LOC. | TELEPHONE NO.

CHECK BOX IF APPLICABLE. IF CONDITIONS ARE NOT LISTED, DESCRIBE ABOVE. | DISP.

ALARM........ ☐ FIRE ☐ SILENT ☐ AUDIBLE ☐ HOLDUP

ACCIDENT..... ☐ PERS. INJ. ☐ PROP. DAM. ☐ HIT & RUN ☐ PRIVATE PROPERTY

DISTURBANCE.. ☐ FAMILY ☐ JUVENILES ☐ VEHICLES ☐ ANIMALS

PERSON....... ☐ INJURED ☐ MISSING ☐ SUSPICIOUS ☐ NEEDS ASSISTANCE | ARR.

THEFT........ ☐ VEHICLE ☐ BICYCLE ☐ FROM AUTO ☐ AUTO ACCESSORIES

REMARKS | COMP.

UNIT ASSGND. | UNITS ASSISTING | REPORT SUBMITTED ☐ M. I. ☐ CASE ☐ ACC. ☐ ARREST | RECEIVED BY | DISPATCHER

IACP 176-1.2

FRONT

VEHICLE | PERSONS | TIME

COLOR | YEAR | MAKE | NO. 1 | SEX | RACE | AGE | HGT | WGT | HAIR | EYES

STYLE | BODY | COMP. | GLASSES | CLOTHING

LIC. NO. | LIC. YR. | NO. 2 | SEX | RACE | AGE | HGT | WGT | HAIR | EYES | DESCRIPT. B'CAST.

STATE | LIC. TYPE | COMP. | GLASSES | CLOTHING

OTHER IDENTIFYING INFORMATION | DIRECTION OF FLIGHT ON

NOTIFICATIONS ☐ AMBULANCE ☐ FIRE DEPT. ☐ WRECKER

NAME | TELEPHONE NO. | BASIS ☐ OWNER'S REQUEST ☐ ROTATION ☐ NEAREST AVAIL. | NOTIFICATIONS MADE

DEPT. MEMBERS NOTIFIED: TITLE & NAME

ADDITIONAL INFORMATION | NOTIFIED BY ☐ DISPATCHER

BACK

Fig. VI-12 Example of Dispatch Cards

A basic source of demand data is the dispatch card. An example of a pair of dispatch cards is shown in Fig. VI-12. One card is used to describe a complaint and the other to describe out-of-service or request calls.

A card is prepared each time there is a citizen complaint call, each time an officer receives an internal request for services, and each time an officer goes out-of-service (that is, becomes unavailable for assignment). The cards constitute a complete file of the events which create demands for the complaint-dispatch functions.

Because of the size of the file, it is difficult to obtain a picture of the demand without further processing of the information. Data processing, computer, or tabulating equipment may be a necessity for this task. For smaller volumes, manual tabulating is possible. The cost of the manual labor should be considered and compared to the costs of mechanical or electronic processing if the manual approach is considered.

If data processing equipment is used, the information must be put into an appropriate form, usually by means of punched cards. This step should be considered when the dispatch card or form is designed. The dispatcher's effort in filling out the form should not be significantly increased by key-punch requirements, but key punching should not be made unnecessarily difficult. Data processing personnel should be consulted when the form is designed. Experience with data processing of complaint information indicates that procedures for processing the data must be established, for example, by a systems analyst or programmer who has practical police knowledge and a police officer who knows some of the capabilities and constraints of data processing.

Forms for recording demand data are shown in Section VI.1.4. The number of radio messages is entered in Form 2, *Dispatch Facilities,* and the number of telephone calls is entered in Form 4, *Telephone Lines.*

Demands on the complaint-dispatch functions constitute the bulk of the demands on the system. Others include the demands to enter and cancel messages (stolen vehicles and articles, missing and wanted persons), process and answer information requests, and prepare reports. A summary of information retrieval system activities may be provided by the system. The number of information retrieval activities is entered in Form 6, *Computer Terminals and Teletypewriters.*

In evaluating a system, one wants to know not only how well the system has performed in the past, but also how well it is expected to perform in the future. To find out how the system will perform in the future, the future demands are predicted.

Techniques which can be used to predict future demands range from the simple to the complex. Message volumes for past years may be plotted and a straight line extrapolation used to estimate future demands. An example of this method is shown in Fig. VI-13.[5] In this example the message-volume demands displayed a fairly stable increase. This method of predicting demands may not be practical when there has been a sharp increase in demands. An example of the increase which one department experienced is shown in Fig. VI-14.[6] This department could not use straight line extrapolation.

The demands may be related to the population of the community which the department serves. The demands per person would be multiplied by population projections. Obtaining population projections from municipal or area planning commissions is particularly important if a rapid population growth is expected due to migration or annexation. More elaborate statistical techniques including time-series analysis and multiple regression may also be used.

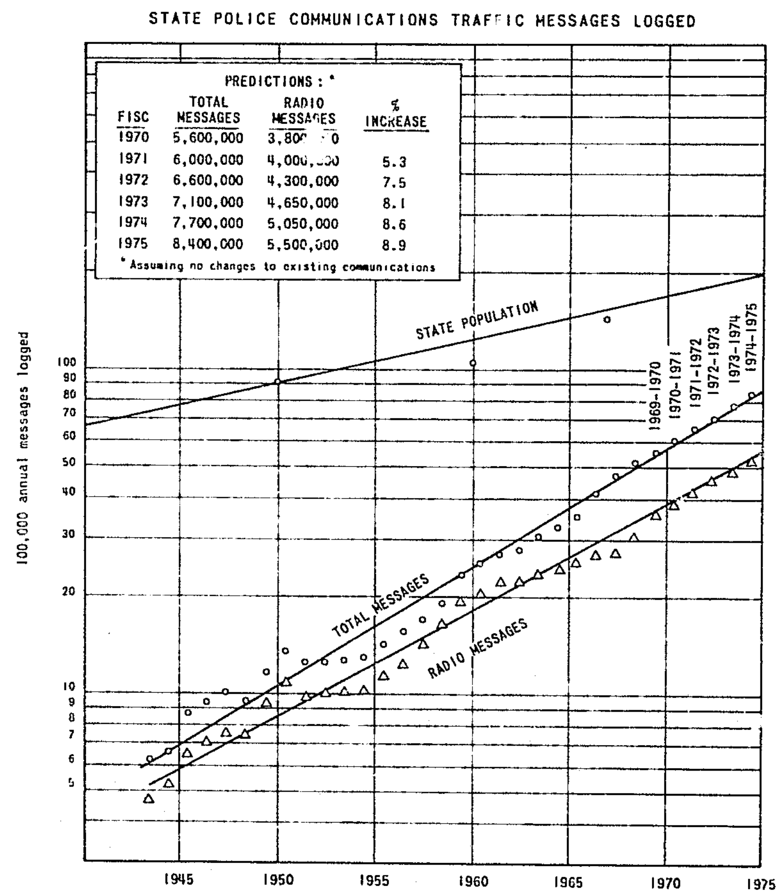

Fig. VI-13 Example of Straight Line Extrapolation

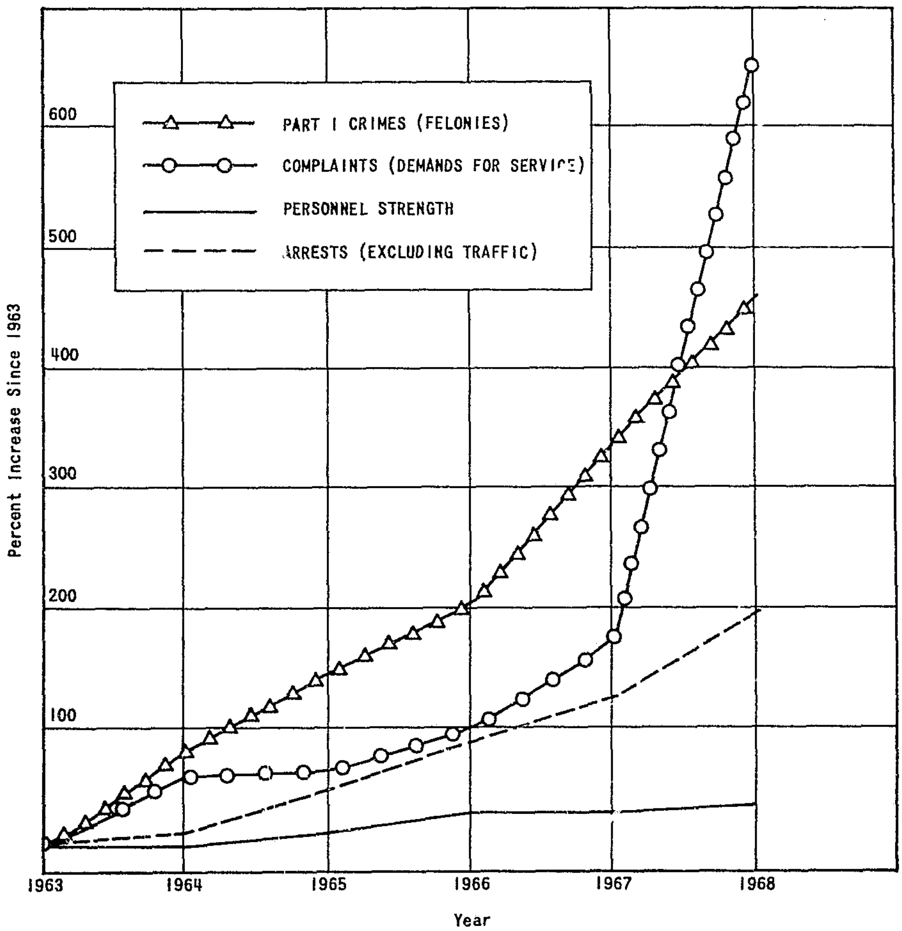

Fig. VI-14 Example Where Straight Line Extrapolation Cannot Be Used

VI.1.2.3 General System Requirements

General system requirements are requirements which are common to all or almost all functions. If the system as a whole meets the requirement, those function requirements are also met. One such requirement is that the system adhere to all FCC rules and regulations. A discussion of FCC Rules and Regulations is contained in Chapter V, Section V.3.6 and selected portions are reproduced in Appendix F.

Physical protection of equipment is another requirement on the system. The system must be reliable. It must be able to operate at all times, regardless of equipment or power failures. There is a general requirement that the communication staff be capable and trained to perform the functions assigned to them.

The organization must be structured so that necessary authority and responsibility is assigned. These requirements are discussed in detail in Chapters IV and V.

General system requirements should be listed on a separate sheet of paper.

VI.1.2.4 Conclusion

The function requirements can be determined by examining each function and deciding how well the department can reasonably expect the function to be performed. A number of general requirements which apply to the total system are also obtained. A requirement, whether of the function or general type, may be subjective in nature or may take the form of a numerical standard. Just as the functions should be carefully checked and updated, the requirements should also be checked and updated.

Requirements, which currently are impossible to meet, may become feasible in the future with technical advances or the availability of more resources.

VI.1.3 Identifying the Existing System

The third type of information used in evaluation is a description of the existing system. The system is identified in order to answer the following questions: "How is the system constructed to perform each function?", and "What provisions are made to meet the requirements?"

The description contains identification of the physical as well as organizational configuration of the system. The description should also include documentation of the following:

- Procedures which are followed to perform each function
- Provisions which are made to meet the requirements

VI.1.3.1 Physical Configuration

Documentation of the communication system should include physical descriptions of radio channels and equipment, telephone equipment, dispatch and complaint facilities and maintenance service. In order to simplify the documentation, a number of forms are presented on the following pages. When completed, the forms provide an orderly compilation of pertinent information which serves as a reference for specific system details. Some forms also have space for recording performance data. Collection of performance data is discussed in Section VI.1.4. The description of the physical system, documented in an orderly manner, gives the evaluator a single place to look to see what provisions have been made to meet the total system requirements which relate to the physical system. The information also allows one to check that necessary equipment is available to perform every system function. When performance data (e.g., failure and maintenance records) are added to the forms, current or potential equipment problems can be identified easily. Finally, the completed forms provide a record of the communication system which serves as a starting point for planning modifications and improvements.

Some of the questions asked in the forms may not be applicable to every police department. For example, a smaller department might not employ the type communication console which is discussed on Form 1. In such cases, the questions should be ignored. On the other hand, there may be departments for which the forms are insufficient, in which case, questions should be added as required.

The spacing indicated on the forms may not provide adequate space for some of the required information. Each department should prepare forms for its own use which contain adequate room for answering the applicable questions.

The forms are presented as follows:

Form 1:	Communication Center
Form 2:	Dispatch Facilities
Form 3:	Complaint Room
Form 4:	Telephone Lines
Form 5:	Alarms
Form 6:	Computer Terminals and Teletypewriters
Form 7:	Channel Assignments—Base Stations and Mobiles
Form 8:	Base Station Equipment
Form 9:	Vehicle Equipment
Form 10:	Personal/Portable Unit
Form 11:	Miscellaneous Equipment
Form 12:	Antenna Site
Form 13:	Emergency Power Equipment
Form 14:	Service

Form 1

Communication Center

Include a blueprint or sketch of the layout which gives dimensions and location of all equipment.

Is the room air conditioned?
Yes ☐ No ☐

Is the room sound conditioned?
Yes ☐ No ☐

If the above is yes, describe how.

What special emergency procedures are set-up for the communication center?

What are the provisions for physical security of the communication center?

Are there any other activities in the communication center besides complaint and dispatch operations (e.g., report typing, handling the reception or complaint desk)?
Yes ☐ No ☐

If the above is yes, describe the activities.

What is the volume of complaint assignments and the communication center delay?*
(Enter below.)

Shift	Beat	Total Number of Assignments Past Year	Average Communication Center Delay (seconds)	Average Communication Center Delay During Monitored Busy Period (seconds)

Length of Busy Period (hours) ______________

Time and Date of Monitoring ______________

* Maintain a yearly record.

Form 2

Dispatch Facilities

Number of dispatcher positions? ____________

What is the position manning schedule?

Describe capabilities provided at each position.
Position No. 1 ____________
Position No. 2 ____________

Are positions comfortable and equipment easy to operate?
Yes ☐ No ☐

If no, describe difficulties.

Are there any other locations from which base station transmissions can be made?
Yes ☐ No ☐

Where are these locations?

What kind of control unit (desk set, small, desk-top console, full console) is employed?

____

Does the dispatcher have supervisory control over these locations?
Yes ☐ No ☐

Does the dispatcher switch these locations in and out or are they connected at all times?

____

What locations, if any, monitor the communication system?

Are radio channels recorded?
Yes ☐ No ☐

If yes, describe recorder and what channels are recorded.

WHO

controls status board? ____________
selects car to be dispatched? ____________
stamps complaint form? ____________
stamps complaint form with case number? ____________
marks unit back in service? ____________

Form 2 (Continued)

How many status levels (e.g., *available, enroute, on assignment, out of service)* are there for field personnel (vehicles and foot)? ____________

What are they? ________ ________ ________ ________

Are any levels of status of low priority so that a man assigned to a lower level complaint can be reassigned to a higher level complaint?

Yes ☐ No ☐

Describe the status level priorities and who decides to reassign a man.

Are there any priorities assigned to complaint assignments (e.g., immediate dispatch, delayed dispatch).

Yes ☐ No ☐

If yes, describe the priorities and how the priority of a complaint is determined.

During the past year, how many times was the priority given lower than the actual level of the complaint? __________% __________ number

During the past year, how many times was the priority given higher than the actual level of the complaint? __________% __________ number

What is the volume of radio messages?* (Enter below.)

Channel	Total Number of Messages Past Year	Total Number of Messages During Monitored Busy Period	Average Radio System Delay During Busy Period (seconds)

Length of Busy Period (hours) ____________

Time and Date of Monitoring ____________

* Maintain a yearly record.

What was the average message length ________ seconds?

Does the dispatcher handle radio messages for other services (e.g., fire, public works).

Yes ☐ No ☐

If yes, which services? ____________________________

Form 3

Complaint Room

If telephone calls are received in a separate complaint room or separate positions within the control center, please answer the following:

Number of positions (total). ____________

Does supervisor have full operating position? Yes ☐ No ☐

What is the position-manning schedule?

Describe capabilities provided at each position.

Position No. 1 ____

Position No. 2 ____

Are positions comfortable and equipment easy to operate?

Yes ☐ No ☐

If no, describe difficulties.

Is the complaint room equipped with its own status board?

Yes ☐ No ☐

What special emergency procedures are set-up for the complaint room?

What are the provisions for physical security of the complaint room?

Is the room air conditioned?

Yes ☐ No ☐

Is the room sound conditioned?

Yes ☐ No ☐

If yes, describe how.

Describe any other activity in the complaint room besides the taking of telephone complaints (e.g., report typing, handling the reception and complaint desk).

How do messages get from the call taker to the dispatcher?

Form 4

Telephone Lines

Does department have separate emergency and administrative phone numbers?
Yes ☐ No ☐

If no, how many incoming lines are there? ____________________

If yes, how many incoming lines are there for: Emergency ______ Administrative ______

Does the department utilize 911? Yes ☐ No ☐

If yes, are operators specially trained? Yes ☐ No ☐

What other services (e.g., fire, ambulance) are also using 911? ____________________

How many unlisted number lines does the department have for its own business? _____

Are telephone lines recorded? Yes ☐ No ☐

If yes, describe recorder and what lines are recorded.

What is the volume of phone calls? * (Enter below.)

Telephone Number	Total Number of Calls Past Year		Total Number of Calls During Monitored Busy Period	
	Dispatch	Non-Dispatch	Dispatch	Non-Dispatch

Length of Busy Period (hours) ____________________
Time and Date of Monitoring ____________________

* Maintain a yearly record.

What percent of the time are all lines busy? (If possible, obtain from telephone company percent of calls which received a busy signal.)

Emergency lines ____________ % Administrative lines ____________ %

(If possible, obtain from telephone company a breakdown on the number of rings before a call is answered.)

What are the costs? (Enter below.)

Type of Line	Installation	Monthly
Emergency		
Administrative		

Is there any backup telephone equipment? Yes ☐ No ☐

If yes, describe backup.

Do the operators handle telephone calls for other services (e.g., fire, public works)?
Yes ☐ No ☐

If yes, which services? ____________________

Form 5

Alarms

At what location are bank or store alarms monitored? ______________

Are there any tape recorded burglar alarms with telephone attachments?
Yes ☐ No ☐

Are any jail alarms monitored?
Yes ☐ No ☐

If yes, where? ______________

Are any other types of alarms or closed-circuit television systems monitored? If so, where is the monitoring point?

____

How many alarms were received this year?*

Valid Alarms ______________

False Alarms ______________

Which alarms had the most false alarms?

* Maintain a yearly record.

Form 6

Computer and Teletypewriter Terminals

List below the computer and/or teletypewriter terminals the agency uses. Be sure to indicate if a terminal is shared between two or more networks or information retrieval systems.

LETS Yes ☐ No ☐

NCIC Yes ☐ No ☐

OTHER (Name) ____________________

Who operates the terminals? ____

If the terminal position is not equipped for radio operation how does the radio dispatcher send information requests to the terminal operator and get back the required information?

What are the physical locations of the terminals?

If each terminal is not at a dispatcher location, is the terminal location equipped with a control unit so that the terminal operator can communicate with field forces?

Yes ☐ No ☐

Using the agency's present information flow system, how long on the average does it take to:

Run a license check? in-state: _____ seconds out-of-state: _____ seconds

Run a check on a vehicle registration?

in-state: _____ seconds out-of-state: _____ seconds

Run a check on a wanted person?

in-state: _____ seconds out-of-state: _____ seconds

For each data file what was the volume of information requests, entered messages, cancelled messages during past year? (Enter below.) *

Computer System	Number of Information Requests	Number of Messages Entered	Number of Messages Cancelled	Number of Miscellaneous Uses (specify what)

* Maintain a yearly record.

439-911 O - 71 - 15

Form 7
Channel Assignments—Base Stations and Mobiles

Channel Designator	Frequency (Base Transmit)	Frequency (Base Receive)	Tone Squelch		Function	Portables and Vehicles
			Transmit	Receive		

NOTE: Under "Portables and Vehicles" column indicate, by Y (Yes) or N (No), the type of units which are on channel, e.g.,

Y V — Yes Vehicles N V — No Vehicles
Y P — Yes Portables N P — No Portables

Form 8
Base Station Equipment

Identification Number	Item	Qty.	Mfg.	Model	Band	Power	Channel Capability	Loc.	Control		Rad.	Age	Tone Squelch	Acquisition Date	Cost
									Rem.	Rptr.					

Failure Record		Maintenance Record		
Date	Type of Failure	Date	Scheduled	Non-Scheduled (State Reason)

NOTE: Abbreviations:
Qty. — Quantity
Mfg. — Manufacturer
Loc. — Local
Rem. — Remote
Rptr. — Repeater
Rad. — Radio

Form 9
Vehicle Equipment

Identification Number	Item	Quantity	Manufacturer	Model	Band	Power	Channel Capability	Age	Tone Squelch	Acquisition Date	Cost

Failure Record		Maintenance Record		
Date	Type of Failure	Date	Scheduled	Non-Scheduled (State Reason)

Form 10
Personal/Portable Unit

Identification Number	Item	Quantity	Manufacturer	Model	Band	Power	Channel Capability	Power Source	Age	Tone Squelch	Acquisition Date	Cost

Failure Record		Maintenance Record		
Date	Type of Failure	Date	Scheduled	Non-Scheduled (State Reason)

Form 11
Miscellaneous Equipment

Identification Number	Item	Description	Quantity	Manufacturer	Model	Age	Acquisition Date	Cost

Failure Record		Maintenance Record		
Date	Type of Failure	Date	Scheduled	Non-Scheduled (State Reason)

Form 12

Antenna Site and Associated Equipment

Site Number ______

Address and Legal Description ______

______

Latitude (degrees, minutes, seconds) ______

Longitude (degrees, minutes, seconds) ______

Height above ground (feet) ______

Ground height above mean sea level (feet) ______

Total height above mean sea level (feet) ______

Antenna specifications:

Manufacturer ______ Model ______

Gain (decibels) ______ Type ______

Directional Yes ☐ No ☐

If yes, state direction ______

Type of connector ______

Wind load (pounds per square foot) ______

Make and type of tower ______

Guyed Yes ☐ No ☐

Type of lighting ______

Type of lighting switch (manual, automatic) ______

Equipment building Yes ☐ No ☐ Size ______

Name of nearby airport ______

Distance (feet) ______ Direction ______

Transmission line specifications:

Manufacturer ______ Model ______

Size ______ Type ______

Length (feet) ______ Type connector ______

Form 13

Emergency Power Equipment

Describe the type of emergency power equipment used. ______________________

Electrical capacity (kilowatts) ______________________

Automatic start and load transfer Yes ☐ No ☐

Describe the type of fuel and the storage system. ______________________

____

Does the fuel storage system meet fire regulations and other safety standards? Yes ☐ No ☐

Is the power equipment in a separate room from the communication gear? Yes ☐ No ☐

If no, are there any electrical interference, corrosion, vibration, or heat problems? Yes ☐ No ☐

Describe the cooling and ventilation facilities. ______________________

____

Is the emergency power equipment run and checked periodically? Yes ☐ No ☐

If yes, is a log of the test runs kept? Yes ☐ No ☐

Form 14

Maintenance Service

Does agency have own maintenance service organization? Yes ☐ No ☐

If yes, continue up to Contract or Other Service.

If no, go to Contract or Other Service and provide answers.

Self-Servicing Agency

Personnel

Number of licensed technicians ____________

Number of unlicensed technicians ____________

Facilities

Square feet shop space ____________

Square feet installation area ____________

Is installation area covered ____________

Number of bench positions ____________

Are any bench positions devoted to specific equipment servicing? Yes ☐ No ☐

Is there a separate stock room for spare parts? Yes ☐ No ☐

Approximate square feet ____________

Does service shop have a screen room? Yes ☐ No ☐

Size (feet) ____________

Are there any current plans for service-shop changes? Yes ☐ No ☐

What are these plans? ____________

Form 14 (Continued)

How far is the service-shop location from police headquarters? ______________

Does service shop use service vans or other vehicles? Yes ☐ No ☐

How many ______________

Describe ______________

Test Equipment

List below basic test equipment and quantity on hand.

____

Spares and Standby Equipment

What policy does the service-shop have regarding spare mobiles, personals, etc.

____

____

Are any standby base station facilities provided at the service shop? Yes ☐ No ☐

Describe standby facilities at shop. ______________

____

Contract or Other Service

Who is servicing agency (company, county, etc.)? ______________

____

Where are they located? ______________

Must mobiles go to shop for service? Yes ☐ No ☐

Number of technicians

Licensed ______________

Unlicensed ______________

Describe service facility, including installation area. ______________

VI.1.3.2 Organizational Configuration

The first step in identifying the organizational configuration is to prepare an organization chart. The purpose of an organization chart is to enumerate the different divisions and positions in the communications unit and to show the relationships between them. This information helps to identify the specific personnel involved in the implementation of each system function. Also, the chart provides a record which may serve as a basis for planning future system modifications.

Examples of such charts are shown in Figs. VI-15 and VI-16 (see also Fig. V-30). Figure VI-15 is the organization chart for the records and communications division of a suburban police department which has 35 sworn personnel and 5 civilian employees. The population of this suburb is about 25,000.[7] Figure VI-16 is the organization chart for a municipal communications department for a community of about 400,000.[8]

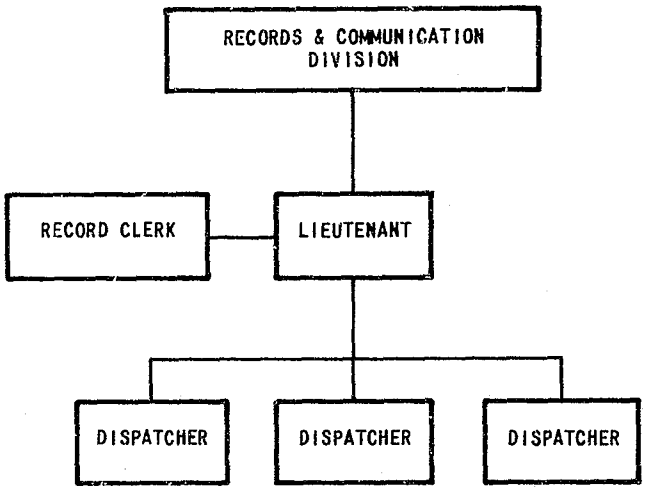

Fig. VI-15 Communications Unit

The chart in Fig. VI-15 shows a combined Records and Communications Division. A Lieutenant is in charge. It consists of civilian dispatchers and clerks and an officer who compiles statistical data.

Dispatchers operate the base radio station. One police radio channel is for base-mobile operations. The other provides point-to-point communication. The operators dispatch for the Fire Department and monitor the Public Works channel.

Dispatchers handle all incoming telephone calls and serve as desk clerks to deal with the public at the police building.

The figures are included as examples of the way the organizational configuration can be displayed. They are not included for the purpose of making any recommendations. A discussion of recommended attributes of organizational configurations is contained in Chapter V, Section V.2.5.

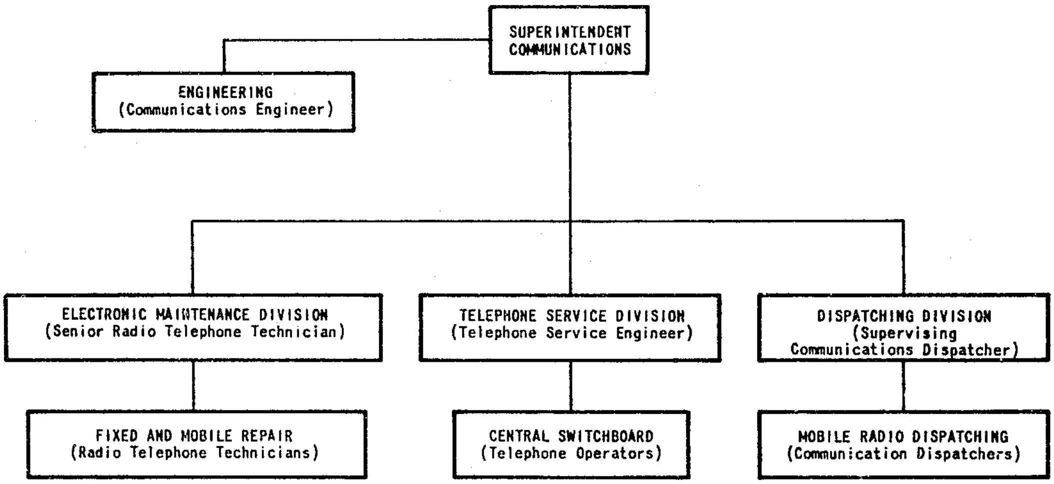

Fig. VI-16 Communications Department

The second step in identifying the organizational configuration is preparing a job description for each entry in the organization chart. Examples of such descriptions are given in Figs. VI-17 and VI-18. The description in Fig. VI-17 is for a combined dispatcher and complaint-clerk position.[9] The description in Fig. VI-18 is for a dispatcher position in a system where the dispatch and complaint operations are separate.[10]

DEFINITION

She functions as a radio dispatcher, receptionist, desk officer, teletype operator, clerk-typist, police matron/policewoman and records technician. She represents the Department in the majority of initial contacts between the Department and the public. She processes requests for police service, dispatches police units or makes other referral. She assists police officers in the investigation of offenses involving women and juvenile girls as suspects or victims. She processes fire calls and dispatches equipment accordingly. She is responsible for many other service functions, including the preparation of reports, indexing and filing of administrative and crime reports and recording of statistical data.

TYPICAL DUTIES

Operates the fire-police dispatch center, monitoring the teletype, police and fire frequencies and alarm systems.

Dispatches fire equipment in response to fire calls according to fire run cards and Fire Dispatching Instructions.

Processes incoming calls for police service, dispatching units as needed, and referring calls to others if necessary.

Functions as receptionist/desk officer in front office, makes preliminary inquiries prior to referrals and prepares initial reports in minor cases.

Prepares and sends teletype messages and inquiries, processes incoming messages.

Investigates crimes where juvenile girls are involved as suspects or victims, assists in the investigation, processing or transportation of women arrestees.

Receives and processes monies from parking tickets and bails posted at the Department.

Maintains a daily bulletin of reports covering police activity, reproduces, indexes and distributes various police reports.

Functions as relief meter maid when required.

Is aware of her role as a city employee and is alert to non-police problems and hazards in the community taking whatever action is necessary to correct the problem.

Fig. VI-17 Radio Dispatcher Job Description

DISTINGUISHING FEATURES OF WORK

This is responsible work in operating police base radio and teletype equipment to receive and transmit messages and information.

Employees of this class are mainly responsible for operating central departmental base radio and teletype equipment in providing accurate and timely transmittal of information and messages that frequently involve emergency situations affecting human welfare or safety. Information is transmitted upon request or according to established procedures. Work also includes related typing and filing work. The employee is expected to exercise considerable judgment in performing routine work under the general direction of a supervisor who is available for immediate consultation on non-routine matters.

EXAMPLES OF WORK PERFORMED (Any one position may not include all of the duties listed, nor do the listed examples include all tasks which may be found in positions of this class.)

Receives coded forms requesting police investigation from the complaint section. Time stamps and assigns "request forms" to appropriate base radio operator for notification of responsible field unit.

Operates base radio and maintains constant radio contact with mobile units on assigned frequency. Receives investigation request forms or telephone calls of messages to be transmitted; transmits and follows up to ensure accurate receipt and understanding.

Receives radio calls from field units, transmits messages via radio or telephone; makes inquiries of various sources such as officials, outside agencies and companies, to obtain requested information or services.

Logs information received or transmitted by radio; keeps continuous record of the status of mobile units on board. Reviews length of time mobile units are on case and notifies supervisor if excessive. Consults supervisor regarding non-routine matters.

Operates teletype machine to provide written notification, to various sections, of significant police matters such as complaint investigations and dispositions, stolen cards and other criminal activities.

Operates teletype machine according to precise formats necessary to enter information and make inquiry of sophisticated computer systems.

Monitors State Highway Department, Fire Department and County Sheriff radio frequencies; also Highway Patrol network teletype messages. Relays pertinent information or requests for information to responsible city personnel.

Receives reports on car thefts. Maintains master file and notifies police personnel of stolen and recovered cars via radio and teletype.

Prepares activity reports on stolen and recovered cars. Contacts owners of recovered cars to arrange for return.

Types reports and cards for information files; files data and performs other routine clerical work.

REQUIRED KNOWLEDGE, SKILLS AND ABILITIES

Working knowledge of Police Department organization, policies, operating procedures and methods.

Working knowledge of the City streets and areas, including geographical layout of operating districts and associated police problems.

Ability to operate base radio and teletype equipment; to type and perform routine clerical work.

Ability to understand and follow moderately complex oral instructions and to remain calm and effective under heavy workload and emergency situations.

Ability to speak with a clear, well-modulated and pleasant voice and to use good grammatical construction in choice of words.

Ability to write legibly, using proper grammar and spelling.

Ability to exercise good judgment in making decisions in accordance with established procedures and guiding concepts used within the assigned department and to maintain effective working relationships with personnel.

DESIRABLE EXPERIENCE AND TRAINING

Some experience in the operation of two-way radio and/or telephone switchboard equipment including some experience in general typing and clerical work; graduation from standard high school, including or supplemented by courses in typing and clerical procedures.

NECESSARY SPECIAL REQUIREMENT

Possession of or ability to obtain a restricted radio-telephone operator's permit as issued by the Federal Communications Commission.

Fig. VI-18 Police Communications Dispatcher Job Description

A brief discussion of procedures for training a new employee should be attached to the job description. Training and employee selection are discussed in Chapter IV, Section IV.5.

As the system evaluation continues, these descriptions may be expanded and refined. The final job descriptions will be an aid in recruitment, training, job evaluation, and review of salary structures.

Another aspect of organizational configuration to be identified is the structure of common systems such as mutual aid or emergency systems, information retrieval systems, and shared coordinated systems. The structure includes rules and regulations, the governing body, the membership, costs, etc.

In collecting information about the organization configuration, one should document provisions for meeting general system requirements which relate to organization. These requirements include requirements for training, supervision, and defined authority.

VI.1.3.3 Communications Department Procedures

Next, one would identify the communications department procedures by preparing a written description for each procedure. The description should include a list of provisions for meeting function requirements. Some examples of procedure descriptions are given in Figs. VI-19 and VI-20.

SUBJECT: EMERGENCY CALLS

It is imperative that emergency calls received be dispatched as quickly as possible. Many operators have a tendency to copy all the information before dispatching the calls. This procedure, in emergency cases, is wrong.

The following procedures shall be followed by all operators on emergency calls:

1. Determine the type of incident and location.
2. Ask the informant to stay on line and immediately give the information to the Radio Operator so the necessary unit or units may be dispatched.
3. Resume your conversation with the informant, advising him/her that units are on the way, and obtain the necessary information to complete the dispatch sheet with particular attention given to the informant's name, address and phone number.
4. If, during your conversation with the informant, pertinent facts are obtained, these should be relayed immediately to the Radio Operator for broadcast to the responding units.

Fig. VI-19 Communications Department Procedures

Subject: Police Dispatch
Citizen Initiated (Telephone)

Effective Date ____________

Responsibility	Action
PBX	1. Receive all from complainant.
	a. If call received on police emergency (Hot-Line), quickly screen call and, if a routine business call other than complaint, inform party that they should call regular Police line and given them that number to call.
	b. If not routine business call, keep party on police emergency (Hot-Line) line.
	2. If call is of such a nature that the complaint could potentially become a police emergency, place call on one of the urgent lines.
	a. If no such potentiality, follow 1.a. above.
	3. Transfer call to complaint desk personnel using method noted above to determine whether call is transferred on Hot-Line (ambulance, police emergency in progress, or burglar alarm) urgent line, or routine lines.
Complaint Desk Personnel	4. Complete "Complaint Dispatch" card with *all* information.
	5. Time stamp card and forward to Radio-Telephone operators.
Radio-Telephone Operator	6. Dispatch vehicle assigned to location indicated; time stamp card and place in time slot.
	a. If hot line, dispatch emergency equipment necessary as per location indicated and then proceed with card process as indicated.
	b. If vehicle not available in indicated location, assign vehicle in adjacent location.
	7. If no response from officer within 15 minutes, and red status lamp begins to flash, check buff card to ascertain nature of the complaint.
	8. If nature of complaint indicates the officer should be 1008, try to contact.
	a. If assistance is required, assign vehicles.
	9. When officer reports he is back in service, remove cards from slot, time stamp, and file.

Fig. VI-20 Communications Department Procedure Manual

The example in Fig. VI-19 documents the procedures to be followed for a citizen-initiated police dispatch.[11] In the central communication system which employs this procedure, the switchboard operators, complaint desk personnel, and the radio-telephone operators are in three separate rooms. Information goes from the complaint desk to the radio-telephone operator via a conveyor belt.

In a system where the telephone operators and the radio operators are in the same room, an example (given in Fig. VI-20) documents the procedures to be followed by the telephone operator for the citizen-initiated police dispatch.[12]

The description of the procedures is input to the qualitative evaluation of the system. The written descriptions can also be used in training and as a guide for the operating personnel.

VI.1.3.4 Conclusion

Identification of the existing communication system consists of describing the physical and organizational configuration and documenting the procedures. The information compiled serves as an orderly reference for specific system details. This reference enables one to determine how each system function is implemented. The data also aid one in checking that no system function is overlooked in the overall design. In addition, a record of the communication system is obtained which forms a starting point for planning modifications and improvements. Information obtained in this way can be used not only in the evaluation process but also in scheduling, training, and supervising personnel.

VI.1.4 Collecting System Performance Data

Several types of data are required to measure the performance of a communication system. This information describes:

- The effectiveness of the response to demands on the system
- The effectiveness of the physical system
- The effectiveness of the operational system

In the first category are:

- Measures of the communication center delay caused by the complaint—taking process
- Measures of the radio system delays in the dispatching of patrol units

The second category includes data on:

- The failure and maintenance records of specific equipments
- System down time
- Areas of poor radio reception

The third category includes data such as:

- Frequently violated operating procedures
- Productive and non-productive man-hours per shift and position
- Employee turn-over

The criteria for determining which types of data to collect are based upon the numerical standards which have been defined to express quantitatively the communication system function requirements.

The objective of the collection of each type of data should be clearly stated. Some functions of the communication system are to collect data for other users, such as recording patrol-car odometer readings for use by the vehicle maintenance group. Justification of this data collection should not be confused with justification of the collection of data to evaluate the system. Often the same data can be used to serve several purposes. For example, the complaint record is used for supervisory evaluation of the patrol units, for compilation of annual reports, and for measuring the demand on the communication system. An accurate record should be kept of the collection procedures, of the definitions of each category of data, and of the rules which were used to resolve conflicts in the classification of data.

For instance, in data taken to analyze communication center delay, was the "initial time" recorded when the telephone was answered, or was it recorded after the operator hung up. In other words, the technique used to collect the data must be specified exactly. To analyze and compare the communication center delay encountered by emergency and non-emergency calls, a definition of emergency and non-emergency calls must be made. If the distinction is not clear-cut, there must be rules for deciding into which category each call will fall.

The collection of system performance data is divided into collection of data about:

- Performance of the system with respect to system standards and criteria
- System expenditures with respect to budgetary planning

VI.1.4.1 Performance Data

Performance data are observed measures of the performance of the system. These measures include communication delay and the components of that delay, the proportion of the service area in which radio signal strength is below specifications, and the down time records of particular equipments.

(1) *Response Time—Communication Center Delay*

A primary measure of performance for a communication system is the communication center delay—a component of complaint response time. The response time increments are shown in Fig. VI-21.[13]

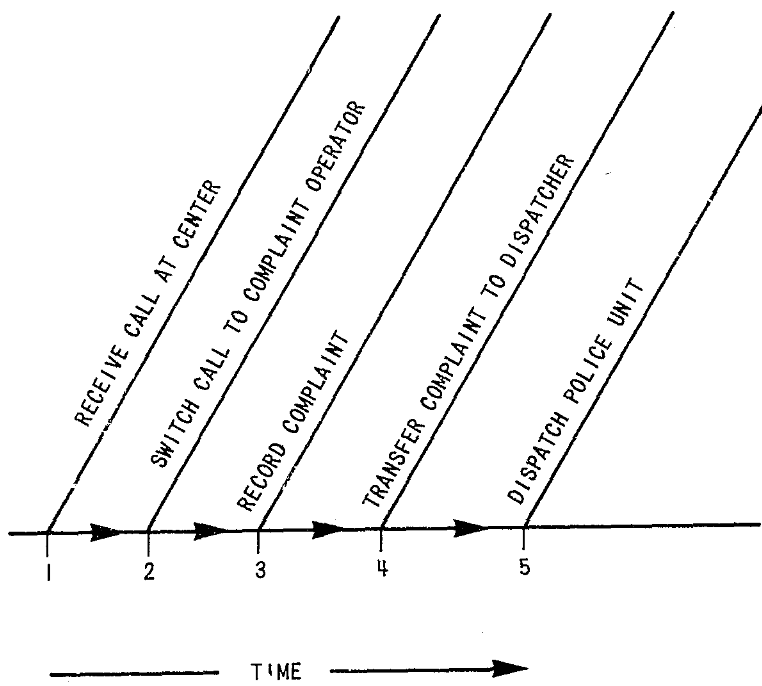

Fig. VI-21 Communication Center Delay

The dispatch card can provide the basic input data for measuring communication center delay. A time clock can be used to stamp the time the telephone call was received and the time a unit was dispatched. An example of a listing of these cards is shown in Fig. VI-22. This listing contains the date and time each complaint was received, the communication center delay, the field response time, and the required time to handle the complaint. If there is a large number of complaints, summaries may provide a picture that is easier to understand and use. An example of a summary is shown in Figure VI-23. In this example the average delay and field response time are computed for each shift on each beat. Data collected on communication center delay is entered in Form 1, *Communication Center*, shown in Section VI.1.3.1.

POLICE DEPARTMENT DISPATCH INCIDENT REPORT								
Date	Beat No.	Shift	Number of Complaints	Time Received	Delay (Hrs:Min)	Travel (Hrs:Min)	Response (Hrs:Min)	Elapsed Time (Hrs:Min)
03/02/70	925	3	1	0014	:33	:02	:35	:30
03/02/70	925	3	1	0146	:03	:02	:05	:16
03/02/70	925	3	1	0008	:04	:02	:06	:47
03/02/70	925	3	1	2350	:05	:04	:09	:19
Shift Totals			4		:45	:10	:55	1:52
Beat Totals			21		2:26	1:45	4:11	10:21

Fig. VI-22 Example of Complaint Card Listing

POLICE DISPATCH AVERAGE TIME REPORT BY BEAT AND SHIFT						
			Time			
Beat	Shift	Number of Complaints	Average Delay (Hrs:Min)	Average Travel (Hrs:Min)	Average Response (Hrs:Min)	Average Elapsed (Hrs:Min)
710	1	169	1:09	1:06	1:15	1:54
710	2	257	1:09	1:06	1:16	1:45
710	3	107	1:07	1:04	1:12	1:36
Beat Totals		533	1:09	1:06	1:15	1:46

Fig. VI-23 Example of Communication Delay

(2) *Telephone-System Delays*

The communication center delay, as defined, does not include all of the delay the telecommunication system can cause a citizen. The dispatch card is not stamped until the telephone is answered. However, the time that the telephone is ringing is a delay too. Furthermore, if the caller receives a busy signal, his delay is even greater.

In some areas the telephone company can, on request, supply a breakdown on the number of rings and the number of times callers received a busy signal. This information is entered in Form 4, *Telephone Lines.*

> *The expected delay and the expected proportion of calls that will receive a busy signal may be estimated by queueing models if the frequency distribution of the time between calls and the frequency distribution of the length of calls are known. If the distributions are exponential, analytic techniques have been developed to compute the delay. Because of the finite number of telephone lines and the strategy of the persons who receive a busy signal, the techniques are quite complicated. They are further complicated if there is more than one complaint clerk.*[14]

(3) *Radio System Delays*

One component of the communication-center delay is the dispatching delay encountered because the frequency is busy. A similar delay can be encountered by field requests. This delay can be estimated by a queueing model.

> *Several models have been developed which can predict queueing or delay time, if the times between messages arriving have an exponential distribution.*
>
> *If the service time (i.e., message length) is also exponentially distributed, the average delay time,* w_q, is

$$w_q = \frac{\lambda}{\mu(\mu-\lambda)}$$

where

$\frac{1}{\mu}$ = *average message length, and*

λ = *average number of arrivals in unit time.*

The assumptions that the police radio message lengths and time between police radio messages have exponential distributions appear valid, based upon the data collected in APCO Project III Phase 2.[15]

439-911 O - 71 - 16

A stop-watch study is the simplest and cheapest way to determine the average message length and the average number of messages. The length of each message during a selected period should be timed and recorded. It is desirable to do the timing from a recording of the transmissions because there will be less disruption of the system and because a known busy period can be selected.

A message consists of the complete two-way conversation between users that occurs in a continuous time period and concerns one subject. In order to establish consistency in grouping the transmissions into messages, the following rules may be used for deciding which transmissions make up one message:

- The transmissions have to be concerned with the same subject. If the subject of conversation changes during a series of transmissions, two separate messages are created.
- The time between the end of one transmission and the beginning of the next must be less than 5.0 seconds. If not, a new message is created.
- There must be no interruptions by other users of the channel. If so, the message ends at the interruption and a new message is started at the first pertinent transmission after the interruption.

Computed radio system delays are entered in Form 2, *Dispatch Facilities.*

(4) *Service Area Signal Strength*

Surveys of field-strength measurements in the radio system service area are frequently conducted in preparation for modifications or establishment of base-mobile radio systems. Large departments may have their own technical staff and facilities to conduct such surveys. Smaller departments generally contract commercial organizations for such surveys. They may also be conducted by equipment vendors as part of the service offered to the buyer.

(5) *Maintenance Records*

Maintenance records are useful in that they contain performance data on equipment. The records are simple to keep and readily summarized. Periodic examination of such records may indicate system problems caused by equipment failures. Unexpectedly high failure rates may indicate equipment quality problems, abuse of equipment, or shortcomings in maintenance procedures. Maintenance and failure records are kept in Forms 8-11, *Base Station Equipment, Vehicle Equipment, Personal/Portable Unit,* and *Miscellaneous Equipment.*

VI.1.4.2 Expenditures

A communication system cannot be evaluated without reference to cost. Insofar as possible, the cost should be broken down and related to the activities for which the costs were incurred. In many departments, this breakdown is made for budgetary and planning purposes. The budget may provide a complete picture of the activities undertaken by the department and the funds that were expended for those activities as well as projections for the next year. Figure VI-24 describes a portion of such a budget. This budget contains the estimate for the coming year as well as a projection, or "program", for the following year, thus reflecting and enabling longer range planning.

The budget has another use besides a request for funds. The actual expenditures for the year should be compared to estimates of expenditures made in the preceding year, and the reason for major discrepancies established and evaluated.

There are many factors outside the control of the communication staff that can increase the cost of operating and controlling the communication system. The major factors are increases in the cost of services, materials, and equipment, and increases in demands. These external factors must be taken into consideration when using cost data to pinpoint problem areas. For instance, an unexpected rise in expenses can be an indication that there is an underlying problem which can be resolved by the staff or director of communication. An unexpected increase in the costs for maintenance and repair parts can indicate that there is an equipment problem due possibly to age or improper usage. Requirements for additional staff which cannot be justified by a proportionate increase in demand can indicate that proper procedures are not being followed or that inefficient use is made of employee time.

If an increase in budget needs is due to an increase in demand, it is important to recognize it and make plans to meet it. Documentation of an increase in demand on the communication system is most useful as evidence when requesting budget increase.

VI.1.5 Procedures for Gathering Information

Four general types of information have been discussed in the preceding sections. They are functions, requirements, system description, and measures of performance. This section summarizes how the information can be recorded and what other uses there are for the information.

Functions and function requirements can be entered in the Communication System Function forms (Fig. VI-2). General system requirements are listed separately. Most system description and performance data can be entered in Forms 1-14 shown in Section VI.1.3.

PROGRAM INFORMATION

B-80

GENERAL FUND | COMMUNICATIONS | DEPARTMENT 22

245. CONSTRUCTION AND INSTALLATION

Custom electronic equipment and components are constructed as required. Mobile radios, radar, fixed equipment, public address, fire alarm and other electronic equipment and systems are installed.

Work Program Data	Actual 1968-69	Estimated 1969-70	Program 1970-71
Equipment Installed	280	350	400
Activity Cost			
Activity Cost (Final)	$ 17,628	$ 20,000	$ 24,000

251. DISPATCHING SERVICES

252. SENDING AND RECEIVING

All radio equipped City vehicles are dispatched and communications coordinated. Messages are received and the status of vehicles registered. Messages are relayed to City departments, agencies and individuals. Outside emergency equipment is dispatched upon request.

Work Program Data	Actual 1968-69	Estimated 1969-70	Program 1970-71
City Vehicles dispatched	354,000	362,000	370,000
Outside Equipment dispatched	38,726	40,364	43,000
Radio Messages processed	4,943,750	5,529,238	5,970,500
Fire Alarms processed	10,729	11,700	12,300
Outside Fire Alarms Processed	2,145	2,450	2,800
Activity Cost			
Activity Cost (Final)	$ 230,824	$ 287,000	$ 329,000

Fig. VI-24 Example of Communications Department Budget

Other descriptive information for which forms are not provided include the organization chart, job descriptions (including training procedures), procedure descriptions, and rules and governing regulations for any mutual aid, information retrieval, and shared or compact systems.

In Section VI.1.1, there is a discussion of three methods for determining the functions of the system. The selection of a method will, in part, determine the sequence of steps one should take to collect the information. If method one is selected and functions are determined from written procedure descriptions, the requirements can be determined when each function is identified. If method one is selected and the functions are determined by interviewing and observing the communication staff, procedures as well as requirements can be documented when each function is identified. In addition, the descriptive information about the complaint and dispatch facilities may be recorded at the same time.

If method two is selected and communication-system functions are obtained from the functions of the departments, one could record the requirements and the procedures after each function has been identified, or one could wait until all functions have been identified. It depends upon which is easier. If the third method, obtain functions from the information needs of police department personnel, is used, it is probably easier to wait until after all functions have been identified before recording the additional information.

If the information which has been collected is carefully checked by a supervisor of communication, some one at the level of clerk-typist could probably record it. There is one exception—the person who records the descriptive information about the equipment must be familiar with technical aspects of radio equipment.

It should not be difficult to maintain the information after it has been collected initially. A change in equipment, organization, or procedures should be entered in the forms. Periodically the performance should be measured, and the measures recorded each time.

Considerable information about the system will have been collected. This information can be useful in ways other than evaluating the system. Job and procedure descriptions can be useful in selecting and training new employees and in evaluating and supervising the staff.

The failure and maintenance records can be used in scheduling maintenance. Equipment descriptions can be used by the service man to determine what spare parts he should have. These additional uses should be considered when the information is collected.

VI.2 Methods for Comparing Performance to Requirements

After the information about the system has been collected, one can determine whether the system does what it is supposed to do on the basis of the requirements defined. Some functions of the communication system listed in the Communication System Function form (Fig. VI-2) have numerical standards associated with them, which can be compared to the performance data. By the quantitative comparison, the user will know not only which requirements are not met, but how far the system is from meeting the requirements. This will help him determine the magnitude of the changes which are required.

If the performance barely measures up to the standards, the user will be alerted to problems which might arise from a growth in demand. With this information, the user can plan for future needs which require system modifications. He can also consider those potential needs when evaluating modifications which were proposed to meet other requirements.

An historical record of the measures of performance should be maintained. In this way, a gradual decrease in performance can be observed, and perhaps the trend can be reversed before it becomes critical.

Numerical standards have not been established for all requirements. In such cases only a qualitative comparison of the performance to the requirements is possible. Guidelines for qualitative comparisons are given in the later pages of this section. Examples of comparing measures of performance to standards are given in the following paragraphs.

VI.2.1 Communication Center Delay

In Chapter V, Section V.3.2.1, an average communication center delay of 90 seconds was discussed in connection with three minute overall average response time to complaint. This requirement may be established for normal weekly busy hours. It may also be applied to shorter or longer busy periods.

Another approach is applicable when complaint calls are assigned priorities. In a three priority system a different requirement may be established for each category. For example, communication center delay time may be required to be less than

- 25 seconds for emergency calls
- 75 seconds for urgent calls
- 105 seconds for non-urgent calls

These limits may again be applied for overall averages or during specified time periods. If priorities are assigned to dispatch calls as part of operating procedures, errors in making the assignment should be measured and compared to a standard error expectancy.

VI.2.2 Radio Delay

Assume the standard is that the average delay in getting a message on the air during a normal busy period should not exceed 5 seconds—the criterion suggested in Section V.3.2.2

of Chapter V. By monitoring the channel, counting the number of messages, and measuring the message lengths during a normal busy period, the average message length and average number of arrivals in unit time can be computed. The formula of Section VI.1.4.1 may then be used to calculate the average delay time.

If the channel is not shared with other users and if the department knows exactly how many messages there were during the busy period, it would not be necessary to measure message length every time the radio delay is computed. Periodically, though, the monitoring should be repeated to determine if there is a change in average message length.

VI.2.3 Inquiry Delay

When setting standards for inquiry response from information retrieval systems, one must consider the time delays caused by other agencies involved in supplying the requested information. Figure VI-25 shows the comparison for a State Police Department.[16] In this example, only the delay for wanted checks (10-29 in the APCO code) approaches the standard. The delays in obtaining vehicle registration and driver's license checks far exceed the standards.

Inquiry			
Signal	Meaning	Measured Delay	Standard for Delay
10–29	Wanted check	3–10 min.	No more than 5 min.
10–28	Vehicle Registration:		
	License	3 min. – 3 hrs.	No more than 15 minutes
	Ser. No.	2 hrs. – 3 wks.	No more than 15 minutes
10–27	Drivers License Information	10 min. – 3 hrs.	No more than 15 minutes

Fig. VI-25 Example of Comparison of Performance to Standards

VI.2.4 Qualitative Comparison of Performance to Requirements

System requirements include general requirements for the total system and requirements associated with the individual functions of the system. If the function requirements are not met, the function does not adequately fulfill department information handling needs. The requirements for each function are listed in the fourth column of the Communication System Function form (see Fig. VI-11). The first step in determining whether the requirements are met is to evaluate the procedures which have been defined for performance of each function.

The evaluation method consists of answering a series of questions such as the following:

- Have provisions been made for assuring that all requirements are met?
- Under what conditions would they not be met?
- Are there any disadvantages to the existing setup?

Sometimes the answers to the last question are subtle. For example, consider the requirement that evidence be maintained in case of a lawsuit charging police negligence in responding to a complaint. This requirement can be met by recording telephone conversations. An undesirable side effect could be that the complaint taker may not exert the same effort to calm the complainant and get the correct information as he would if the conversation were not recorded. (This risk can be minimized by use of the same recordings for training and supervision.)

For every function there exists the requirement of efficient utilization of equipment and man-power. The procedures used to perform each function should be examined to determine whether the maximum efficiency is being realized.[17] Each step in a procedure should be examined:

- Are any actions unnecessary?
- Are there any redundant actions?
- Could any actions be combined?
- In general, is there an easier way to accomplish the same tasks?

The physical arrangement of each staff member's working area should also be examined:

- Is the arrangement efficient?
- Are all supplies and equipment within easy reach?
- Is any item in an unwieldly position?
- Is it necessary to move something to reach something else?
- Does anyone have to move from one location to another to complete a task?
- Can that movement be eliminated by changing locations?

The designs of the forms staff members frequently use should be considered:

- Was the order in which the form is completed considered when the form was designed?
- Is it necessary to skip around?
- Is it necessary to turn the form over?
- Is the form of a desirable size and shape to fill out, process, and file?

The routes or paths that each form or card takes should be examined:

- Is each handling of the form or card necessary?
- Can any of the operations be combined?
- Is there any backtracking?

Another feature to be examined is the general atmosphere of the working environment:

- Is it too noisy?
- Is it too crowded?
- Is there too much confusion?

Each of these factors can reduce the effectiveness of the staff.

One should also look at the utilization of equipment:

- Is any equipment more complex than necessary?
- Can the same task be performed manually?
- What problems arise because of down time?
- Could a different maintenance policy reduce these problems?
- Is a patrol car out of service when the radio is inoperative or is a back-up radio available?

Another important resource to consider is the spectrum:

- Is air time being wasted with messages that are longer than necessary, with messages which are not needed, with interference, or with poor discipline?
- Is the radio coverage of the patrol area complete, or are there "dead spots" which lack two-way communication?

After the procedures have been critically evaluated, it is necessary to determine whether they are being followed. The procedure documentation and actual practice, unfortunately, are not always the same. Ensuring that procedures are followed is a responsibility of supervision. The comparison of performance to requirements would not be complete without establishing that the procedures which have been established are actually being used.

In comparing performance of general system requirements, the provisions (i.e., the arrangements made and steps taken) for meeting the requirements must be identified. These provisions are documented in the system identification described in Section VI.1.3. In the comparison it is necessary to establish whether the provisions are adequate. To evaluate the provisions one can ask "Under what conditions or in what situations would the provisions not be adequate?"

For example, in order to evaluate the adequacy of the provisions for continuous operation of the system, the following questions (among others) should be asked:

- What can cause a major element of the system to fail?
- How likely is each possible cause of failure?
- Is it likely that an element and its back-up will fail at the same time, for the same reason?
- Is the cause that produces a failure likely to create also an unusually heavy demand for police services?
- Can the primary back-up provide an adequate level of service in most situations?
- If the primary back-up fails, will the secondary back-up (if there is one) be able to maintain an adequate level of service?
- How quickly can the back-up facility be put into operation?
- Is maintenance service provided on a 24-hour per day, 7-day per week basis to ensure continuous system operation?
- Are communication equipment and personnel well protected against damage and interference with their duties?

VI.2.5 Summary of Comparison

When numerical standards have been established, the system performance can be measured and compared to the standard. When numerical standards cannot be established, a subjective decision is needed to determine whether the requirements are met. The quantitative and qualitative comparison of performance to requirements made here identifies current or potential weaknesses in the system.

VI.3 Conclusions

These comparisons complete the final step of the evaluation process. The functions that a police telecommunication system must perform have been determined. The requirements, that is, standards or criteria, for each function have been established. This information documents the overall requirements of a system, answering the evaluation questions: "*What* should the system do?" and "*How well* should it do them?"

This part of the process, while discussed here in reference to an existing system is applicable to the planning phase of new system design as well. The plans and designs for a new system depend on the choice of functions it must perform and the standards required of them. Until these are established a system cannot be designed. The sources of this information will, of course, be different for new system planning than for existing system evaluation. The experience of established systems serving similar needs is a useful source of such information. The next step in new system design is the procedure described in Chapter VII, which contains a list of the planning steps required and a list of choices available to the designer.

The physical system components of existing systems and the way these components are organized to make a system have been identified. Also, how well the system performs has been determined. With this information, a comparison has been made between the actual system and its performance on the one hand, and the desired performance standards that apply to the required functions, on the other. This comparison should point out the weak and strong points presently existing in a system and should also indicate potential weaknesses and strengths that may develop in the system in the future.

The choices to be made in deciding on modification of a system found to have deficiencies are given in Chapter VII. Pertinent material from Chapters III, IV and V is utilized to establish the variables available for planning either a modification or new design. The choices available for each variable, and the relative merits of these choices are presented.

The evaluation of needs and performance tells the planner if an improvement is needed. If need for improvement exists, the planner has obtained the information he needs to examine the choices available to him to correct current weaknesses. In the design of a new system, by determining the functions and the requirements, the planner has obtained the information he needs to examine the design options available to him.

CHAPTER VII

DESIGN AND MODIFICATION OF POLICE TELECOMMUNICATION SYSTEMS

This chapter is concerned with procedures for making major modifications to existing police telecommunication systems or designing new systems. The preceding chapters contain information that is essential for understanding and carrying out these planning functions. The material in Chapters III, IV and V may be considered to be the data base on which the evaluation and planning methods of Chapter VI and this chapter are founded. To aid the planner in using the procedures outlined here, references to the earlier material will be made where appropriate.

Chapter VI bears a particularly close relationship to the present chapter, since the ability to evaluate a system or alternative systems is necessary if sound decisions are to be made by the planner. Thus, the planning process will generally utilize the procedures described in both these chapters. Although topics treated in earlier chapters will recur here, there is a shift of emphasis. Step-by-step procedures are described here for solving the telecommunication planning problems with which departments are faced.

In preparing this text the attempt has been made to present the fundamentals of telecommunication system planning in a way that will be directly useful to the small and medium-sized departments, but also will serve as a guide even for the large departments. It is intended for use by county and state police and planning agencies as well as municipal departments.

The methods to be presented in this chapter encompass the entire range of planning problems, from designing a new telecommunication system to modifying part of an existing system. There are basic principles of good planning practice that should be followed regardless of the magnitude of the problem. A thorough grasp of the communication needs of the agency and the means by which these may be served is essential in both system design and modification. In designing a new system, though, there is a broader scope for integrated planning of all telecommunication functions. This includes the opportunity to incorporate the latest types of equipment and the best operating procedures throughout the system.

On the other hand, major modification of an existing system may in some respects be more difficult to accomplish satisfactorily than designing a new one. The portion of the system that is added or changed must be closely integrated with the remaining portion in such a way that overall system performance is improved. At the same time, the entire system must remain operable, during and after modification. Both the external constraints on the system and the constraint of interfacing successfully with the unchanged portion must be satisfied as a result of the modification.

VII.1 Methods for System Design or Modification

Throughout this text the means whereby police telecommunication is carried out has been called a system. The term conveys the idea of a whole composed of many different parts which must act in harmony to produce desired results. The planner must know both the elements of which such systems can be constructed and the way they can be coordinated to provide the communication capability necessary for effective law enforcement. This requires knowledge of the present and projected communication needs of the agency, and also knowledge of the equipment, manpower, and procedures whereby these needs can be met.

The design or modification of the telecommunication system of a police department, or group of cooperating departments, must be carried out so that efficiency as well as effectiveness is achieved. This means that the cost of a system must be taken into account as well as the performance. A further important aspect is the existence of legal and other constraints that must be observed.

The process of designing or modifying a police telecommunication system can be carried out in a more or less formal manner. It should include certain basic steps that are necessary for successful system planning. The preferred approach, called *systems analysis*, has been developed and extensively applied in recent years. The approach was recommended for application to law enforcement systems by the President's Commission on Law Enforcement and Administration of Justice.[1,2] The steps can be summarized as follows:

1. Define the desired goals
2. Specify the alternative ways of reaching or approaching the goals
3. Determine the effectiveness of each alternative
4. Determine for each alternative the required resources or expenditures
5. Select the most favorable alternative, in terms of both effectiveness and cost

In this chapter a systems-analysis approach to the design and modification of police telecommunication systems is presented. The steps in the process are described in the sequence in which they would normally be taken. However, the approach is flexible and can readily be adapted to meet the special needs of individual police deparments.

The planning steps described in this chapter, and the sections in which they are discussed, are as follows:

VII.2 Establish the information handling needs

VII.2.1 Geographic area to be covered

VII.2.2 Communication needs to be served

VII.2.3 Performance measures and standards

This procedure is aided by the use of three planning forms. The first, to help specify the detailed choices or options open to the planner, is presented in Section VII.6. The second, to help formulate alternative plans, is presented in Section VII.7. The third, to help compare and evaluate alternative plans, is presented in Section VII.8. The experienced police telecommunication system planner may wish to begin with Section VII.5. The earlier sections may then be referred to as needed.

A planning file should be set up at the outset of a study, regardless of its size. This file should be maintained throughout to provide a permanent record of what was accomplished. It should consist of various kinds of documents appropriate to the particular study being conducted. It is recommended that a loose-leaf notebook be kept as the coordinating document. This usually can contain a large proportion of the planning documents and also an indexed list of those documents that are not suitable for inclusion in the notebook itself.

Examples of the kinds of documents to be prepared or acquired and included in the file are as follows:

- The directive authorizing the planning study, with a statement of the problem and the aims, scope, and organization of the study (see Section VII.4)
- Progress reports as scheduled
- The final report prepared at the end of the study, with conclusions and recommendations as to the best plan of action
- Completed analysis and planning forms such as those presented and explained in this text (see Chapter VI and Sections VII.6, VII.7 and VII.8)
- Internal memoranda and schedules relating to the study

- Notices and minutes of meetings
- Correspondence
- Copies of completed official forms (e.g., FCC Form No. 400, Application for Radio Station Authorization)
- Specifications and requests for quotations on equipment, buildings and other facilities
- Budget estimates and requests
- Contracts and purchase orders
- Block diagrams of relationships among system components
- Job descriptions
- Organization charts
- Equipment operating and maintenance manuals
- Training and procedures manuals
- Manufacturers' brochures and prices
- Descriptions of communication services offered and prices
- Blue prints or diagrams of building and equipment layouts
- Maps
- Photographs
- List of reference books and articles consulted

VII.2 Establish the Information Handling Needs

The information handling needs to be met by the proposed system modification or design must be clearly defined if the effort is to achieve practical goals. This requires that the general framework in which the problem must be solved is explicitly stated. This may be done by defining the geographic area to be covered, the communication needs to be served, and the performance standards to be met.

VII.2.1 Geographic Area to be Covered

A description of the primary area to be covered by the communication system (i.e., the area directly served by the department or group of cooperating departments) is basic information required by the communication planner. Much of the information can best be presented in the form of maps. The specific kinds of data on the area that are likely to be of use to the planner include the following:

- The official designation of the area (municipality, cooperating group of municipalities, county, etc.)

- The location of the area (State, metropolitan region, latitude and longitude coordinates of representative points, etc.)
- The geographical extent of the area (square miles)
- The shape (square, rectangular, irregular, etc.; unusual aspects of shape such as extensions into or from adjacent areas)
- Terrain (average elevation, mountains or hills, prominent bodies of water; in particular, any features that might affect propagation of police radio signals, the department mission in general, the location of facilities, and maintenance requirements)
- Population characteristics (total population from U.S. Census, average population density per square mile, composition of the population by sex, race, age group, income level, etc.)
- Population distribution (local population density throughout the area; names, sizes, and locations of towns and cities if not the same as the area)
- Transportation facilities (road network, railroad network and stations, airport locations)
- Crime statistics (data on the occurrence of crimes in the area and incidence of other events requiring immediate police response, such as traffic violations, vandalism, etc.)
- The geographical organization of the police force or forces (districts, beat areas, location of main and satellite headquarters)
- The present locations of the police radio facilities (communication center, remote transmitters and receivers, antennas)
- Telephone service (locations of exchanges and geographical boundaries of the districts served, special calling numbers for communication with the police department, the existing arrangements for emergency and non-emergency calls to and from the department)
- Call boxes (locations, media of transmission such as land-line or radio, and modes of usage)
- Alarm detectors which send signals to the police department (schools, businesses, etc.)

The geographical framework within which the law-enforcement organization and its communication system must function is established by data of the types that have been listed. This information on the primary area to be covered by the communication system

439-911 O - 71 - 17

needs to be supplemented. Additional information is needed concerning the external areas with which there are likely to be substantial interactions, either cooperative or conflicting.

Any of the types of information listed above describing the primary area covered by the agency may, depending upon circumstances, also be required for external areas by the communication-system planner. Again, maps can conveniently present some of the information. Radio charts showing the locations of all fixed antennas which emit potentially interfering signals are useful. The assigned frequencies and powers of the transmitters, type of modulation, antenna heights, radiation patterns, and terrain features affecting the interfering signal strength can be displayed on such a chart.

VII.2.2 Communication Needs to be Served

The cornerstone on which analysis of police communication systems must be based is the nature of the needs to be served. In the detailed description of police telecommunication systems given earlier, it has been made clear how the various functions that a police organization performs give rise to corresponding needs for communication (Sections V.1 and V.3.1). The performance requirements on the communication system itself must be established with the aim of aiding the police agency to function effectively over its entire range of duties.

The volume of information required to be conveyed, the form that the information takes, the content of the messages, and the time allowed for its transmission are factors of basic importance in characterizing the demands that the communication system must satisfy. The load on the system is the total of all the demands. The load varies due to

- The random distribution of demand over short intervals of time
- Daily, weekly, and annual patterns of individual and community activities
- Modification of those patterns due to weather and other conditions
- The scheduling of special events
- The occurrence of emergencies and disasters which inevitably place heavy demands upon the police

Load variation due to all these factors is treated in Section V.3.

The police communication system must be capable of handling the peak demands placed upon it. The average demand on the system over a period of time (hour, day, week, or year) is not an adequate measure of the necessary capacity. To establish the volume of messages, or load, which the communication system must be able to handle, the planner must examine the demands which are placed on the system during the peak periods.

In a rapidly growing area, it may not be sufficient, or possible, to examine the previous peak loads on the system. In Project Three of the APCO Project Series Foundation,[3] the weekly peak-hour radio loadings of eighteen suburban police departments were monitored. The populations of these suburbs ranged from less than 1,000 to about 70,000. For two weeks the number of base-mobile radio messages during the busiest two hours of each week were counted. Regression analysis was used to develop a prediction equation for the average time between messages during a busy hour, based upon the population of the community. The resulting regression equation is

$$Y = \text{antilog}_e\,(5.03 - 0.000021P)$$

where

Y = *average time between messages in seconds*

P = *population of the community*

Using this equation, an estimate of the average time between police radio messages in a community of given size can be computed. The average number of messages per busy hour, for example, is then obtained by dividing 3600, the number of seconds per hour, by the average time between messages in seconds. The results for three values of population are shown in Table VII-1. The estimates given by this equation become less accurate, the greater is the difference between the community population and the average population in the sample used to develop the equation. Therefore, considerable error can be expected if the population exceeds 60,000.

TABLE VII-1
ESTIMATES OF AVERAGE POLICE RADIO MESSAGE LOADS PER HOUR

Population Served	Average Time Between Messages (seconds)	Average Number of Messages (per busy hour)
10,000	124	29
25,000	90	40
60,000	43	84

While it may be helpful to use such an equation in estimating message volume for a police department, caution is advisable on several grounds. The hourly average is the average one would expect over a succession of weeks. In some weeks the busy hour average would be lower or higher. For example, in the long run a community of 60,000 could expect the average number of messages per busy hour to be more than 100 in one out of ten weeks. Also, the messages will not be equally spaced throughout the hour. During an hour one can expect at least one five-minute period to occur when the average time between messages is 30 percent less than the hourly average. The number of messages during such a five minute period will be 30 percent greater than the hourly average. Another cautionary note is that the data were collected in 1969 in the Lake Michigan Metropolitan area. The conditions which gave rise to communication demands there at that time may not be the same as the conditions at a different place and time.

Safety factors, often referred to as system usage factors, should be included in the prediction of future demand on a system. Upper and lower estimates may be made in addition to an extrapolation of the historical trend. Factors whose impact should be considered include economic growth, technical innovations, changes in the area covered, the size and composition of the population, and crime rates.

Methods for determining the functions which a particular police communication system must perform are given in Section VI.1.1. Methods for the collection of data on the present communication load, and for the prediction of future loads, are given in Section VI.1.2.2.

The parts of Chapters V and VI to which references have been made in this section should be reviewed preparatory to undertaking the design or modification of a police telecommunication system.

VII.2.3 Measures and Standards of Performance

Measures and standards of performance for police telecommunications are necessary if sound decisions are to be made concerning the design of a new system or modifications to an existing system. The selection of appropriate measures of effectiveness depends to a large extent upon the missions to be performed by the agency. The communication load generated in the performance of these missions can be described in terms of basic message characteristics which have been discussed in Chapter VI, Section VI.1.

Performance standards are specified values of selected measures of system performance that can be used in determining the acceptability of an existing or proposed plan. A performance standard may be an exact value which must be attained. More frequently such a standard will be an extreme value, i.e., a minimum value that should be equalled or exceeded or a maximum value that should not be exceeded. If both a minimum and a maximum value are specified for a performance measure, then a range of acceptable values is defined. In some instances a single target value may be specified together with the allowable extreme limits of variation above and below the target value.

In police communication systems, as in other systems generally, there is a degree of uncertainty concerning the exact conditions that will be encountered. For example, the number of telephone calls requesting police aid that will occur in some future time interval cannot be known in advance. A central concept in coping with uncertainty is that of probability. This is a numerical measure of the relative frequency of occurrence of alternative conditions or events. The probability, P, of occurrence of one condition or event in contrast to all the alternatives that are considered possible is a number between zero and one; the probability associated with all the alternatives is then the complement of P, i.e., 1-P.

The proper use of probabilities in conjunction with police telecommunication system evaluation and planning introduces a degree of realism that would otherwise be lacking. For example, the provision of a sufficient number of telephone lines to assure that no incoming call will ever receive a busy signal would be operationally desirable. However, the number and cost of lines to meet this requirement would be prohibitive. A realistic goal would be, for example, provision of the minimum number of lines such that the probability of an incoming call receiving a busy signal is 0.01 or less. Hence the complementary probability of the call going through is 0.99 or more.

Performance standards may be expressed in terms of probabilities in conjunction with extreme values or intervals. The standard will in these instances, include a maximum probability that an event will fall above or below the extreme value, or outside the interval. The end points of the interval or the extreme values are, when associated with a probability of being violated, called tolerance limits. So, for example, the performance standard for radio coverage may be expressed as a tolerance limit. The curves in Appendix A are computed to insure 97 percent coverage; that is, the received signal input power will exceed the amount needed to produce a 12 dB SINAD ratio* in 97 percent of the area to be covered.

*A 12 dB SINAD ratio (signal plus noise and distorition-to-noise and distortion ratio) is the standard set by Electronic Industries Association as the condition for an intelligible receiver output (see Appendix A and Chapter IV, Section IV.2.1).

Standards are set in different ways. Reasonable standards will reflect the current state of communications technology as well as the practical needs of law enforcement and the fiscal resources that can be made available. One source of performance standards is a survey of the operations of existing police telecommunication systems. In particular, those systems that exhibit the highest levels of performance should be examined. Another source of standards is a critical analysis of the needs to be served and the inherent capabilities of communications equipment, personnel, and procedures. A third source of standards is the collective judgment of persons with extensive experience in the design and operation of such systems. Combinations of these approaches may be appropriate.

There is no unique and comprehensive set of performance standards applying to law enforcement telecommunication systems that an agency can turn to without question when evaluation or design questions arise. There are too many factors that vary from one situation to another to make universal standards practical. On the other hand, some set of standards is necessary for rational planning. A compromise approach, and the one adopted here, is to explicitly state standards of performance that have been established or recommended by various persons or groups, but to treat these as examples or guidelines and not as absolute requirements. A particular department may decide to adhere to standards that have been developed in other situations, or it may set up its own standards that make more sense under local conditions. In any case, the standards should be explicit and defensible.

The preceding discussion applies to standards other than those which have legal status. The applicable FCC Rules and Regulations, for example, must be observed by all police communication sections.

The following standards are set forth as guidelines for police telecommunication planning. These are in addition to the standards for police radio transmission published by the FCC.

- The probability that an incoming emergency telephone call to the police department will receive a busy signal should be in the order of 0.01 or less under all normal conditions, including normal busy periods.
- If an average response time of 3.0 minutes between receipt of an emergency call by the police department and arrival of police at the scene is taken as a satisfactory overall operational standard, and if the average field response time is half of this total time (i.e., 1.5 minutes), then the average communication center time to process an emergency call should not exceed 1.5 minutes.

- The average waiting or delay time in getting a message on the air on the base-mobile channel during a normal busy period should not exceed five seconds.
- The minimum level of desired signal presented to any police radio receiver should produce a 12 dB or greater SINAD ratio.
- The police radio communication system should be in an operational state virtually at all times, i.e., with an extremely small probability of failure (0.0001 or less). This implies, among other things, continuous staffing and the provision of adequate security and back-up equipment and power.

VII.3 Establish Legal and Other External Constraints

The existence of numerous external constraints on the range of possible solutions constitutes a large part of the challenge in planning police telecommunication systems. Systems must comply with these constraints, which can be of a technical, legal, or fiscal nature. Awareness of all the applicable external constraints is necessary prior to designing or modifying a system.

One of the principal external constraints is the limited portion of the radio spectrum that is available. This is fundamentally a physical limitation, but in practice is expressed in the form of legal requirements that apply to the use of two-way radio systems. The FCC is the agency of the Federal government that exercises this authority, through regulations and rulings on cases brought before it.

FCC authorization is not limited to the frequency channels which a department can use, but includes also factors such as the power levels at which transmitters can be operated, and the locations, radiation patterns, gains, and heights of antennas. FCC Rules and Regulations are treated in detail in Section V.3.6, and frequency coordination procedures in Section V.3.7. Selected portions of the FCC Rules and Regulations are reproduced in Appendix F.

All legal requirements on police communication systems in addition to those imposed by the FCC must also of course be met. Federal agencies other than the FCC may require compliance with certain rules and regulations affecting police telecommunication systems. An example is the height limitation and marking of antenna structures required in certain areas by the Federal Aviation Administration for flight safety. Some states have applicable legal requirements (see Section V.3.8). These relate for the most part to inter-agency agreements.

If the cooperating police agencies are located in different states, special interstate compacts may be required. In some instances, municipal, county, or other local laws may apply to certain aspects of police communication systems. For example, zoning ordinances and building codes may apply to the construction of buildings to house communication equipment.

Other external system constraints are of a fiscal nature. These are discussed in Chapter III and Section V.3.8 of Chapter V. The fiscal resources that a police agency can draw upon for communication or for other purposes are never unlimited, and may be quite restrictive. It should be emphasized that all costs should be included in that portion of the department budget that covers construction or revision, maintenance, and operation of the communication system. Equipment and building depreciation should be included along with maintenance and operating costs. For planning purposes, a fair comparison among alternative designs or modifications can only be made by comparing the respective overall costs. This can be accomplished by preparation of tentative budgets for the alternative plans, applying uniform accounting principles in all cases.

VII.4 Identify the Specific Problem to be Solved

Problems associated with police telecommunication systems arise in a number of different ways. We are concerned here with problems that require for their proper solution some form of system planning. Other problems that can be handled through routine maintenance and repair procedures will not be considered. System planning is required both in the design of new systems and in the major modification of existing systems.

In relation to the techniques presented in this Chapter, any modification that cannot be handled by means of routine repair and maintenance procedures should be considered a major one. It is understood, of course, that a major modification of a communications system in a small police department may to a large department seem like a minor change. The use of system planning techniques is, however, not so much a matter of the absolute size of the undertaking as of its relative impact on the system being changed. Thus, system planning techniques presented here should be used when the proposed modifications of a system will produce significant changes in it.

The need to design a new system generally comes about for one of the following reasons:

- A new police agency is created through government reorganization or to serve a developing municipality or other area
- Two or more police agencies agree to form a cooperative communication system replacing in whole or in part their separate systems

- An existing system is considered sufficiently obsolete or inadequate to warrant consideration of one or more entirely new systems instead of, or along with, consideration of major modifications to the existing system

The need to modify a system that is already in operation will generally occur for one or more of these reasons:

- The communication load changes in size or nature. Population growth in the area served by the police agency is one likely cause of increase in the volume of complaints. Another cause is increases or decreases in the rates of certain types of crime, or crime in general
- The geographical area over which the department requires communication coverage expands or contracts. For instance, the community boundaries may be enlarged through incorporation of additional land. In some cases a department may agree to provide complaint answering and vehicle dispatching on behalf of one or more other departments through a cooperative arrangement. Conversely, the department may relinquish part of its own communication activity to another department through a cooperative arrangement
- Technical innovation in the field of telecommunication equipment makes the existing equipment obsolete relative to what can be accomplished with newer devices. New equipment may replace old or be introduced to perform a new function
- FCC regulations or other legal requirements change, permitting or necessitating a modification in equipment and/or operating procedures. For example, a different segment of the electromagnetic spectrum may become available for police use, enabling the system to shift to new operating frequencies
- The police agency itself is restructured in a way that involves the communication function
- Other police agencies with which the given agency is in active communication undergo changes and the given agency must adapt to them
- Budgetary restrictions are imposed, requiring cutbacks in the expenditures for communication. The question this raises is how to economize with the least possible reduction in effectiveness

- Another important class of occasions for modifying an existing police communication system arises from a recognition that operational improvement is needed, or at least that a study looking toward the possibilities of improvement, is needed. In such instances a critical examination of all aspects of the communication system is indicated, with the aim of identifying the deficiencies and determining remedial measures
- The procedures for continuing or periodic evaluation of a system presented in Chapter VI will detect deficiencies as they arise

It is evident from the examples that have been given that communication system problems can arise in many different ways and be very different in nature.

Following the recognition that a problem exists, it is necessary to state it as clearly as possible. There are several elements to be considered. The existence of the problem implies that there are one or more goals that are not now met. These need to be thought through and stated explicitly. Furthermore, there is no well defined problem unless there is some way of gauging the relative merits of different solutions that may be proposed. In other words, there must be criteria or measures of effectiveness that can be applied to distinguish between better and worse proposals for system design or modification. Then there must be system variables that can be controlled in seeking to bring about desired values or changes in the measures of effectiveness.

There will always be constraints on the possible values of the controllable variables. The variables may interact with each other so that changes in the measures of effectiveness due to altering one variable depend on the values at which the other variables are set. A particularly important aspect in communication systems is the degree of unpredictability, or uncertainty, concerning the demands that will be placed on the system.

A statement of the particular telecommunication system planning problem with which an agency is faced should be prepared in writing by the proper authority at the outset of the planning effort. The content and length of this problem statement will depend upon the nature of the problem and the way the agency intends to seek a solution. This document will, in effect, be the charter under which the planning effort is carried out. The following items are suggested for inclusion in the problem statement. Some of these points will always be relevant; others may or may not be relevant in a particular case; additional points should, of course, also be covered if applicable.

- Identification of the agency that is faced with the telecommunication system planning problem
- The authority by which the problem statement has been prepared

- The date of preparation of the statement
- The scope of the problem (e.g., to design a new system or to improve a specified portion of an existing system)
- The general goals to which the planning effort is to be directed (e.g., to provide two-way radio communication over a specified area using the most suitable equipment available and proven operating procedures)
- Applicable performance standards
- Legal requirements
- Technical or organizational constraints
- Budgetary limitations
- Coordination required with other agencies
- The individual or group that is authorized to conduct the planning study
- The planning tasks and the time schedule for completion

VII.5 Examine the Available Planning Variables

VII.5.1 Planning Variables and Options

In designing a new police communication system or modifying an existing system, there are many variables that must be taken into account. Some of the variables are directly controllable. Others may not be subject to direct control, yet must be considered to anticipate possible difficulties. Examples of variables that can be controlled range from the geographical location of an antenna to selection of men or women as complaint operators. Examples of variables not subject to control range from weather conditions to circuit noise in a radio receiver. Systems are designed or modified by choosing among the available options of the controllable variables.

The variables listed in Section VII.5.2 are subject to control in the design or modification of police telecommunication systems; they are the *planning variables* or "policy variables" of these systems. The number and identity of the planning variables which should be controlled will depend on the problem to be solved. At one extreme, perhaps only one or two variables will need to be considered in searching for a way to overcome a fault in an existing system. At the other extreme, all or nearly all of the variables will need to be considered in the design of a new system.

In some instances there may be a question whether to make a major modification to the existing system or to replace it with a new system. A fundamental decision must be made at some point in time as to which direction to take. The new system and the modification of the old system can be treated as planning alternatives by the procedures presented here.

Likewise, different designs for a new system or different modifications to an existing system can be evaluated as planning alternatives. In other situations the question may arise whether it is better to keep the existing system unchanged or to make a proposed modification. Keeping the existing system unchanged is then one of the planning alternatives. In the case of a newly created police agency there will be no existing communication system and hence the only alternatives will be different designs for the new system.

The options that are open for each variable are indicated, in most cases, in Section VII.5. Where they are not, the options are either obvious or they are discussed in the referenced sections of previous chapters. Only the major options are treated in this text. Further options, such as make and model of items of equipment, will be clear from the information obtained in connection with a particular planning study. The options themselves may consist of a set of discrete alternatives or may be successive points on an essentially continuous scale of possible values of the variable.

VII.5.2 List of Planning Variables

As a convenient way of organizing the presentation of the major planning variables and the available choices or options for each variable, nine subsystems of the telecommunication system have been distinguished. These subsystems are identified as:

1. Organization and staffing
2. Operating procedures and staff training
3. Communication center
4. Telephone subsystem
5. Radio subsystem
6. Teletypewriter subsystem
7. Computers and associated data transmission facilities
8. Emergency equipment and procedures
9. Maintenance

In an actual system, the subsystems are not completely distinct entities with clear-cut boundaries. Hence, the division into subsystems is somewhat arbitrary. Planning variables may interact strongly with each other. A decision made in regard to one subsystem can affect the options which are available in other subsystems.

VII.5.2.1 Organization and Staffing

The two major planning variables for organization and staffing of the communication unit are:

	Planning Variable	Options	Text Reference
1.	Placement of communications unit within the department or group of cooperating agencies	a. Staff section. b. Part of a line unit, e.g., the Patrol Division. c. Separate municipal (or county) communications agency. d. Separate unit formed by two or more cooperating police departments.	V.2.5.1
2.	Organization of communications unit	(see text)	V.2.5.2
3.	Total number of communications personnel	1, 2, 3, . . .	V.2.2.2
4.	Number of complaint operators	1, 2, 3, . . .	V.2.2.2
5.	Number of dispatchers	1, 2, 3, . . .	V.2.2.2, V.2.4.3
6.	Number of maintenance technicians	1, 2, 3, . . .	V.3.3.4

If the procedures for handling the complaint-dispatch functions do not separate the complaint and dispatch operations, Nos. 4 and 5 above are no longer planning variables. These procedures are the planning variable in the next section. If contract (or other external) maintenance service is used, planning variable No. 6 is removed. This choice is made for the planning variable in Section VII.5.9.

Another planning variable regarding the staff is the type of personnel.

7.	Type of personnel	a. Sworn-male b. Sworn-female c. Civilian-male d. Civilian-female	IV.5

VII.5.2.2 Operating Procedures and Staff Training

Complaint processing and radio procedures are the main planning variables affecting procedures. The primary staff training variable is the means for training personnel.

Planning Variable	Options	Text Reference
1. Complaint Processing	a. One-stage b. Two-stage c. Three-stage	V.2.2.2
2. Radio Procedures	(see Ref.)	APCO Standard Operating Procedure Manual[4]
3. Training Method	a. On the job b. Local APCO Seminars	IV.5

VII.5.2.3 Communication Center

The communication center planning variables will affect, and be affected by, the choices made for the radio and telephone subsystems.

Planning Variable	Options	Text Reference
1. Type of control unit	a. Desk set b. Desk-top control console c. Control console	IV.2.3
2. Number of control units	1, 2, 3, . . .	IV.2.3
3. Location of control units	a. In same room b. Each in separate room c. Single and separate room grouping	IV.2.3
4. Number of control points (positions with supervisory capabilities)	1, 2, 3, . . .	IV.2.3
5. Type of status equipment	a. Status boards b. Status cards	IV.2.3.2
6. Use of voice recorder	a. No b. Yes	III, IV.2.3.2
6.1 Type of recorder	1. Tape 2. Stylus	
6.2 Replay feature	1. Instant replay 2. No instant replay	

VII.5.3 Telephone Subsystem

There are a number of planning variables associated with the telephone subsystem. These variables are not completely independent of one another or of the planning variables for the communication center and procedures. A list of the most significant planning variables and their options is as follows:

	Planning Variable	Options	Text References
1.	Total number of lines	1, 2, 3, . . .	IV.2.6, V.2.2
2.	Number of emergency lines	1, 2, 3, . . .	IV.2.6, V.2.2
3.	Number of administrative lines	0, 1, 2, . . .	IV.2.6, V.2.2
4.	Number of unlisted lines	0, 1, 2, . . .	IV.2.6, V.2.2
5.	Number of tape recorded lines	0, 1, 2, . . .	IV.2.6, V.2.2
6.	Number of recorder channels	0, 1, 2, . . .	IV.2.6, V.2.2
7.	Use of 911 emergency number	Yes, No	IV.2.6
8.	Types of lines	a. Switched network b. Two-way automatic private line c. Push button automatic private line d. Push button - push button private line e. Intercommunicating private line	IV.2.6
9.	Types of phones	a. Dial b. Touch-Tone* c. Card dialer	IV.2.6
10.	Type of call routing equipment	a. Switchboard b. Private Branch Exchange (PBX) c. Centrex	IV.2.6, V.2.2.1

*Registered service mark of the Bell System.

VII.5.5 The Radio Subsystem

The design of the radio subsystem consists of choosing values for the variables which allow a set of accepted standards and objectives to be met. A list of the most significant planning variables and their options is as follows:

	Planning Variable		Options	Text References
1.	Modulation type	a.	Amplitude modulation (AM)	III, IV.2.1
		b.	Frequency modulation (FM)	
2.	Frequency band(s)	a.	Low band	IV.1
		b.	High band	
		c.	UHF band	
		d.	Other	
3.	Antenna height and towers			IV.2.2, IV.3.3, Appendix A
4.	Antenna type	a.	Directional	IV.2.2, IV.3.3, Appendix A
		b.	Non-directional	
5.	Antenna gain		(see text)	IV.2.2, IV.3.3, Appendix A
6.	Antenna location		(see text)	IV.2.2, IV.3.3, Appendix A, Appendix B
7.	Transmitter power		(see text)	IV.2.1, IV.3.1, Appendix A
8.	Squelch type	a.	Carrier	IV.2.1, IV.3.1, IV.4.7.1
		b.	Tone coded	
9.	Digital transmission capabilities	a.	Base to vehicle	IV.4.2, IV.4.3
		b.	Vehicle to base	
		c.	Mobile teleprinters	
10.	Location of dispatching points	a.	Central	V.2.3, V.2.4.3
		b.	Dispersed	
11.	Location of base station radio equipment	a.	Central	V.2.3, V.2.4.2
		b.	Dispersed	

	Planning Variable	Options	Text References
12.	Number of frequencies per channel	1 or 2	V.2.3, V.2.4.1
13.	Number of channels per network	1, 2, 3, . . .	V.2.3, V.2.3.3
14.	Simplex, half-duplex or duplex operation of channels	a. Simplex b. Half-duplex c. Duplex	III, V.2.3, V.2.4.1
15.	Direct or repeater operation	a. Direct b. Repeater	III, V.2.3
16.	Number of radio equipped vehicles	1, 2, 3, . . .	VI.1.3.1
17.	Number of portable radios	0, 1, 2, . . .	VI.1.3.1
18.	Employment of voice privacy equipment	Yes, No	IV.4.1
19.	Employment of communication vans	Yes, No	IV.3.5
20.	Employment of satellite receivers and voting equipment	Yes, No	IV.4.9
21.	Employment of vehicle location equipment	a. None b. Manual c. Automatic	IV.6, Appendix E
22.	Employment of microwave equipment	Yes, No	IV.2.4, Appendix B

VII.5.5 Teletypewriter Subsystem

	Planning Variable	Options	Text References
1.	Number of teletypewriter terminals	0, 1, 2, . . .	IV.2.5, VI.1.3.1
2.	Transmission speed (words per minute) and type of circuit	a. Leased teletypewriter circuits b. Purchased teletypewriter circuits	III, IV.2.5

439-911 O - 71 - 18

Planning Variable	Options	Text References
	c/d. Leased/purchased circuits shared with other data terminals (data-phone, time-shared computer terminals)	
3. Type of code employed	a. Baudot b. ASCII c. USASCII d. etc.	IV.2.5

VII.5.6 Computers and Associated Data Transmission Facilities

There are two types of planning variables associated with computer subsystems. One type relates to external or centralized information retrieval systems. These are discussed in Section V.1.5.3. The systems which are available to a department are limited by location and jurisdiction. For a system which is available there are two options: either the department uses the service or it does not.

The various planning variables of computer systems dedicated to the needs of individual departments or groups of cooperating departments are treated in Section V.1.5.2.

VII.5.7 Emergency Equipment and Procedures

Planning Variable	Options	Text References
1. Reserve capacity for emergency radio message loads	a. Standby emergency channels b. Reserve capacity in regular channels c. Shared emergency capacity	V.3.5
2. Types of power plants	a. Diesel b. Gasoline c. Liquified petroleum (LP) d. Butane e. Propane f. Natural gas g. Manufactured gas h. Gas turbine i. Solar cell	IV.2.7.2, VI.1.3.1

	Planning Variable	Options	Text References
3.	Fuel tank capacities	(see text)	IV.2.7.2, VI.1.3.1
4.	Power generating capacities	(see text)	IV.2.7.2
5.	Cooling methods	(see text)	IV.2.7.2
6.	Type of starting	a. Automatic b. Manual	IV.2.7.2
7.	Type of load transfer equipment	a. Automatic b. Manual	IV.2.7.2

VII.5.8 Maintenance

	Planning Variable	Options	Text References
1.	Type of service	a. Self-service b. Contract service c. Separate governmental agency d. Cooperative police agency service	V.3.3.4, VI.1.3.1
2.	Number of technicians	0, 1, 2, . . .	VI.1.3.1
3.	Types of standby equipment	(see text)	V.3.3.4, VI.1.3.1

VII.6 Specify the Planning Variables and Options for the Problem to be Solved

It is assumed that the problem to be solved has been defined in accordance with Section VII.4. The major planning variables and options available to the planner have been listed in Section VII.5. The planning variables applicable to the problem under consideration should be selected from this check list and recorded for reference during the remainder of the planning process. The check list should help the planner to identify all the major variables and options that are available to him for solving the problem with which he is dealing. It should also help to make him aware of the relationships among the variables.

General factors that must be taken into account in identifying the relevant variables in any telecommunication planning problem include the technical possibilities, human performance capabilities, and the dollar cost. The system is composed of the operating staff, organization and procedures, and physical facilities. It is an error for the planner to be "gadgetminded", that is, to concentrate on the "hardware" variables without paying enough attention to human needs and abilities under the circumstances and stresses of system operation. It is equally an error to ignore the advantages that might be realized by obtaining and using superior equipment.

At every stage of the planning process some estimate of the likely costs must guide the choice of alternatives. At first the cost estimates may be rough, serving to rule out alternatives that are clearly uneconomic. Later, the estimates must be refined so that competing alternatives can be fairly and accurately assessed on the basis of cost as well as technical and human factors.

As an aid in the planning process, three forms are described in this chapter. They will aid in recording the essential information required for design or modification of police telecommunication systems. Further, they will contribute to the analysis and evaluation of the alternatives that should be considered. The three forms correspond to logical steps the planner or planning group should take to arrive at a solution to the problem at hand. The forms are titled as follows:

Planning Form No. 1: Specification of Options for a Planning Variable

Planning Form No. 2: Formulation of an Alternative Plan

Planning Form No. 3: Comparison and Evaluation of Alternative Plans

The first form is discussed in this section. Planning forms No. 2 and No. 3 are discussed in Sections VII.7 and VII.8, respectively.

Each of the forms has provision for common items of information. These identify the particular planning task: (1) the police agency requiring the plan, (2) the specific problem to be solved, (3) the person or group performing the work, and (4) the date of preparation or completion of the form.

The first form (Planning Form No. 1) is devoted to specifying possible choices or options for a single planning variable. The list of planning variables of police telecommunication systems in Section VII.2 includes references to the pertinent discussions of these variables in Chapters III, IV, V, and VI. This information is needed to specify the variables for any particular planning problem and the detailed choices that are available.

The particular planning variable, e.g., antenna location or type of control unit in the communication center, is placed on the form following the common information. Any performance standards that apply to this variable, e.g., minimum signal-to-noise-plus-interference ratio over the area covered by the radio system, are given next. Any constraints that restrict the possible choices of values of the variable are also stated, e.g., the antenna tower height must be below a limit set by the Federal Aviation Administration (FAA).

Other information called for is a list of those planning variables that interact strongly with the given variable. For example, base-station transmitter antenna location and antenna height might be treated as separate planning variables. Both directly affect the received signal strength in the proposed reception area of the system and also in other areas where the signal is not wanted. In such instances the interacting variables should be cross-referenced. Then the net effects of changes can be properly assessed.

An alternative way of handling two or more interacting variables is to define a new planning variable which is, in effect, a combination of these. For example, instead of treating antenna location and antenna height as separate variables (which they are physically), a new variable can be defined. For this variable, the possible values or conditions are the feasible combinations of antenna location and height within the local area. This may be especially appropriate if not all values of one variable can occur with all values of another variable. A single tall building may be available as one site for placement of an antenna, whereas other available sites may be on level terrain.

The particular choices available to the planner are specified after the definition of the variable in question and the statements about applicable performance standards, constraints, and related variables. Space for specifying two choices is provided on Planning Form No. 1. Any number of choices can be included by drawing up an extended form. The choices listed under a planning variable should be distinct from each other. They should also cover all the alternatives that are reasonable.

In most cases the options will be discrete alternatives, i.e., either A or B or C or some other particular choice will be made, with no intermediate values possible for the variable. An example is the manufacturer/model of an antenna. On the other hand, some choices will consist of a continuous range of values for the variable within limits, e.g., the height of the antenna. Here, representative discrete values of the variable can be listed as options for choice by the system planner.

For each option under a planning variable, space is provided in Form No. 1 for indicating the advantages and disadvantages relative to the other options. Space is also provided for listing the costs associated with each option. The advantages and disadvantages to be noted here are primarily technical and operational. Cost advantages and disadvantages could be included. However, any dollar amounts that are given will tend to speak for themselves. In some cases there may be no difference in cost among the options.

Since advantage and disadvantage are inherently relative terms, the points of contrast between options can be presented under the heading of advantages, or under the heading of

CONTINUED

3 OF 5

POLICE TELECOMMUNICATION SYSTEMS NCJ 00341

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Planning Form No. 1:

Specification of Options for a Planning Variable

Agency ______________________________

Problem Identification ______________________________

Planner(s) ______________________________ Date __________

The Planning Variable ______________________________

____

Performance Standards ______________________________

____

Constraints ______________________________

____

Related Variables ______________________________

Option No. and Description ______________________________

____

Advantages ______________________________

____

Disadvantages ______________________________

____

Cost Elements ______________________________

____

Option No. and Description ______________________________

____

Advantages ______________________________

____

Disadvantages ______________________________

____

Cost Elements ______________________________

____

disadvantages, or under both headings. Contrasts between options, in terms of the advantages and disadvantages, will involve the performance standards and constraints given in the upper portion of the form. Thus, one option may be advantageous as compared with others in that a certain minimum performance standard is surpassed to a greater degree. Or, an option may be disadvantageous because it is uncertain whether or not a particular constraint will be satisfied under actual operating conditions. There can be many points on which the choices differ for planning purposes, i.e., with respect to which they are better or worse. It is obvious, too, that any choice of a planning variable may be superior on some points and inferior on others.

Careful consideration of the available options for each major variable will pay off in later stages of system design or modification. It is particularly important not to overlook options that may not be immediately apparent to the person or group doing the planning but may in fact have substantial benefits to offer. Technical innovation is a potential source of advantageous options, but so also is imaginative formulation of alternative facility layouts and operating procedures.

Advantages and disadvantages may be made manifest only under certain circumstances. Therefore, it behooves the planner to review in his own mind, or with others in the department, the range of situations that may arise in the operation of the system. He must also consider the way system response is dependent upon the alternative options that might be selected for the variable under consideration.

VII.7 Formulate Alternative Plans

The options for the planning variables are the elements or building blocks for alternative systems or modifications. The formulation of candidate designs or plans for meeting the telecommunication needs of a police agency is the next step in the planning process. This creative step of synthesizing designs and plans from the system elements and choices is the subject of this section.

Planning Form No. 2 is an aid in developing a candidate plan for the design or modification of a police telecommunication system. This is an intermediate step in the planning process. It lies between specification of the individual planning variables and options (considered in the previous section), and the comparison and evaluation of different designs and plans (to be considered in the next section). Any number of alternative designs and plans can be developed, as appropriate within limitations of planning budgets and deadlines. It is advisable, and usually possible, to keep the number reasonably small in order not to be swamped by a mass of detail.

Planning Form No. 2:
Formulation of an Alternative Plan

Agency ____________________

Problem Identification ____________________

Planner(s) ____________________ Date __________

Plan Designation ____________________

____

Planning Variable ____________________

Option ____________________

Expected Performance ____________________

____

Estimated Cost ____________________

Comments ____________________

____

____

Planning Variable ____________________

Option ____________________

Expected Performance ____________________

____

Estimated Cost ____________________

Comments ____________________

____

____

One approach that can be taken is to formulate initially two or more alternative plans that differ in their basic concepts. For example, one alternative for achieving adequate radio coverage over a wide area may be the use of a mobile relay system with one central mobile relay station. The other alternative may to be utilize a satellite receiver system with a number of receivers placed throughout the area. Choice can often be narrowed to one or more of these general alternatives without going into great detail. Detailed plans within the framework of the chosen general alternatives can then be developed for a second stage of the planning process. More than two stages in the planning process may be advantageous for complicated problems.

A single candidate plan is developed by selecting one of the available options for each of the relevant planning variables. Any number of planning variables can be handled by repetition or extension of Planning Form No. 2. Under each planning variable the specific option selected is listed. The expected performance of the system is stated in so far as it is affected by the option which was selected. If applicable, the estimated cost of implementing that option is also recorded on the form.

Space is provided for comments pertaining to the variable and the particular option as elements of the candidate design or plan. Cross reference to other elements of the plan can be made here. For example, suppose the planning variable is the type of console and the choice is a certain manufacturer/model of console. Then an appropriate comment could be that there is a good match between this console and a certain manufacturer/model of base transmitter and receiver specified in this plan under the base transmitter and receiver planning variable. Reference can also be made back to the available options for the planning variable (e.g., console type) listed on Form No. 1. Other information would be delivery time for a piece of equipment, modifications that are required to adapt a standard piece of equipment to meet local conditions, retraining of personnel to operate new equipment, etc.

Any number of alternative designs and modification plans may be developed. Sometimes, only one alternative may appear worthy of consideration, and this may in fact turn out to be the best solution. Even here, however, it may be desirable to search for alternative solutions to the design problem. A better plan may sometimes be found. If not, the conclusion is strengthened that the best course of action is being adopted. Each plan should be developed as a serious proposal, with realistic performance and cost estimates. There is little to be gained from setting up a "straw man", i.e., an obviously unworkable or uneconomic approach to the problem. The aim should be to formulate competitive plans so that a good choice can be made in the next step of planning.

A useful planning strategy, where feasible, is to divide the overall problem into parts that are largely independent of each other. Alternative plans are then formulated for each separate sub-problem. This leads to a smaller number of overall plans than if all combinations are explicitly considered. An example would be the treatment of antenna location and communication center staffing as separate problems in designing a communication system. Caution must be observed, however, that interactions are not overlooked in such a procedure. The plans that appear best for the different portions or aspects of the system then must be combined into a single overall plan. Any difficulties which arise must finally be reconciled prior to final adoption of the plan.

VII.8 Select the Best Plan

The set of candidate plans formulated as alternative ways of meeting the information handling needs of the agency must be compared and evaluated fairly in order that the final decision may be a wise one. Objective criteria should be applied as far as possible, so that well-informed judgments can be made, with minimum reliance on preconceived opinions or prejudices. Decisions necessarily involve subjective aspects because of the intangible factors that are always present, but the factual foundation should be as strong as it can be made with reasonable (or even unreasonable) effort.

Planning Form No. 3 is designed to aid in the comparison and evaluation of alternative plans. Space is provided on the form for information concerning three candidate plans. The plans are to be specified by name or number on the left and the items of information pertaining to each plan are to be entered in successive columns to the right. The entries are: first, the ratings of the candidate plans with respect to the critical performance goals; next, the overall performance rating of the plans and the overall cost estimates; finally, the overall ranking of the plans for purpose of recommendation or decision.

Provision is made for four critical performance goals. Any number of candidate plans and any number of critical performance goals can be handled by use of multiple forms or by drawing up an extended form.

The candidate plans are those that have been formulated separately with the aid of Planning Form No. 2 or its equivalent. There is thus a close connection between the items of information called for on Forms No. 2 and No. 3. The information assembled on Form No. 3 is that which is essential for determining the relative merit of the different plans from an overall point of view. The main points on which the plans differ are therefore emphasized, while the points of similarity and the detailed data which have been gathered are

Planning Form No. 3:

Comparison and Evaluation of Alternative Plans*

Agency ______________________________

Problem Identification ______________________________

Planner(s) ______________________________ Date ______

Critical Performance Goals (Specify)

Alternative Plans (Specify)	Goal: ____	Goal: ____	Goal: ____	Goal: ____	Overall Perfor-mance	Overall Cost	Rank
Plan: ______							
Plan: ______							
Plan: ______							

* The entries to be made in the columns labeled "Goal" are the ratings of the alternative plans with respect to each critical performance goal. These are followed by the overall performance rating, the estimated overall costs, and finally the overall ranking for purposes of recommendation or decision.

de-emphasized. The critical performance goals are those important system characteristics in which there are contrasts among the candidate plans. For example, a critical performance goal might be average delay in establishing radio contact between a police vehicle and the base station, if the plans under consideration differ in this characteristic. The critical performance goals of a given problem are to be named in the column headings of Planning Form No. 3 and the alternative plans are to be rated under each such heading.

The rating of the candidate plans with respect to a critical performance goal can be done in various ways. The method that is most suitable will depend upon the nature of the goal and the pattern of contrasts that exists among the plans. In some instances the plans will differ in an all-or-none sense, that is, any one plan either has a certain feature or it does not. An example is the use of tone-coded squelch. If the use of tone-coded squelch is considered a desirable feature, then this would be a plus factor for those plans that incorporate it and a minus factor for those plans that do not.

In other instances, the plans may differ in a quantitative sense, i.e., in providing levels of performance that are measurable on a more or less continuous scale. Thus, no two plans may provide identical anticipated performance with respect to a critical goal such as average delay time. In a situation such as this, the plans can be ranked in order of increasing average delay time.

In still other instances it may not be feasible to estimate performance on a quantitative scale of measurement, yet the plans can be ranked in terms of having more or less of a given property. An example is the vulnerability of a communication center to sabotage.

A column is included in Planning Form No. 3 for an overall performance rating of the candidate plans. This rating will be made after the ratings have been completed for the individual critical performance goals. Whoever carries out an overall performance rating should fully take into account the results of the separate critical goal ratings. Again, different rating schemes are possible.

The simplest scheme is perhaps to classify each plan either as "acceptable" or "unacceptable" if this accurately reflects a fundamental division into the two categories. For any plan that does not qualify as acceptable, the reasons for disqualification should be noted on the planning form. In some cases it may be possible to rate overall performance on a numerical scale of measurement. For example, a modification of the telephone subsystem may consist primarily of adding trunk lines, the question being how many to add. The probability of a caller getting a busy signal might be an adequate overall performance figure, which would vary depending on the number of lines added. In many situations the overall performance rating will be simply a ranking of the various plans based on the analysis of the critical performance goals combined with subjective judgment.

The estimated overall cost of each of the candidate plans is to be entered in the next-to-last column of Planning Form No. 3. This will ordinarily be a dollar amount, but other resources, such as man-hours of department personnel time, or use of existing facilities may be specified. A breakdown of the costs associated with each of the candidate plans, by the major variables and options, will have been presented on Planning Form No. 2.

If the plans under consideration are relatively elaborate, it may be advisable to prepare a separate budget estimate in conjunction with each of the plans. The form that the budget estimates take should follow uniform departmental practice. The overall cost figures from these budget estimates can then be transferred to Planning Form No. 3.

If the preceding steps have been completed, the analysis of the candidate plans in terms of their cost relative to their overall effectiveness can be undertaken, leading to the selection of the preferred plan. The final column in Planning Form No. 3 is to be used for ranking the plans on the basis of performance and cost considered jointly. The set of candidate plans at this stage will consist of those which have survived initial and subsequent screenings and are serious contenders for the ultimate selection. If only one candidate plan remains in contention, the choice has already been made. Otherwise, a decision procedure must be carried out.

The competitive relationships among the plans may vary rather widely. For instance, it could turn out that all candidate plans are acceptable in terms of performance, but one is least costly. Generally, the situation will be more complex. The more costly plans will in many cases rate higher in performance than the less costly plans. In other words, there are tradeoffs among the plans. Dollars may be traded off for benefits in terms of superior performance, or superior performance in some areas may be traded off for superior performance in other areas.

The final ranking of the candidate plans may be made by one person or may be made by a group. If made by a single person, that person must weigh the alternative plans carefully, taking into account the tradeoffs that have become apparent from the analysis of the costs and the performance goals, and also the less tangible implications of each plan. In some situations cost will turn out to be the predominant factor, in others performance ratings will be most important, and in still others a balance will be struck between cost and performance.

Consider next situations in which the final ranking of the candidate plans is the responsibility of a group. An example is the design of a coordinated dispatching system to serve several police departments, each of which has a representative on the policy making council.

It is possible that a consensus may emerge that points to one of the plans as clearly preferable to all the others. If this is not the case, some group decision procedure akin to voting can be carried out. One way of doing this is for each member of the group to independently rank the candidate plans just as if he alone were responsible for the outcome. Average ranks can then be computed for all the plans and the recommendation or decision can be made in favor of the plan with the highest average rank. Many other group decision procedures are possible.

VII.9 Implement and Evaluate the Chosen Plan

Once a decision has been reached as to the best plan for the design or modification of a police telecommunication system, there remain the practical steps of implementing the plan and evaluating the results achieved in comparison with the results anticipated. One important aspect of plan implementation is budgetary. Other important aspects are the scheduled introduction or replacement of physical facilities and equipment, and the training and operational deployment of department staff members.

The actual operating budget which covers the plan adopted will reflect the budget estimate prepared in conjunction with the plan itself. Telecommunications is, of course, only one of the many activities engaged in by a police department in pursuit of its objectives. Likewise, it accounts for only a portion of the expenditures that are required to sustain the department. Departments in general operate on an annual budget which covers all items of expenditure.

The preparation of a budget proposal, including the telecommunications component, usually will be a responsibility of the chief officer. He may request advance budget estimates from members of the department who are responsible for the various line and support activities. These estimates are likely to be due well in advance of the beginning of the fiscal year to which the budget will actually apply. Therefore, advance planning and cost estimation must be carried out even earlier to ensure that the budget request is realistic. Communications is usually considered a general support function of a police force, in contrast to a line function, and will enter the budget in accordance with the place it occupies on the organization chart.

In addition to the municipal, county, state or other budget within which the police organization operates as the law enforcement arm of that unit of government, there are other sources of funds for selected police needs. Communications is, of course, one of the areas eligible for such support. This financial aid may come to a local department from the

State, from the Federal government, from other sources, or from a combination of these. Some of these are discussed in Chapter III.

An application for funds outside of, or to supplement, the regular budget of a police agency will generally require the preparation of a detailed document in support of the application. This proposal—which may be for the system design or modification planned by using the procedures outlined here—will include a statement of the reasons justifying the request, the objectives to be attained, a discussion of the approach adopted, the plan of action, the personnel who will be involved in the supervision and execution of the project, the time schedule, and the amount requested, with a breakdown of costs in as much detail as is appropriate. Provision for the preparation of progress and final reports on the project will also be required. If the procedures suggested in this chapter have been followed, this material will be already at hand.

If the request involves the acquisition of communication equipment, specifications and cost figures will be included in the proposal. Likewise, if the support of an outside organization or individual consultants is needed in the execution of the project, details of the services to be furnished and the subcontracts will be included.

The strongest argument for fiscal support of the communication section of a department is a clear demonstration of needs, together with convincing evidence that the proposed system modification or design will contribute to meeting those needs in a cost-effective manner. Ultimately there must be a satisfactory return to the citizens of the community in terms of police protection for the tax dollars expended.

In the execution of the plan that has been adopted for setting up or modifying a telecommunication system a realistic time schedule for the key events should be drawn up and adhered to as far as humanly practicable. In this way the required actions can be coordinated, and a reasonably smooth transition can be made to the new or modified system. In the original formulation of the plan there will usually be at least a rough indication of the sequence of steps that is required to put the plan into effect, including the time requirements.

A refined schedule should be prepared at or near the date on which final approval is granted. Commitments on delivery and installation times can be obtained from outside contractors, if any are involved, and integrated with the activities within the department itself or other units of government with which cooperation is necessary. A clear assignment of responsibility and authority within the police or other agency should be made for monitoring progress on the implementation of the plan and taking whatever measures are required to coordinate the various lines of activity and correct any difficulties that arise.

The impact that the system design or modification will have on the headquarters and field personnel and the way in which they will react, either favorably or unfavorably, to the innovation are of crucial importance for the success of the entire effort. It is a universal truth that any system design, no matter how good it appears on paper, can fail in practice if the people involved are not committed to making it work. On the other hand, a design that looks awkward on paper may succeed in actuality if there is sufficient determination to achieve the goals to which the organization is dedicated.

A degree of leadership, depending on the magnitude and scope of the plan being introduced, should be exerted by the administrative officers to prepare the staff for the changes that are to come. If those working at headquarters and in the field understand the plan, the effect it will have on the tasks they perform, and how telecommunications will be facilitated, their reaction is likely to be active cooperation and perhaps even enthusiasm.

The telecommunication system that has been designed and constructed, or the modification that has been carried out, must be thoroughly tested to ensure that the work has been done correctly and that the system performs as intended. The performance standards which were set forth in the formulation of the plan are the main criteria against which the system is to be checked out. Additional criteria may be introduced as the plan becomes a reality. For example, the agency will need to observe or conduct tests proving that all the manufacturers' equipment specifications are met and that there is full compliance with the terms of the contracts that have been entered into.

Some tests can usually be made on the component parts of the system while others will be made on the system in its entirety or on major subsystems. As the system or modified subsystem is phased into a condition of operational readiness and then becomes fully operational, close monitoring of its performance will be mandatory. Any system of any considerable complexity will exhibit some unexpected traits when it first goes operational. Defects or "bugs" may appear as well as characteristics that are neutral or even desirable but not anticipated in advance. This is in part a matter of making equipment corrections and in part a learning process for those administering and operating the system. At the end of the transition period, if the plan has proved successful, the system will be standardized, requiring only normal maintenance and monitoring.

VII.10 Use of Mathematical and Computer Techniques in System Planning

The system planning process has been presented in terms of the basic steps that should be taken. The procedures have been kept as simple as possible. In many cases they can be applied by a department without drawing on specialized planning skills. It is the purpose in this section to point out that there are advanced planning techniques which can be used to aid in solving large or difficult telecommunication system problems.

The methods which will be mentioned have two characteristics in common: (1) a mathematical representation or model of the system, or portion of the system, is constructed; (2) computers are generally employed to analyze the model and derive results which would not otherwise be apparent. If the results are satisfactory, they can be applied in the design or management of the system itself. Special proficiency in these techniques is required if they are to be used successfully. Computers, with associated programs, make it feasible to perform the extensive calculations which are often encountered in the analysis of the model.

Good judgment is, of course, required throughout the planning process whether the methods are simple or complex. There are inevitably aspects of the structure and operation of communication systems that are difficult or impossible to quantify in a realistic way.

Selected methods will be mentioned which have applications to the planning of police telecommunication systems. In some instances results presented in the text have been derived through the use of these methods.

- Statistical regression analysis

  Prediction equations can be developed from historical or other data. For example, volume of police two-way radio traffic can be related to population of the area served by analysis of data on cities with known population and radio traffic. Population itself can be predicted from a growth equation based on past census figures. The uncertainty of the predicted values can be estimated.

- Queueing theory

  The behavior of communication systems under various kinds of loading, including random occurrence of calls, can be analyzed. For example, the minimum number of emergency-number telephone trunk lines can be determined which will yield a probability of 0.01 or less that a call will receive a busy signal during a normal busy period.

- Simulation

  Models can be formulated to represent time sequences of interacting events in complex systems. The detailed behavior of a system can be investigated in response to specified inputs. Some or all inputs may be random. For example, the processing of calls to a police department

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can be simulated step by step under various assumptions as to communication equipment and operating procedures. Alternative system plans can be compared on the basis of the simulation results.

- Linear programming

  This is a method for maximizing or minimizing a quantity that depends, in a linear sense, on a number of controllable variables, where there are various constraints (again linear) on the values that can be assigned to the variables. Potential applications to police telecommunication systems include the assignment of transmitter frequencies and powers to achieve satisfactory transmission of desired signals with a minimum of interference to receivers outside the areas to be covered.

- Critical Path Scheduling

  The model is a network of activities and events occurring in time, where some activities must be completed before others can be started. The model can be applied for the purpose of scheduling and monitoring the construction of a communication system so that the completion date is as early as possible.

APPENDIX A

RADIO TRANSMISSION, PROPAGATION, AND ANTENNAS

Basically, a radio communication link is comprised of the following components:

- A transmitter, or source of radio frequency (RF) energy
- A transmission line to convey the RF energy from the transmitter to the transmitting antenna
- A transmitting antenna to couple the RF energy from the transmission line into space
- A receiving antenna to intercept the propagated energy and couple it into a transmission line
- A receiver transmission line to convey the received energy from antenna to receiver
- A radio receiver

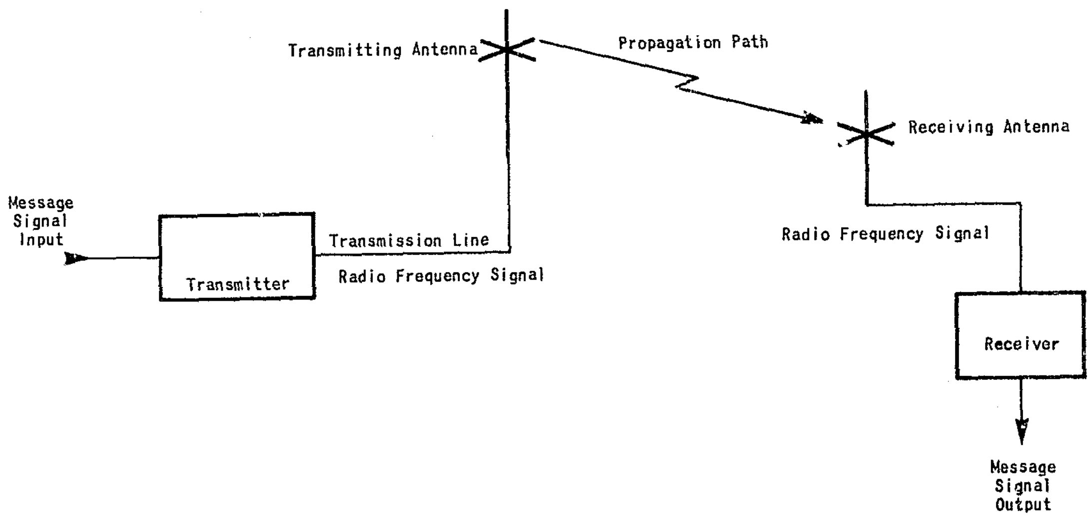


Fig. A-1 A Basic Communication Link

The relationships between these components are schematically illustrated in Fig. A-1. Each of these system components has a set of operating characteristics which governs its performance. The characteristics of each component are expressed in various ways and a number of pertinent figures of merit can be employed to estimate and compare different aspects of competing equipment.

The following sections will deal with the fundamental performance requirements imposed upon the system components by the basic system design. A method for estimating the necessary transmitter RF output power for a given range of operation and the important relationships between radiated power requirements and antenna height and gain, are given. Since these sections are primarily concerned with radio transmission, antennas, and propagation, only those parameters of the transmitter and receiver which directly affect radio transmission, antennas, and propagation will be discussed. Specifically,

- Transmitter RF output power
- Receiver sensitivity
- Receiver capture ratio

will be of interest.

A.1 Receiver Sensitivity, Local Noise and Interference

The basic demands imposed upon the transmitted power level and the antennas in a radio communication system are simply that a sufficient power level must be available at the receiver at all times. The receiver input power level which can be considered sufficient is dependent upon three principal factors.

1. The design of the receiver, in particular the receiver sensitivity
2. The ambient level of local (man-made) electrical noise
3. The possible presence of an interfering signal at the same frequency as the signal of interest (co-channel interference)

If the receiver is designed to meet Electronic Industries Association (E.I.A.) specifications,[1] the conditions for satisfactory operation will be expressed as the minimum receiver input voltage necessary to provide an intelligible receiver output. This is termed: the receiver sensitivity for 12 dB SINAD, and the receiver input is usually expressed in microvolts. Four our purposes this minimum input is more conveniently expressed as an input power level into a 50 ohm receiver input impedance. Using Fig. A-2, microvolts can be directly converted to decibels relative to one watt (dBW). In this form the minimum acceptable input power will be termed the receiver sensitivity (S_R). It is primarily limited by internal receiver noise (thermal, tube and transistor noise) and is measured in the absence of external electrical noise. This ambient noise is generated by automobiles, electrical motors, and other electrical and electronic devices as well as by natural phenomena such as lightning. Predictably, it tends to be at a considerably higher level in urban and suburban areas than it is in rural regions. If the various sources of external noise are considered collectively in each type

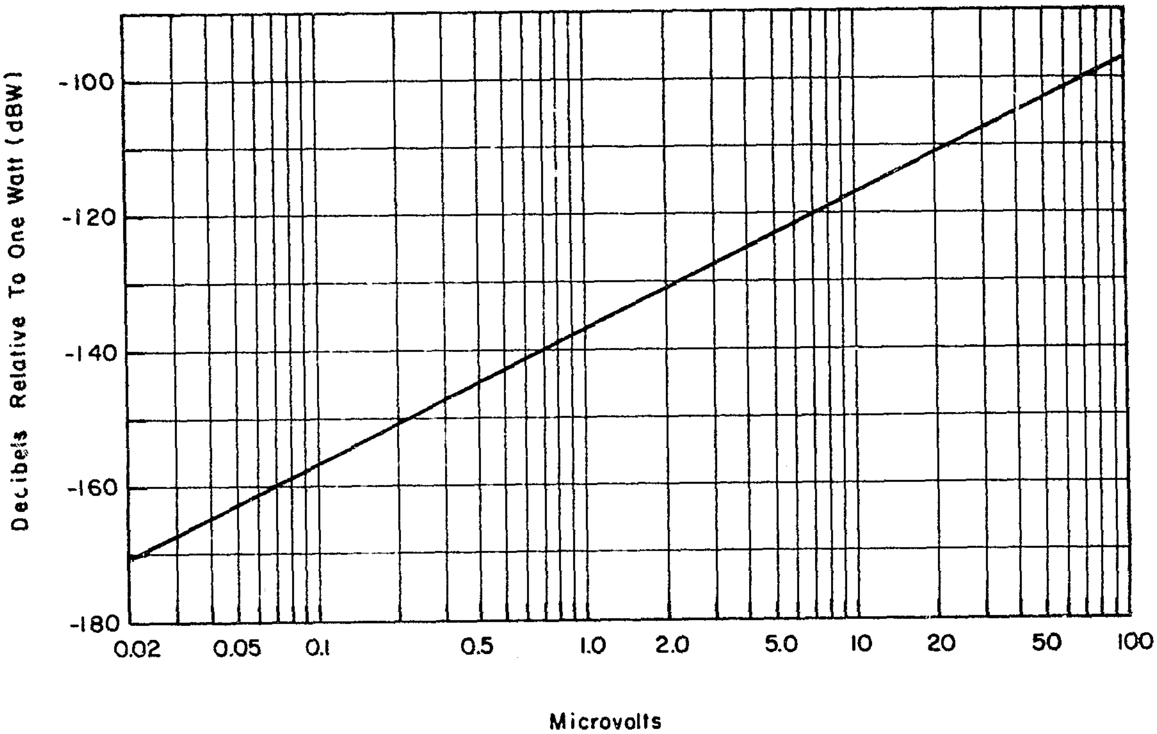


Fig. A-2 Conversion from Microvolts (Across 50 Ohms) to Decibels Relative to One Watt

of area, then an approximate guide to the probable ambient noise level can be established on a statistical basis.[2] It can then be stated that for a receiver to meet E.I.A. specifications, in a noisy environment, it is necessary for the minimum input power requirement to be increased to (S_R+N) dBW where N is an external ambient noise compensation factor expressed in decibels. The external ambient noise compensation factor, which will be employed in the calculations to follow, has been derived from data collected from several sources, but largely from that given in Reference 2. The curves given here are intended only as an approximate guide in the absence of detailed survey information on the service area for each specific system.

Although a receiver can, in general, discriminate between a desired signal and interfering signals which differ in frequency, the presence of an interfering signal on the same frequency as the desired signal may demand an increase in the signal power to a level above that given by (S_R+N) dBW. The effectiveness with which a given FM receiver can discriminate between two signals at the same frequency is expressed in terms of the capture ratio of the receiver. The capture ratio merely indicates how much larger than one signal another signal must be, in order for its audio modulation to be detected by the receiver. If the ratio of the desired signal power to the interfering signal power exceeds the capture ratio, then the receiver output will be the desired signal only. Under these circumstances, the desired signal is said to have 'captured' the receiver.

The capture ratio of a receiver is not always available from the manufacturer and the power level of interfering signals may be difficult to determine. If the interfering signal originates from a known source, such as a second radio communication system, then it may be possible to predict the maximum level of this signal occurring at points within the service area. If the interfering source is less well defined, it may be necessary to make a worst case estimate of its signal strength based on field measurements. If the power level of a co-channel interfering signal can be determined, then the minimum acceptable receiver input signal power is given by (I+C) dBW, where I is the power level of the interfering signal, in decibels relative to one watt (dBW) and C is the capture ratio of the receiver, in decibels. However, if (I+C) dBW is less than (S_R+N) dBW, then the minimum acceptable power level is given by the larger power level.

If no information is available with regard to power levels of possible co-channel interfering signals, then the minimum acceptable power level at the receiver can be taken as that given by the sum (in decibel measure) of the receiver sensitivity (S_R) and the ambient noise factor (N). However, it is understood that the minimum power requirements so derived will be sufficient only in the absence of co-channel interference.

A.2 Transmitter RF Power and Propagation Loss

For a base station-to-mobile communication system it is desired that the minimum acceptable signal level be achieved or exceeded at all points within the defined service area. Ignoring, for the moment, topographical peculiarities of a given service area, it is evident that, in general, the critical signal strength will occur at points which are farthest from the base station. Since it is neither economically desirable nor legally permissible to employ excessive levels of transmitted power, it is obviously of value to make some estimation of the minimum system radiated power requirements. The minimum system transmitter power required could be defined as that power which provides the minimum acceptable signal level at distances corresponding to the maximum range from the base station. We shall denote this radio frequency (RF) power level P_{min}.

To determine the value of P_{min} for a given maximum range it is necessary to estimate the anticipated propagation loss suffered by the signal travelling the path between the transmitting and receiving antennas. If we consider initially two ideal, lossless half-wave dipole antennas at given heights above a flat earth, then it is possible to calculate theoretically the propagation loss incurred at any given range. The propagation loss between these dipole antennas can be expressed simply as the ratio of the power received to that transmitted. It will be dependent only on the respective heights of the antennas and the distance separating them. The use of directional antennas can then be taken into account by reducing this propagation loss by the relative power gains of the specific antennas. While this approach can be extended to account for the curvature of the earth's surface, the theoretical model of a smooth earth still bears little resemblance to the irregular terrain of most service areas.

Without a detailed field survey of the service area in question the propagation loss involved can only be estimated on a statistical basis. Using statistical techniques it is possible to arrive at an estimate of the probable propagation loss incurred between base and mobile antennas or mobile-to-mobile antennas over irregular terrain.[3] This probable propagation loss is dependent on antenna heights and range as before, but also on the operating frequency and the percentage of locations one could expect to cover statistically at a predescribed range. For example, if at a radial range of 10 miles the maximum range circle is divided into 100 parts and each division represented by a point, then 90 percent coverage would imply that 90 of the points would receive satisfactory or better transmission, while 10 would not have satisfactory reception. In terms of propagation loss directly, this percentage indicates that the given propagation loss would be valid for 90 percent of the locations at that range, while 10 percent would have a greater loss. To simplify the procedure, the figures given in the graphs to follow will assume 97 percent coverage as a constant system requirement. Data for other percentage coverages may be obtained from the referenced work.[3]

A.3 Overall System Power Losses and Gains

The propagation loss between transmitting and receiving antennas does not constitute the only power loss in the overall system. The total power losses will include the dissipative losses in the transmission lines between transmitter and receiver and their respective antennas, and additional losses arising from impedance mismatching occurring between the antennas and their transmission lines. However, these additional losses may be partially compensated by the reduction in propagation loss achieved by the power gain of the antennas.

The overall power losses and gains of a radio communication link can be usefully illustrated in tabular form, and it is convenient to express each of the losses and gains in decibel measure. In Table A-1, each source of power loss (A), or gain (B), in the overall system is described and the form in which the loss or gain is usually given is indicated.

TABLE A-1
OVERALL SYSTEM LOSSES AND GAINS

Item	Description	Commonly given as
	Power Loss	
A_1	Attentuation loss in transmitter transmission line	dB per 100 feet of line
A_2	Mismatch loss between transmission line and transmitting antenna	VSWR
A_3	Propagation loss between two half-wave dipoles at heights 'h_1', 'h_2' and range 'd' at frequency 'f' Hz over irregular terrain	h_1, h_2, f and d
A_4	Mismatch loss between receiver antenna and receiver transmission line	VSWR
A_5	Attenuation loss in receiver transmission line	dB per 100 feet of line
	Power Gain	
B_1	Power output of transmitter (as measured into a matched load)	Watts or dBW
B_2	Power gain of transmitting antenna } Relative to a half-wave dipole	dB
B_3	Power gain of receiving antenna } Relative to a half-wave dipole	dB
B_4	Either (i), receiver sensitivity plus ambient noise factor (S_R+N) dBW, or (ii) known power level of a co-channel interfering signal plus capture ratio of receiver (I + C) dBW	microvolts dBm or DBW

Notes on Table A-1.

A_1 Some typical coaxial cable attenuation factors are shown in Fig. A-3.

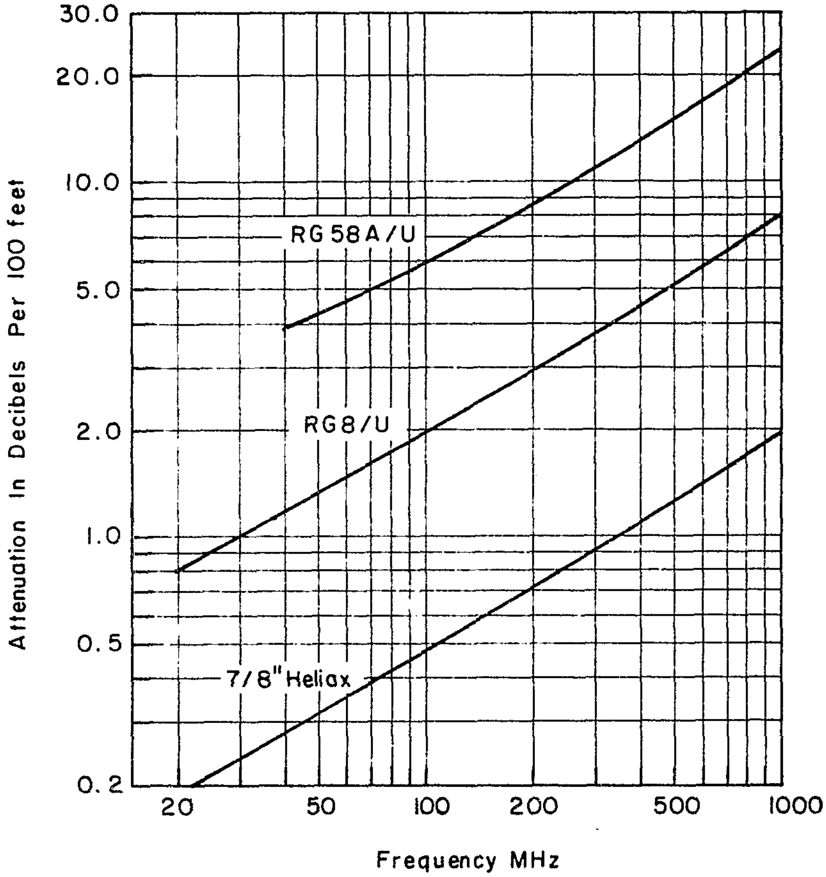


Fig. A-3 Attenuation Losses for 3 Common Types of Coaxial Cable Transmission Lines

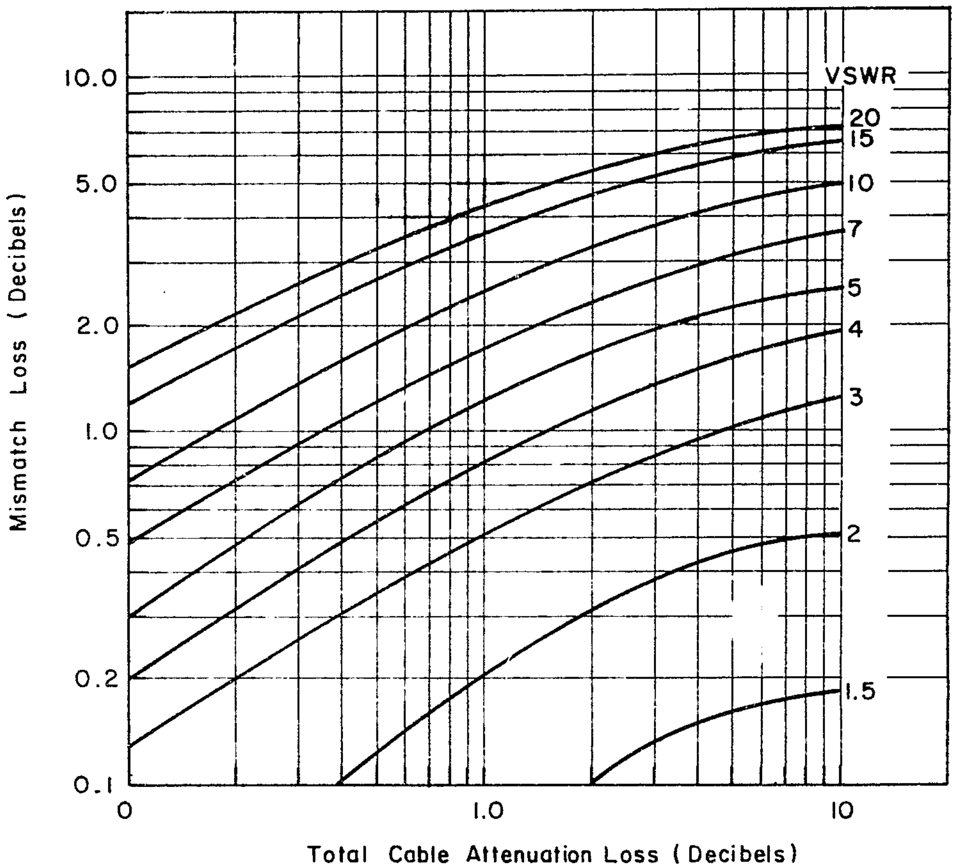


Fig. A-4 Knowing the Total Cable Attenuation Loss (from A_1) and the VSWR, the Graph Provides the Mismatch Loss (for A_2)

A_2 To convert the Voltage-Standing-Wave-Ratio (VSWR), to power loss in decibels use Fig. A-4 and the total cable attenuation obtained in A_1. VSWR values are generally less than 2 : 1 and typically of the order of 1.5 : 1.

A_3 The propagation loss is obtained from Figs. A-5, A-6 and A-7. Knowing the maximum range 'd' use Fig. A-5 to determine the range loss; knowing each antenna height 'h_1', 'h_2' use Fig. A-6 to determine the height gain for each antenna; knowing the frequency 'f' use Fig. A-7 to determine the terrain (loss) factor. The propagation loss is the sum of range loss plus terrain factor less the two antenna height gains.

A_4 See note A_2 above.

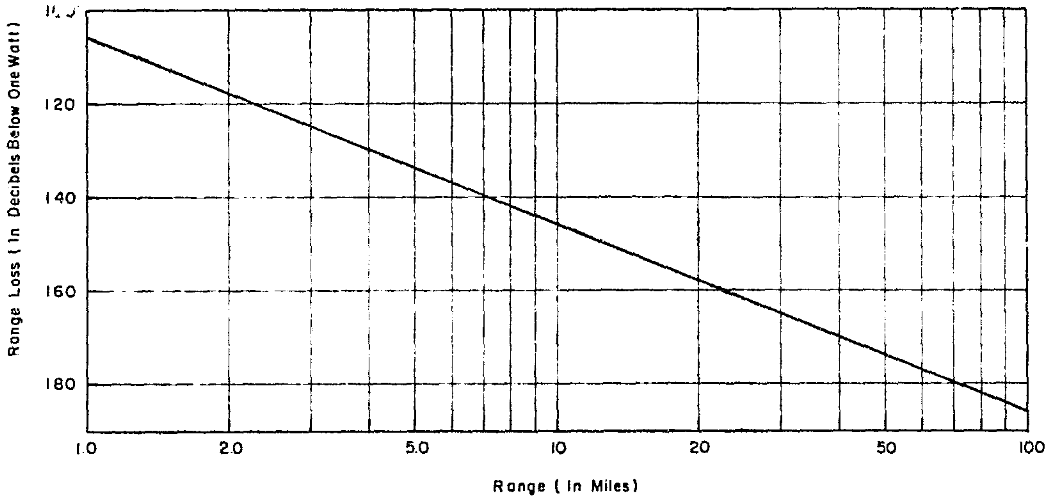


Fig. A-5 Propagation Loss Due to Increasing Range
(Relative to 2 Dipole Antennas 6 Feet Above Flat Earth)

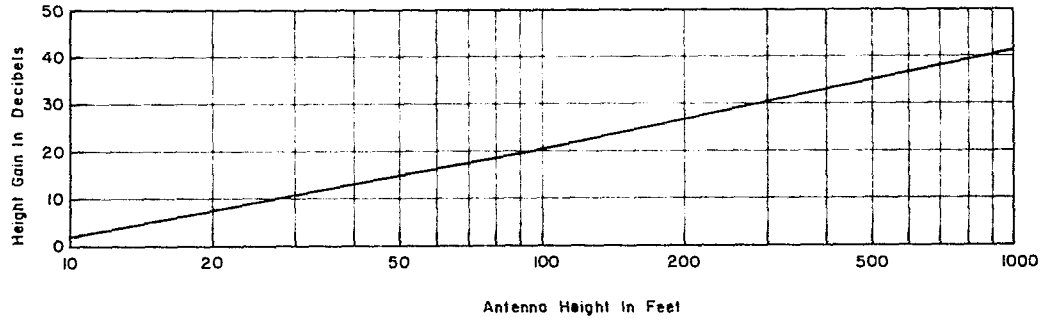


Fig. A-6 Height Gain of Antennas. Height Considered Is That of the Base of the Antenna, Over the Surrounding Terrain.

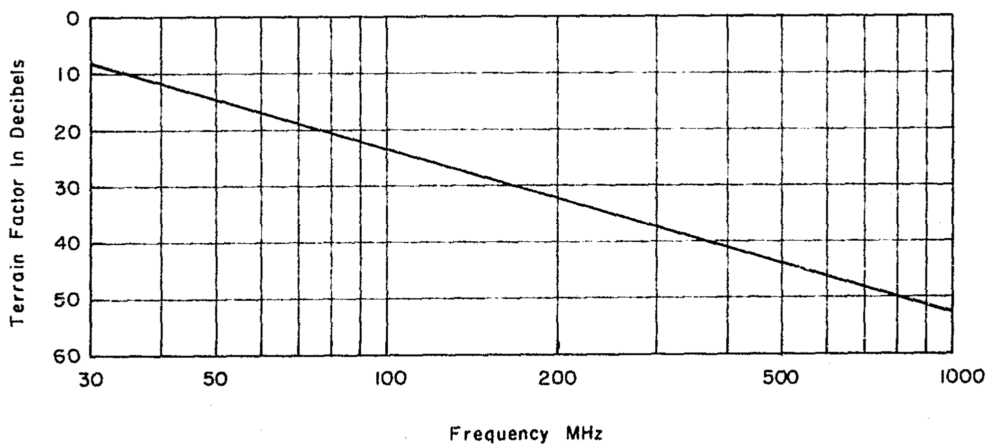


Fig. A-7 Terrain Factor for Communication to 97 Per Cent of Mobile Locations

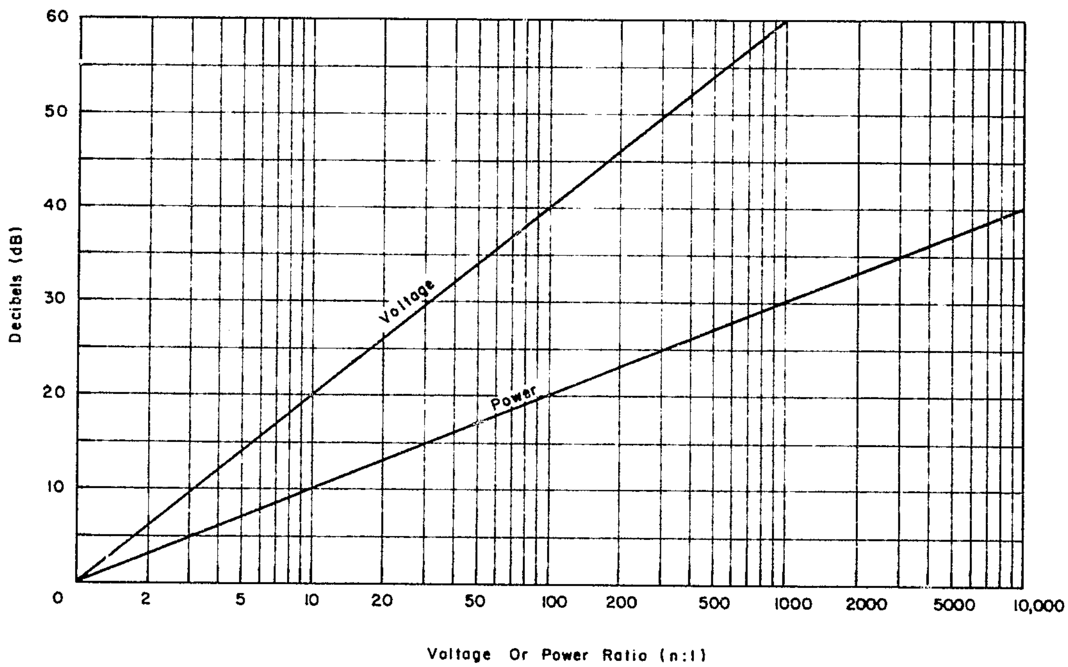


Fig. A-8 Conversion of Voltage or Power Ratio to Decibels

B_1 For conversion from power in watts to dBW use Fig. A-8. For example, 16 watts is 12 dBW, 2 watts is 3 dBW and 1/10 watt is -10 dBW. The matched load used to measure the transmitter output power should have the same impedance as the system transmitter transmission line. A 50 ohm impedance is normally standard.

B_4 If the power level of the interfering signal (I) is known, use (I + C) dBW, providing it is greater than (S_R+N) dB. Otherwise use (S_R+N) dBW. (Note that S_R is usually negative while both N and C have positive values. Note also that, for example, -130 dBW is *greater than* -140 dBW). For receiver sensitivities expressed in terms of microvolts into a 50 ohm input impedance, the conversion to dBW is given in Fig. A-2.

Where the loss or gain is provided in units other than decibels, the relevant numbered notes, following the table, give instructions on the conversion to decibels. For conversions from decibels relative to one milliwatt (dBm) to decibels relative to one watt (dBW), subtract 30 dB (e.g., 120 dBm = 90 dBW and -120 dBm = -150 dBW).

The height of the antenna is taken as the height of the base of the radiating element above the surrounding terrain. Thus a hill or mountain top location will effectively add to the antenna height.

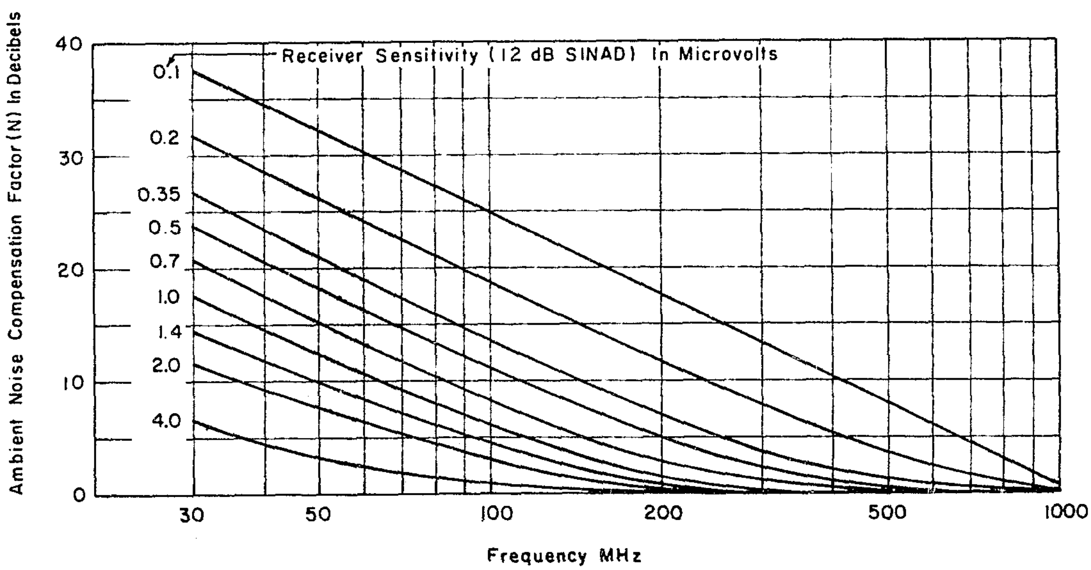


Fig. A-9 The Ambient Noise Compensation Factor for Suburban Man-Made Noise

To determine the indigenous ambient noise compensation factor (N) refer to Fig. A-9, and use the curve corresponding to the manufacturer's quoted receiver sensitivity. (E.g., a 0.35 μV sensitivity for a 12 dB SINAD output would be a typical value.) The curves are based on a receiver noise bandwidth of 10 kHz, and are given for both suburban and rural noise (Fig. A-10). The suburban curve may be used for suburban and urban regions if the maximum range of either system will exist outside of a downtown or heavily industrial area. For purely rural areas the lower compensation given by the set of rural curves will apply.

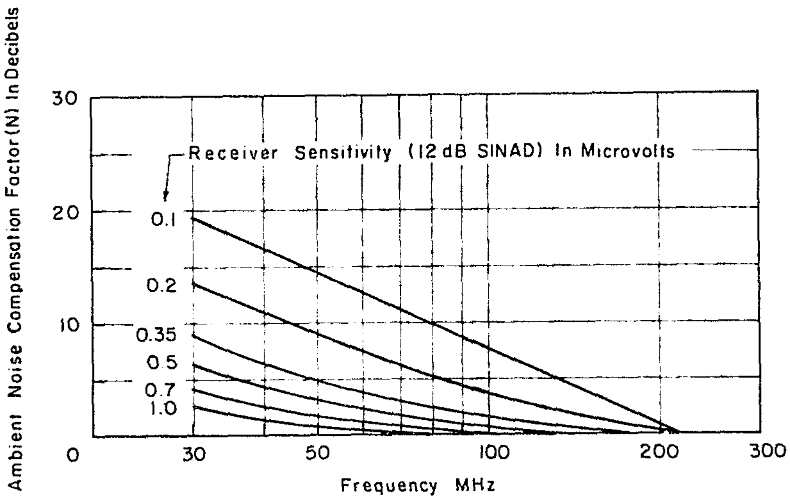


Fig. A-10 The Ambient Noise Compensation Factor for Rural Noise

A.3.1 Applications of System Losses and Gains Table

When each item has been expressed in decibels, or decibels relative to one watt, then the decibel sum of A_1 to A_5 constitutes the overall system loss, while $B_1 + B_2 + B_3 - B_4$ indicates the overall system gain. For this system to be operable the B group total or system gain must be at least as great as the A group total or system loss. The critical condition of minimum acceptable signal at the receiver and minimum transmitter power (P_{min}) is indicated when the totals are equal.

A tabulation along the lines of that shown in Table A-1 can be prepared either to analyze an existing system or to obtain estimates for an intended system. Having prepared the table, trade-offs can be studied and a variety of basic systems evaluated.

Obvious trade-offs can be made by increasing either antenna height or antenna power gain to achieve either a reduction in the required transmitter power output or to extend the range of the system. An increase in the height of the base station antenna, for example, can be employed to reduce the propagation loss, say, by 3 dB (see Figure A-6). To maintain the same balance of gains and losses either the range can be increased to bring the propagation loss at maximum range back to its original level (see Figure A-6), or the transmitted power can be reduced by 3 dB (i.e., halved). Trade-offs of this nature, and their economic aspects are discussed in the relevant sections on fixed and mobile equipment. Use of the table also indicates the relative importance of several commonly specified component parameters, including, voltage-standing-wave-ratios (VSWR) of antennas, receiver sensitivity, antenna power gain, and coaxial cable attenuation factors.

An example of the tabulation is illustrated in Table A-2. Assume that we wish to determine the approximate transmitter RF power requirements suitable for the following 150 MHz suburban system specification: Maximum range 20 miles, base-station antenna height 150 feet, mobile antenna height 6 feet, base-station antenna gain 7 dB , mobile antenna gain 0 dB (over a half-wave dipole in each case). The item numbers below correspond to those of Table A-1, and while the middle column indicates the raw data, the final column gives the decibel measure using the conversion graphs. The transmitted power requirement (P_{min}) has been chosen to balance the total losses and gains of the system.

TABLE A-2
EXAMPLE OF LOSSES AND GAINS TABULATION

Item	Raw Data	Decibels
A_1	200 feet of 7/8'' Heliax cable at 0.6 dB/100 feet	1.2
A_2	VSWR = 1.2 : 1	Negligible
A_3	h_1 = 150 feet, h_2 = 6 feet, d=20 miles f = 150 MHz	161
A_4	VSWR = 2 : 1	0.5
A_5	20 feet of RG-8/U at 2.5 dB/100 feet	0.5
	Total Loss	163.2

B_1	Transmitter Power (P_{min}) (166 W)	22.2
B_2	Antenna power gain	7
B_3	Antenna power gain	0
B_4	Receiver sensitivity 0.35 μV (for 12 dB SINAD), suburban noise (-146 + 12)	-134
	Total Gain	163.2

A.4 Base Station Antenna Specifications

Before a specification for the base station antenna can be developed, it is necessary to consider the location of the base station within the service area of interest. Two of the fundamental parameters of the antenna system are the height of the antenna relative to the surrounding terrain and the desired radiation pattern of the antenna itself. Since the effective height of the antenna is relative to the surrounding terrain and since we have seen in Section A.3.1 that an increase in antenna height can be employed to reduce the transmitted power requirements of the system, it is desirable in many cases to locate the base station antennas on a high point, such as a mountain or hillside or upon a large building. However, because many channels are used by several neighboring communities, locating the base station antenna at the highest point available is not always the best choice. The best antenna location is one that achieves a compromise between transmitter power and antenna height; one that allows the required area to have sufficient signal strength for reliable operation, and, at the same time, minimizes interference to other departments operating on the same channel.[4] A line-of-sight path between transmitter and receiver is desirable ideally, but this can rarely be achieved for all locations in practice. Fortunately, due to reflection and diffraction effects, radio communication can be achieved beyond this limit, although the presence of large obstructions in the signal path can create shadowed regions where communication is either poor or non-existent.

The antenna location need not necessarily be that of the base station. The RF transmitter and antenna at a remote station can be adequately controlled with a land line to the base station proper. Another alternative is to locate an unmanned repeater station on a high point and use a secondary transmitter and antenna at the base station to send the signal to the repeater. Either of these, or a variety of similar techniques, may be employed to achieve a greater range of service without use of excessive quantities of transmitter power. The employment of a remote antenna site which makes use of available terrain height-gain may also prove to be more economical than the construction of a large tower at the base station.

Obviously, the radiation pattern requirements of the antenna are dependent upon the location of the antenna within the service area in question and the direction, or directions, to which power is to be radiated. If the base station antenna is centrally located within the service area, then, in the horizontal plane, the antenna must transmit equally to all points of the compass. Since antenna gain is only achieved by reinforcing the radiation in one direction at the expense of other directions, it is apparent that gain can only be achieved in this case by electrically "squeezing" the radiation pattern in the vertical direction. However, the vertical beamwidth of the antenna radiation must not be made too narrow, since the radiation must illuminate both hill tops and valleys in the service area. The minimum acceptable vertical beamwidth may vary in specific cases, but a minimum of six degrees between the directions in which the radiated power falls to half its peak value might be typical for flat or gently undulating terrain. To achieve this "squeezing" (or directivity gain) the antenna structure will tend to be large in terms of wavelengths in the vertical direction. As a result, at lower frequencies, when the wavelength is large, the physical size of the antenna structure may become a limiting factor.

As an illustration of the development of the base station antenna specification, let us consider the case of the centrally located base station (within the service area) and un undulating terrain with no particular height advantages. The antenna will be based on a tower or mast and, from the above, it is apparent that the required radiation pattern will be uniform in the horizontal direction and with as great a power gain as can be obtained without allowing the vertical beamwidth to become less than six degrees.

The antenna will be used in conjunction with a transmission line which connects the antenna to the terminal equipment. To provide a best match condition, between the antenna and the transmission line, it is necessary that the input impedance of the antenna be equal to the transmission line characteristic impedance (nominally 50 ohms). The Voltage Standing Wave Ratio (VSWR) is a measure of this match and the antenna VSWR should not exceed 2 : 1 over the band of frequencies of interest.

For a single operating channel the required antenna bandwidth is very narrow in any of the available bands; (i.e., less than 0.01 percent of the operating frequency). If the antenna has to handle more than one channel, then the antenna bandwidth required is given by the greatest frequency separation of the channels employed. However, except at low-band (37.02-46.02 MHz) the maximum frequency separation will still be less than 3 percent of the operating frequency. Thus in most cases a narrow-band antenna which is designed to operate at the band's center frequency will provide adequate bandwidth for these channels. Nevertheless, for multiple channel operation and, in particular, in the low band case, care should be taken that the antenna selected will perform satisfactorily over the necessary bandwidth. In general, for operation over wider bandwidths, a price has to be paid in the form of a small reduction of the antenna power gain and a worsening in the VSWR over the range of frequencies concerned. For antennas providing significant directional gain, some deterioration of the radiation pattern may also occur with wide-band operation.

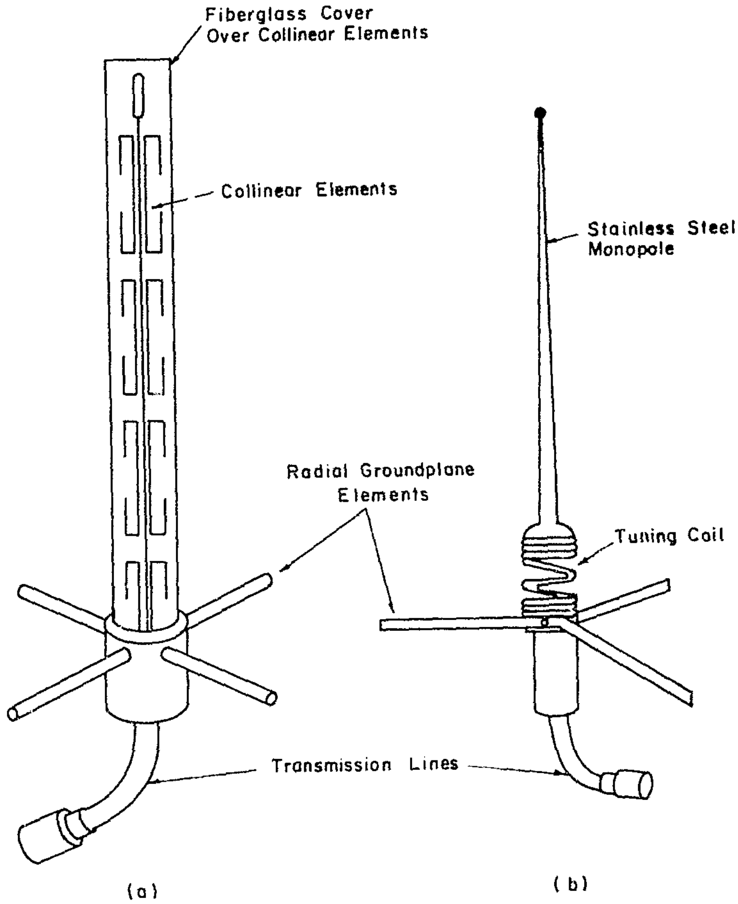
439-911 O - 71 - 20

Since the antenna must handle the total transmitted power, it is necessary to ensure that its RF power handling capabilities exceed the total transmitted power. The total transmitted power can be determined by use of the tabulation in Section A.3. For this example we will assume an antenna power handling capability of 250 watts.

The base station antenna will, in general, be vertically polarized to optimize communications with the vertical receiving antennas on the mobiles. However, although it is not in general use for police communications, there are certain advantages to be obtained in the use of circular polarization at the base station. While a given vertically polarized transmitted signal produces a maximum received signal when the receiving antenna is vertical, it produces little or no received signal when the receiving antenna is horizontal. A circularly polarized transmission of the same transmitted power results in a 3 dB decrease in signal at the vertical antenna, but the received signal remains constant regardless of the orientation of the receiver antenna. This characteristic of circular polarization may find applications in the future, particularly with regard to communication with hand-held portables. For the example considered here we will assume a conventional arrangement, with a vertically polarized base antenna.

Finally, attention must be given to the overall weight and the mechanical strength of the antenna and its supporting structure. The possible conditions in the service area may include corrosive air pollution, large temperature variations, high winds, lightning, rain, snow and ice—all of which must be borne by the antenna with an absolute minimum of maintenance.

If we assume that mechanical requirements dictate that the antenna structure should not exceed 25 feet in height (excluding the tower), then from examination of manufacturers' catalogues the following antennas might be selected. The high-band and UHF antennas are basically the same design and are suitable for operation at specified frequencies within the range 144-174 MHz and 450-470 MHz, respectively. The low-band antenna operates at a specified frequency in the range 25-100 MHz. The full antenna specifications, as taken from the catalogue, are given in Table A-3 and Table A-4. A bandwidth requirement of 0.5 percent has been assumed. The antennas are illustrated in Fig. A-11. The series-fed collinear array shown in the figure employs periodic annular slots in the outer conductor of a coaxial line to excite half-wave dipoles formed by adding skirts symmetrically about the slots.



a) Collinear Element Antenna for UHF or High-Band

b) Tuned Whip Antenna Suitable for Low-Band

Fig. A-11 Base Station Antennas

TABLE A-3
HIGH-BAND AND UHF ANTENNA SPECIFICATIONS

Electrical Specifications	Antenna 1 (High-Band)	Antenna 2 (UHF)
Frequency range*	144-174 MHz	450-470 MHz
Power gain (over a half-wave dipole)	5.8 dB	10.0 dB
VSWR over 0.5% bandwidth	Less than 1.5 : 1	Less than 1.8 : 1
Nominal input impedance	50 ohms	50 ohms
Maximum power input	500 watts	300 watts
Polarization	Vertical	Vertical
Vertical beamwidth (to half power points)	18 degrees	6 degrees
Horizontal pattern	Omnidirectional	Omnidirectional
Termination (for connection to line)	Type N female	Type N female

*Frequency to be specified when ordered.

Mechanical Specifications	Antenna 1 (High-Band)	Antenna 2 (UHF)
Antenna radome	Fiberglass	Fiberglass
Support tube (galvanized steel)	2-3/8" diam. x 24" long	2-3/8" diam. x 24" long
Groundplane rods	18" long	6-1/2" long
Radiating elements	Copper or brass	Copper or brass
Rated wind velocity	100 mph	100 mph
Weight	29 lbs	30 lbs
Overall length	20' 3"	21 feet

TABLE A-4
LOW-BAND ANTENNA SPECIFICATIONS

Electrical Specifications	Antenna 3 (Low-Band)
Frequency range*	25 - 100 MHz
Power gain (over a half-wave dipole)	0dB (unity gain)
VSWR over 0.5% bandwidth	Less than 2 : 1
Nominal input impedance	50 ohms
Maximum power input	650 watts
Polarization	Vertical
Vertical beamwidth	60 degrees (approx.)
Horizontal pattern	Omnidirectional
Termination (for connection to line)	Type N female

*Frequency to be specified on ordering.

Mechanical Specifications	Antenna 3 (Low-Band)
Skirt, aluminum alloy	2" diameter
Support tube (galvanized steel)	1-5/16" diameter
Whip, aluminum alloy with iridite finish	13/32" diameter
Rated wind velocity	100 mph
Weight	20 - 40 lbs
Length	25 feet (approx.)

From an examination of the antenna specifications above, it can be seen that only the UHF antenna (No. 2) has sufficient gain to provide a vertical beamwidth approaching the six degree limit. Antennas 1 and 3 are both limited by the physical size constraint. Antenna 1, for example, would have to be approximately 63 feet long to achieve the same vertical beamwidth and gain as Antenna 2, although both antennas are basically the same design. This arises because the gain of any given antenna type is related to its dimensions in wavelengths. Thus, since a wavelength in the high-band is approximately three times greater than a wavelength at UHF, the necessary dimensions to achieve the same gain tend to approach the same ratio. Similarly, it will be found that, for the same antenna type, the beamwidth at UHF will be approximately one-third times that at high-band, when the antennas have the same physical dimensions. From the physical point of view, the shorter and smaller antenna elements required for the UHF band represent an advantage over high-and low-band antennas.

A.4.1 Base Antenna Locations Other Than Central

If the base antenna is located other than centrally within the service area, it may be advantageous to use an antenna which provides a radiation pattern which is also directional in the horizontal plane. Using a suitable antenna with a correctly shaped radiation pattern can thus provide increased gain in the directions of interest and reduce the radiation of power outside the service area.

In this case, for flat or undulating terrain, an antenna is required which provides the maximum possible gain, with a vertical radiation pattern having a beamwidth of not less than six degrees and a horizontal radiation pattern providing radiation in the directions of interest. Again, the antenna specifications will include factors such as VSWR and capability to operate over the required bandwidth, mechanical factors, etc. A variety of antenna types can be employed to achieve adequate performance; these include arrays of radiating elements (including Yagi types) and combinations of driven and reflecting elements, corner reflectors, and parabolic reflectors.

A.5 Point-to-Point Communications

If the main base antenna is located with its transmitter on a remote site, communications with the base station may be achieved either by land-line or by a secondary radio system. For point-to-point communications of this nature, both of the secondary antennas should ideally provide pencil type beams, with narrow beamwidths in both the horizontal and vertical planes. Such radiation patterns imply high gain antennas which are more practicable at the higher frequencies since the physical size necessary to achieve high gain at lower frequencies becomes a limiting factor. This performance can again be achieved by use of suitable antenna arrays and/or reflector systems. To achieve a narrow beam in both principal planes, the radiating elements can be arrayed in two dimensions to form a plane, while a typical reflector system would be of the parabolic type.

A.6 Repeater Stations

Even with a relatively good base antenna location it is possible that a mountain, hill or other obstruction may result in a shadow region where received signal strengths are extremely weak. In such cases, rather than attempting to improve signal strengths by increasing the power radiated by the base station and the mobiles, it may be worthwhile to incorporate an unmanned repeater station which is located such that it can receive the transmitted signal from the base station and redirect it into the shadow region, and vice versa. In some cases the repeater station could comprise a purely passive device which merely intercepts and redirects the base station (or mobile) transmission, by means of a suitable antenna or reflector system. However, it is often necessary to incorporate additional signal gain at the repeater. In this case, a suitable receiver and transmitter combination will be used at the repeater, in addition to the antenna system.

A.7 Transmission Lines

The transmission lines employed in police communication systems will, in general, be of the 50 ohm (characteristic impedance) coaxial cable type. The attenuation losses in these cables, which are normally expressed in decibels per 100 feet, have been discussed and are obviously of major importance when selecting cables for specific applications. Low-loss cable types are available, and for long runs of line (e.g.,100 feet or more), the additional cost of low-loss cable becomes an economic proposition when compared with the alternatives necessary to obtain a required level of radiated power. Low-loss cables can be of the fully flexible type, or for very low loss applications a semi-rigid or completely rigid coaxial line can be adopted. For most purposes the flexible types will be sufficient.

In addition to cable attenuation, another important characteristic of the transmission line is its maximum average power handling capacity. As for attenuation, the power handling capacity of a cable is, in general, a function of frequency. For example, Fig. A-12 shows the power handling capacities of the three cable types whose attenuation characteristics were given in Fig. A-3.

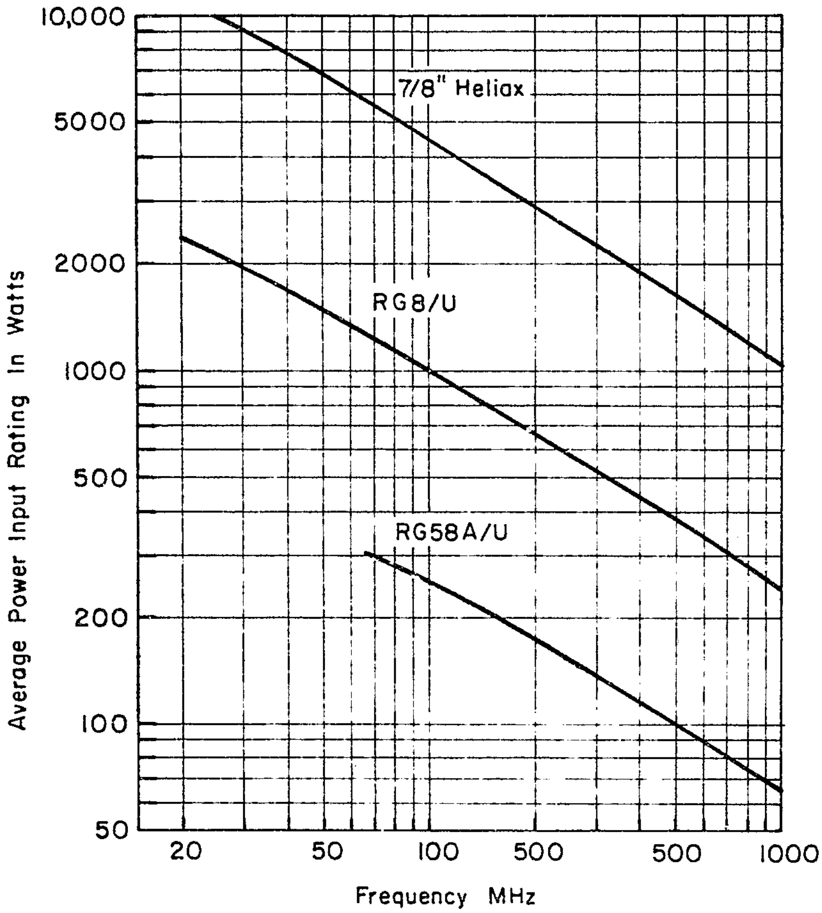


Fig. A-12 Maximum Average Power Handling Capacity for 3 Coaxial Cables

The characteristic impedance, attenuation and power handling capcity of a coaxial cable are the principal electrical features of interest here. However, from the practical viewpoint, the size, weight, flexibility, and cost must be considered, such that the chosen cable for a particular application should not be 'over engineered' electrically at the expense of the practical and economic considerations.

A.8 Improving the Performance of an Existing System

If it is necessary to improve the range or general effectiveness of a given fixed mobile system, four possibilities can be immediately examined. The possibilities are: (1) increase transmitter power and/or receiver sensitivity, (2) increase the height of the base station antenna, (3) increase the gain of the base station antenna, and (4) reduce any system transmission line losses. The relative change necessary for each of these possible solutions to produce the same overall improvement can be estimated by referring to Table A-1 and the associated graphs in Section A.2. For example, an increase in received power of 6 dB demands either an increase of four times in the transmitter power, or a doubling of the base antenna height, or 6 dB increase in the antenna gains, or a 6 dB reduction in transmission line losses, or some combination of lesser improvements. It is assumed here that the system has already been examined for obvious faults such as a damaged or mismatched antenna, a faulty transmission line, etc.

Increasing the transmitter power provides an apparently simple solution to the problem. However, the cost of new terminal equipment, or extensions to terminal equipment, is not small and the solution is often not attractive economically. Secondly, the FCC regulations impose an upper limitation on the level of radiated power, and an increase beyond the limit for which the station is presently licensed may involve considerable legal problems. In addition, an increase in the transmitted power may resolve the problem of base-to-mobile communications but will not improve the mobile-to-base link. It may also increase the problems of intermodulation interference to other stations. Overall, an increase in transmitter power is a competitive solution only if the station is operating below its legal maximum limit, and providing the effectiveness of the system is particularly poor in the base-to-mobile direction.

To improve the mobile-to-base link by acquiring new receiving equipment will only prove effective providing that reception is limited by the receiver sensitivity and not by the ambient noise level. This can best be determined by noise measurements at the receiver. However, Fig. A-13 gives some approximate guidance to the maximum usable receiver sensitivity in terms of the operating frequency and the receiver location. Figure A-13 is based upon the Ambient Noise Compensation Factors (N) described in Section A.2.

Increasing the height of the base station antenna will have the effect of reducing the propagation loss between fixed and mobile antennas and will provide, in general, improved communication in both directions. An increase in the base station antenna height can be achieved by either raising the tower or mast to which the antenna is fixed, or completely relocating the antenna. Obviously, relocation is not an inexpensive solution and thus it becomes attractive only if the alternative solutions have either been tried, or are even less desirable. Other than on purely economic grounds, relocation should only be considered if the present antenna location is particularly poor.

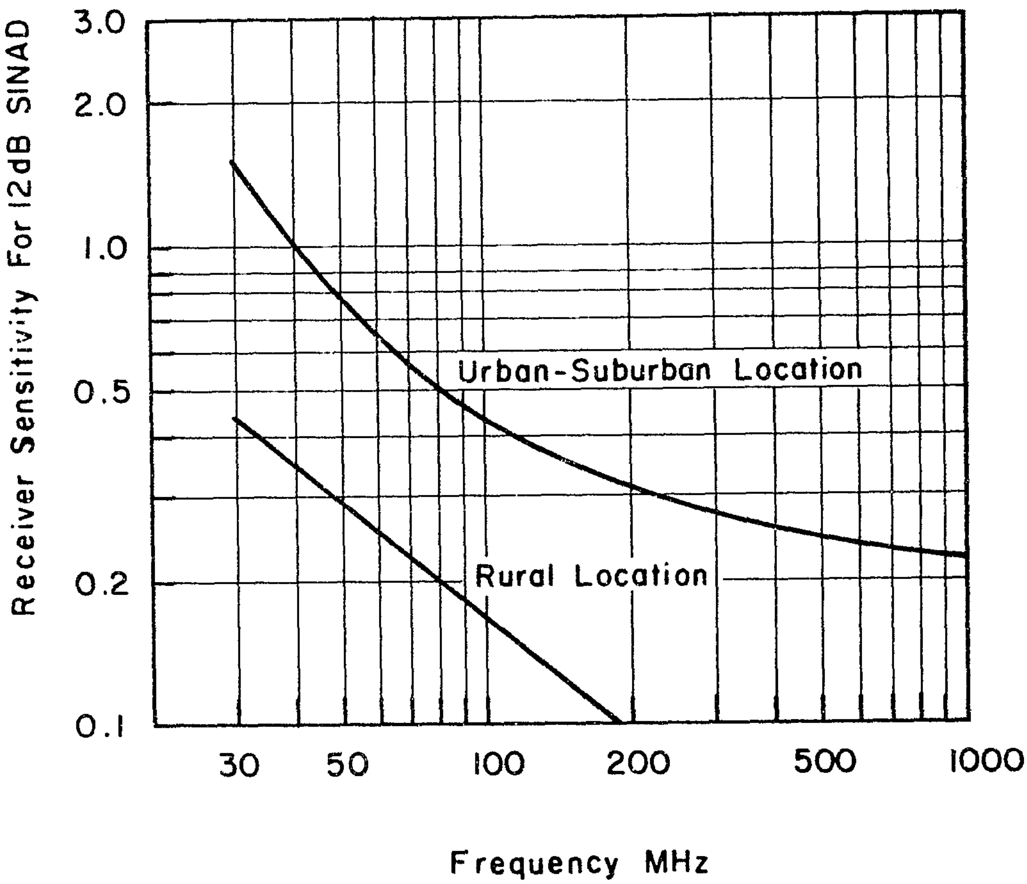


Fig. A-13 Increase of Receiver Sensitivity Below Value Indicated Will Be Unlikely to Increase Effective System Gain

Increasing the gain of the base station antennas provides what is probably the most economical way of improving two way communications. To determine how economical this might be for a particular system, a specification should be prepared for the particular base station antenna, along the lines of Section A.4. This specification should then be compared with that of the present antenna and with available antenna manufacturers' literature.

If it is found that another antenna can meet the necessary specification with improved gain, then the cost of the improvement can be estimated immediately.

The transmission lines interconnect the antennas with the terminal equipment. For the majority of systems coaxial transmission lines will be employed and while the attenuation losses of short lengths of such lines are usually negligible, longer runs may involve significant losses. Hence, to minimize these losses, the distance between the terminal equipment and the antennas should be kept as small as possible. Where a large separation between the antennas and base control is unavoidable, it may be desirable to locate the transmitter closer to the antenna and operate the equipment by remote control. Similarly, the losses in the cable in the receiving direction may be reduced by locating a pre-amplifier close to the antenna with the main receiver in the control area.

If the coaxial cables employed as transmission lines are of the flexible type, a reduction in attenuation loss can often be achieved by using more expensive low-loss types or semi-rigid, or even rigid cables with lower attenuation losses. Some typical cable attenuation factors are given in Fig. A-3.

To determine the most economical way of improving an existing system, each of the suggested solutions should be considered and a rough estimate of the cost of each solution obtained. Obviously, the total gain could comprise some combination of partial improvements in more than one of the areas discussed above.

A.9 Mobile Equipment Antennas

Mobile antennas are, in general, types which are suitable for mounting on motor vehicles and as such, suffer from greater restrictions with respect to physical size and ruggedness than does the base-station antenna.

For general applications, the mobile antenna will have the same direction of polarization as the base station; i.e., conventionally vertical. The radiation pattern will be omnidirectional in the horizontal plane and thus any directivity gain achieved will be obtained via a narrowing of the antenna beamwidth in the vertical plane. To achieve such gain it is necessary that the antenna vertical dimensions should be long with respect to the operating wavelength.

Since in the low-band the wavelength is of the order of 39 feet, it is apparent that the gain of a practical antenna in this band will be small. In the high-band, the wavelength is of the order of eight feet and thus only small directivity gains are to be expected. At UHF the wavelength is approximately 2.5 feet and moderate power gains can be achieved with comparatively compact structures.

For example, a collinear element antenna of the type illustrated in Fig. A-11 can be designed for a vehicle metal rooftop mounting (with the radial ground plane elements, shown in Fig. A-11 removed) such that, in the UHF-band, a power gain of 4.5 dB, over a half-wave dipole, is achieved with an antenna length of 4.3 feet. A simple whip antenna of the same length and operating in the high-band might provide 2.5 dB of power gain if similarly located. A 4.3-foot whip antenna operating in the low-band would require an additional tuned coil at the base of the antenna for efficient operation. The directivity gain of this arrangement is unlikely to exceed 0 dB while the power gain may be less than 0 dB due to losses originating in the coil.

A considerable variety of mobile antennas is available commercially. These include antennas for permanent and temporary installation, and, also, especially rugged types which are protected by a radome cover to prevent damage.

The important electrical specifications of the mobile antenna are the same as those discussed for the base antenna; i.e., radiation patterns, input impedance (VSWR), power gain, bandwidth and polarization. The mechanical specifications must take particular account of the hard wear and extreme conditions to which the antenna may well be exposed.

APPENDIX B

MICROWAVE SYSTEMS

B.1 Introduction

Microwave line-of-sight systems have been in practical use for a long time for short and long distance high capacity communication purposes. Over the last decade, such systems have been used more and more by private as well as public agencies like police departments. Such systems are, in fact, preferred to the conventional wire or cable communication systems in rough, mountainous areas where the cost of installing and maintaining such a system is excessive. In most practical systems, transmission over distances exceeding the maximum line-of-sight range is covered by installing a number of repeater stations arranged in tandem. Given reasonable well-designed microwave equipment, the performance of a system is directly related to the quality of the fundamental engineering of the route, antenna sizes and elevations. In the following sections, a brief description of the various factors affecting the design of such a system are discussed.

B.2 Propagation Influences

In a typical microwave relay system, a pair of highly directive microwave antennas pointing toward each other are located within a line-of-sight distance usually in the range of 10 to 40 miles. The radiation pattern of the antennas is made highly directive to ensure that most of the radiated and received energy is confined within a narrow beam centered on the line-of-sight path between the antennas. If every point on the path were far enough removed from the underlying terrain, free space propagation would result. However, the profile of the intervening terrain may range from smooth to mountainous. Moreover, in practice, some part of the terrain intercepts a portion of the radiation. This is then reflected onto a path leading to the receiving antenna. Receiving signals that have traveled two or more paths in this way cause interference (multipath propagation). Besides this, multipath propagation can arise directly due to non-uniformity in the atmosphere itself and due to abnormal changes in refraction within the line-of-sight path.

Multipath propagation discussed above is time varying, It is found in practice that there are random path length variations between different components of the received signal. Consequently, the resultant received signal is found to vary with time. In such cases, the signal is said to fade, and the process whereby signal loss occurs through such causes is called fading. Generally, fading is classified as either slow or fast fading depending on the rate. Slow fading is generally due to refractive bending and ground reflection phenomena. Fast fading, on the other hand, is mainly due to atmospheric multipath.

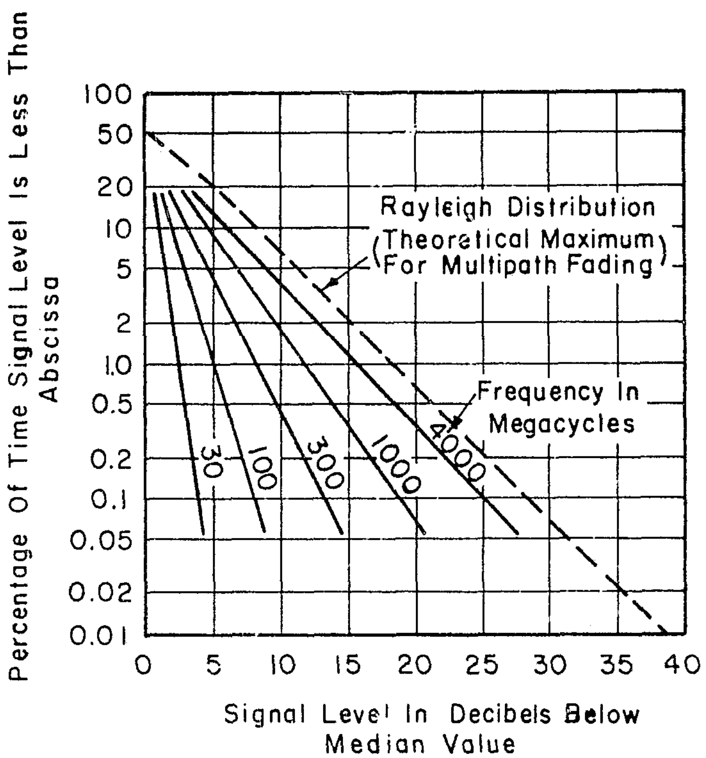


Fig. B-1 Typical Fading Characteristics in the Worst Month on 30 to 40 Mile Line-of-Sight Paths with 50 to 100 Foot Clearance (from Ref. 1)

It is customary to describe the behavior of a fading signal in statistical terms through a function defined as follows. The function is defined as the probability that the signal will be received at or less than a specified power level. This is usually taken as the power level at which the signal will be received in absence of the fading. The function may also be interpreted as the fraction of time that the signal is expected to be received at or less than the median value. Representative values of fading on a path with adequate clearance are shown in Fig. B-1 (see Ref. 1).

The above discussion has shown that in spite of providing enough clearance, thus avoiding ground reflection, the received signal fades. The most effective means used to combat fading is the diversity technique. Methods commonly discussed in the literature are (1) frequency diversity, (2) space diversity, and (3) polarization diversity. Frequency diversity is not permissible in the Public-Safety Service under FCC regulations. Space diversity is most commonly used because it is more effective than polarization diversity.

B.3 General Discussion

A block diagram of a typical microwave line-of-sight system is shown in Fig. B-2. The system consists of two terminal stations A, B and one or more repeater stations. Many police and municipal microwave systems are direct, however, and do not use any repeater stations. The stations have a transmitter and a receiver connected to the same antenna for two-way transmission. The frequencies of the transmitted and the received signals are different so that the respective signals can be separated by filters. Polarization is also used in many cases as an additional means to separate two signals which are too close in frequency to be separated by practical filters.

Consider the operation of the system of Fig. B-2. The input signals are in the form of voice or digital data. In general, a large number of such signals are to be transmitted simultaneously. It is customary to assign a channel number to each of these signals as shown in Fig. B-2. The signal from each channel is fed into a frequency division multiplexer which converts them into a single video signal using single-sideband modulators.

The video signal is then used to frequency modulate a radio frequency (RF) signal. The frequency modulated (FM) signal is fed to the transmitter via a transmission line. The transmitter location need not necessarily be that of the terminal station. The transmitter heterodynes the RF signal to the desired microwave frequency and amplifies it for radiation to the next station. In some cases, the video signal is used directly to FM modulate a klystron, the output of which is transmitted. The receiver at the next station heterodynes the microwave signal down to the IF frequency for amplification and equalization. The output is connected to another transmitter for transmission farther down the route or may be connected to an FM receiver through a transmission line. The FM receiver demodulates the signal and delivers the video signal to the terminating equipment where it is separated into the original channels.

B.3.1 System Design Considerations

There are various factors for consideration in the design of a system described above. These factors will now be discussed:

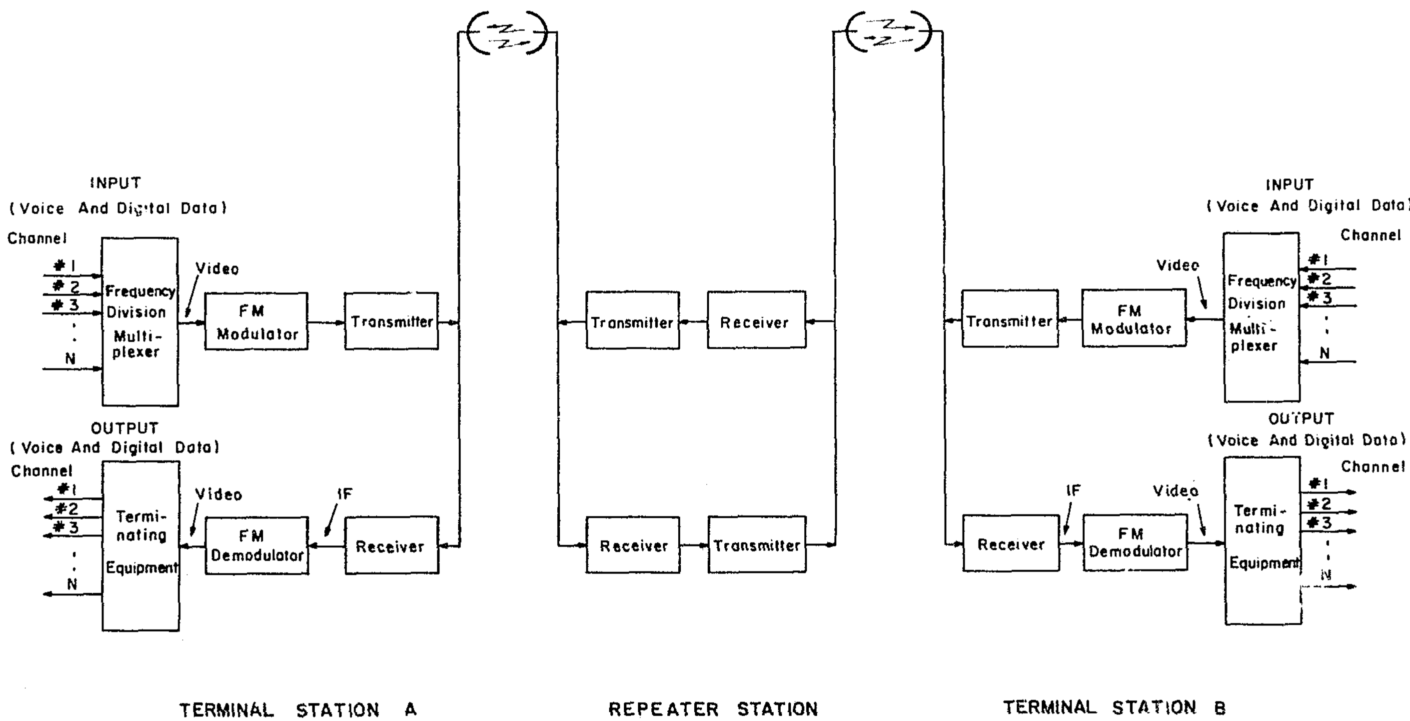


Fig. B-2 Microwave System

B.3.2 Antenna System

A large portion of the expense of any line-of-sight relay system is the cost of repeater sites, access roads and towers to support the antennas. Any new system should be designed to utilize the repeater sites and towers of older systems if at all possible.

The parabolic antenna is used in most line-of-sight systems. The antenna consists of a solid-surface aluminum parabolic reflector with a primary radiator feed at the focal point of the reflector. These antennas make a reliable, economic choice for the majority of users. Antennas are available in standard sizes from 4 to 16 feet in diameter.

Two of the fundamental parameters of the antenna system are the height of the antenna relative to the surrounding terrain and the antenna electrical characteristics. The antennas should be installed as high as possible so that the intervening terrain has enough physical clearance from the line-of-sight path receiving antennas. The electrical characteristics of importance are gain, beamwidth, and radiation pattern.

The gain and beamwidth of a parabolic antenna depend on its size, frequency and feed design. Typical gains and beamwidths of microwave parabolic antennas are given in Table B-1 and Table B-2.

Table B–1
Parabolic Antenna Gains

Antenna Diameter (ft.)	Gain (in dB)		
	2 GHz	6.5 GHz	12.7 GHz
4	25.4	35.8	41.4
6	29.0	39.3	44.9
8	31.5	41.8	47.4
10	33.4	43.8	48.6
12	35.0	45.4	----
15	37.0	47.3	----
16	38.0	47.8	----

439-911 O - 71 - 21

Table B-2
Parabolic Antenna Beamwidths

Antenna Diameter (ft.)	Antenna beamwidths (in degrees)		
	2 GHz	6.5 GHz	12.7 GHz
4	8.74	2.72	1.38
6	5.83	1.82	0.92
8	4.37	1.36	0.69
10	3.4	1.1	0.55
12	2.9	0.91	----
15	2.33	0.72	----
16	2.29	0.68	----

These beamwidth are quite narrow running from approximately 1.1° at 6 GHz to 3.4° at 2 GHz for a 10 ft. diameter antenna. The main lobe drops off to a null at 1.2° off axis. This factor brings out the importance of sturdy mounts and careful tower design.

The importance of the radiation patterns of antennas has become more apparent with an increase in microwave congestion and the need to prevent potential interference from other microwave systems. In planning a route, it is necessary to determine the potential interference from other sources operating at the same frequency within a 100 to 200 mile radius. If the carrier to interference ratio is better than 90 dB, interfering noise may be neglected. However, in moderate capacity systems, if this ratio is 50 dB or lower, preventive measures should be taken.

B.3.3 Frequency Allocation

The frequency allocation in the system should provide maximum utilization of the assigned band consistent with the transmission objective. Interference between transmitter and receiver in the same station is minimized by operating the transmitter in one half of the assigned bandwidth and the receiver in the other half.

B.3.4 Type of Modulation

The type of modulation of the RF carrier should be chosen to give the best compromise between noise and distortion performance on the one hand and bandwidth and practical equipment limitations on the other. The main contenders are (1) pulse modulation systems, (2) wideband FM systems, (3) single-sideband suppressed carrier systems, and (4) narrow-band FM systems. The first two systems can be designed to give excellent noise and distortion performance but are generally not used because of their large bandwidth requirements. Single-sideband suppressed carrier systems, on the other hand, make efficient use of the available bandwidth but require a high degree of linearity in the amplifiers for small or negligible distortion. Such systems are used in a number of cases where such distortion is tolerable. However, narrow-band FM systems are widely used.

B.3.5 Diversity System

System reliability can be improved through the use of space diversity systems to combat the frequency selective multipath effects. In a typical space diversity system, the signal from a single transmitter is received by two antennas installed on the same tower having a vertical separation of 30 to 80 ft. The two independently received signals are connected to a diversity switch which selects that signal which has the higher power level, and disregards the other. In some cases a diversity combiner is used instead of a diversity switch. This may result in a gain of 1 or 2 dB at the cost of extra equipment complexity.

B.4 System Parameters

B.4.1 Interference Between Direct and Reflected Rays

The presence of the ground modifies the generation and propagation of radio waves so that the received power, or field intensity, is ordinarily less than that expected in free space. For the case of one reflected ray combining with the direct ray at the receiving antenna, the resulting field intensity is given by[1]

$$E = 2E_d \sin \frac{2\pi h_t h_r}{\lambda d}$$

where E = resulting field strength, μvolts/meter

E_d = direct ray field strength, μvolts/meter

h_t, h_r = transmitting and receiving antenna heights

d = distance between transmitting and receiving antennas

λ = wavelength.

In practice, the line-of-sight links are designed to use highly directive antennas with narrow beamwidths so that the ground reflection problems are minimized. For this purpose, the antenna heights are chosen to provide sufficient clearance between the intervening terrain and radio line-of-sight ray. Under such conditions, mean free-space propagation conditions may be assumed to apply.

B.4.2 Required Path Clearance

A criterion to determine whether the intervening terrain is sufficiently removed from the direct line-of-sight path is to have the first Fresnel zone (see Ref. 1) clear all obstacles in the path of the ray. The radius of the first Fresnel zone at a point P (see Fig. B-3) is given by[1]

$$R_1 = 2280\left(\frac{d_1\, d_2}{f\, d}\right)^{1/2}$$

where d_1 = distance between the transmitter and point P in miles
d_2 = distance between the receiver and point P in miles
f = frequency in MHz
d = distance between transmitter and receiver in miles.

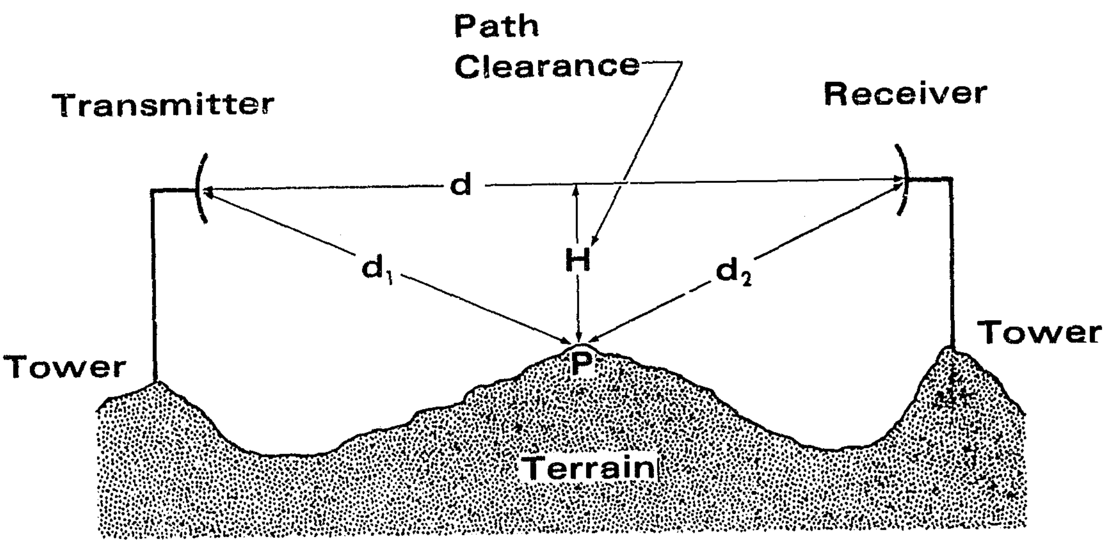


Fig. B-3 Interference Between Direct and Reflected Ray

Referring to Fig. B-3, if the path clearance H is made greater than or equal to the first Fresnel-zone radius, mean free-space propagation conditions may be assumed to apply. Consequently, while designing a microwave route, the location and the heights of the transmitting and receiving antennas should be properly chosen to provide sufficient path clearance.

B.4.3 Transmitter Power Requirements

Once the antenna heights and locations have been selected, the transmitter power requirements can be obtained from the following equations:[2]

The required transmitter power for a single-hop line-of-sight link operating under normal free-space propagation conditions is given by:

$$P_t = \frac{L_1 L_2}{2.5} \frac{Bd^2}{f^2 D^4} F \frac{S}{N}$$

In presence of fading, the above equation should be modified to include a fading margin parameter σ. Under such conditions the transmitter power required for a single-hop link is given by:

$$P_t = \frac{L_1 L_2}{2.5} \frac{Bd^2}{f^2 D^4} F \left(\frac{S}{N}\right)_m \sigma$$

For multi-relay transmission in n hops in presence of fading, the transmitter power at the terminal station and each of the repeater stations can be obtained from the above equation. In such cases, the distance d should be the distance between the transmitter and receiver of the hop for which calculations are made. In practice, the repeater stations are approximately at equal distances from each other and consequently, similar transmitters are used at each station.

The variables in the equations above are defined as follows:

P_t = power, in watts, available at transmitter output terminals
L_1 = loss power ratio (numerical) due to transmission line at transmitter
L_2 = same as L_1 at receiver
B = root-mean-square bandwidth (generally approximated to bandwidth between 3-decibel attenuation points), in megaHertz
d = total length of transmission, in miles
f = carrier frequency, in megaHertz
D = diameter of parabolic reflectors in feet
F = power-ratio noise figure of receiver (a numerical factor)

σ = numerical ratio between available signal power in case of normal propagation to available signal power in case of maximum expected fading

S/N = required signal-to-noise power ratio at receiver

$(S/N)_m$ = minimum required signal-to-noise power ratio in case of maximum expected fading

$(S/N)_{nm}$ = same as above in case of n hops, at repeater number n

$(S/N)_{1m}$ = same as above at first repeater

n = number of equal hops

The parameter σ may be considered as fading margin and its choice is dependent on the required degree of reliability in accordance with Table B-3.

Table B–3
Reception Reliability for Various Fading Margins

σ (numerical radio)	σ (dB)	Reliability (per cent)
10	10	90
100	20	99
1,000	30	99.9
10,000	40	99.99

B.4.4 Summary

In the design of a microwave line-of-sight communication system, the most important problem to be tackled is the route design. The locations and antenna heights at the base and repeater stations should be selected to ensure that the intervening terrain does not obstruct and reflect the direct line-of-sight ray path. Seasonal variations, such as tree foliage, should be taken into account. Once these locations have been selected, the transmitter power requirements can be determined from the equations discussed in Section B.4.3.

B.5 Automatic Protection System

An automatic protection switching system is required to ensure continuity of service in case of transmission equipment failure. In a hot standby station, two receivers and transmitters are used. Both transmitters are operated simultaneously with one disconnected from the antenna. Both receivers are also operated simultaneously with the output of the receivers combined into a single output. Fault sensing equipment senses failures of the equipment and causes automatic switchover of the transmitters if a failure occurs in the operating transmitters, or disconnects the failed receiver if a receiver fails. Switchover requires only a few millionths of a second. The over-all reliability of the system is thereby very substantially improved.

B.6 Conclusion

A brief description of the microwave line-of-sight communication link has been presented. In such systems, a number of channels of baseband voice and/or digital data signals are multiplexed into a single video signal. The video signal then frequency modulates an intermediate frequency (IF) signal which is transmitted at microwave frequencies after proper frequency conversion and power amplifications.

It has been shown that fluctuations in the propagation medium give rise to fading of the received signal. In most cases, sufficient fading margin is provided to ensure reliable communication. Space diversity reception is also used in some cases to improve the reliability.

Route design is a most critical problem in the overall design of the multi-hop microwave links. Proper care should be taken in selecting the locations and antenna heights of the base and repeater stations.

APPENDIX C

INTERFERENCE IN POLICE TELECOMMUNICATION SYSTEMS

C.1 Mechanisms of Interference Effects

C.1.1 General Nonlinear Theory

Where interference to a radio receiver by other radio equipments does not fall into the category of simple co-channel interference, the chances are that at least one of several "nonlinear" mechanisms is at work. This is not always the case, but since it is so often true, this appendix will begin with a discussion of some general nonlinear effects. They will in turn be applied to various cases of interest in the following sections.

This discussion of specific cases will be somewhat receiver oriented. However, many of these effects can appear in both transmitters and the environment, as well as in receivers. The references give more complete discussions of several specific nonlinear effects.[1,2,3]

All electronic circuits are nonlinear. By this is meant that the output quantity is not strictly proportional to the input quantity. Certainly, amplifiers can be built that have a high degree of linearity, but a large enough input will overload any practical amplifier. It is physically impossible for an amplifier to supply an unlimited output, so at some point, the output must cease to be proportional to the input.

It is characteristic of nonlinear circuits that, if one or more pure tone frequencies are applied to the input, the output will contain new frequencies in addition to those applied. This is true not only of amplifiers, but of many other devices. Thus, a rusty tin can lying on a metal roof can act as a short antenna and can form a rectifying contact with the roof. It can pick up radio signals, combine them to yield new frequencies, and radiate these new frequencies. This type of effect is a source of interference in practice.

Nonlinear effects are not always undesirable. The radio receiver is a practical device largely because it uses the superheterodyne technique. Incoming signals are combined with a local oscillator signal in nonlinear mixers to yield (lower) intermediate frequency signals that can be amplified more easily. In transmitters, nonlinear frequency multiplying circuits are used—doublers and triplers—to enable crystal frequency control and to overcome the natural limitations on operating frequency typical of practical crystals. Thus, nonlinearity is not inherently a bad thing.

One aspect of nonlinear behavior that needs to be pointed out is that the number of frequencies generated by a nonlinearity of any kind tends to grow much more rapidly than the number of frequencies applied to it. For example, if f_1 and f_2 are applied, the two frequencies $f_1 + f_2$ and $f_1 - f_2$ (that is, the sum and difference frequencies) are typical low order products that could appear. If f_3 is added, $f_1 \pm f_3$ and $f_2 \pm f_3$ appear, and perhaps $f_1 \pm f_2 \pm f_3$ also. This simple illustration should help the reader to understand why nonlinear interference problems are growing out of proportion to the number of new transmitters in use. The actual mathematical relations between the number of sources and the number of nonlinear products involve factorial numbers, which means that the number of outputs grows very rapidly as inputs are added.

C.1.2 Specific Cases of Interest

C.1.2.1 Intermodulation

The term intermodulation is sometimes used in a very general sense to mean any generation of new frequencies that takes place in a nonlinear circuit. In this broad sense it could include harmonics, or the desired output of a mixer. However, it is used here in another frequently used sense. *Intermodulation is the combination of two signals at closely spaced frequencies to yield a signal at a new frequency which is close to the first two.*

This is best illustrated by the most common example; namely, third order intermodulation. This is the combination of frequencies of the following form:

$$2f_1 - f_2$$

If $f_1 = f_2$, then $2f_1 - f_2 = f_1$. Thus, two undesired signals that are close to a desired frequency can cause a large interference signal at the desired frequency. The frequency relationships are such that receiver selectivity cannot eliminate this type of interference entirely. Thus, two transmitters at 155.43 and 155.46 MHz could combine in a receiver to yield an interference product at the desired frequency of 155.49 MHz. A cavity filter ahead of the receiver would not be effective in keeping out the undesired signals.

Other special odd order difference products such as the fifth order product at $3f_1 - 2f_2$ and the seventh order product at $4f_1 - 3f_2$ have this same type of frequency behavior, namely, that the generated product lies close to the input frequencies.

Intermodulation is a major potential problem in police radio communication systems. The assignment plans used by frequency coordinators usually avoid certain frequency combinations for police radio systems that are located near each other geographically, in order to prevent intermodulation interference.

C.1.2.2 Other Interference Effects

There are some interference effects of concern in the Police Radio Service which are not caused by co-channel stations and which are not of a nonlinear nature. These will be discussed here. The more commonly known effects are those which result in detecting an undesired signal or garbling of the desired signal. Interference which desensitizes a receiver may be equally serious, but it is harder to detect, because no undesired signal is heard (or decoded).

Adjacent Channel Interference comes about when an adjacent channel signal is so strong that it is not rejected by the receiver selectivity. This is not a major problem because typical receivers have large amounts of adjacent channel rejection, and because assignment plans take account of adjacent channel rejection characteristics. There do, however, appear to be cases in which receivers are used on channels which are narrower than the channels for which the receiver was originally designed, leading to some interference problems. This may occur when older receivers, built for wider channels, are used on the narrower, split channels. In the high-band, for instance, channels have been split twice, so that spacing between the "tertiary" channels and adjacent ones is only 15 kHz. At UHF, spacing was 50 kHz but is now 25 kHz. Obviously, it is not reasonable to expect a receiver to operate successfully under conditions for which it was not designed.

Broadband Splatter comes about when a transmitter radiates over a whole frequency band instead of on one channel. Overmodulation is the main cause. It can also happen, for instance, if filter capacitors fail.

Transmitter Noise is the term used to describe the signal spectrum of transmitters which occurs outside of the intended transmission channel. All transmitters radiate energy over a wide frequency range, because of hum, oscillator noise, thermal noise, etc. This energy is generally very far below the carrier level, but is occasionally picked up by a nearby receiver tuned to a different channel.

This dicussion of interference mechanisms is a short listing of the variety of effects that can cause interference in typical land-mobile systems.

C.2 Physical Sources of Interference Effects

The previous discussion described the mechanisms that can give rise to interference. This portion of the appendix will list some of the specific physical nonlinearities that give rise to interference generation in practice.

C.2.1 Receivers

The internal circuitry of a receiver can give rise to intermodulation and related interference effects. The receiver is most susceptible to incoming signals that lie within the passband of the front end tuned circuits (and cavity filter, if any).

C.2.2 Transmitters

The circuits of transmitters are of the amplifier and mixer (or multiplier) variety, and hence they are nonlinear. Some interference signals are, in fact, generated in transmitters. This type of interference usually involves one or more outside signals traveling backward along the output cable, reaching the transmitter, and combining there with each other or with the transmitter signal. The resultant interference signal then travels back on the output cable to the antenna to be radiated, or possibly to a duplexer which feeds a receiver directly. The output amplifier is the nonlinear component in which most transmitter interference is generated, and the output tuned circuit will restrict the range of frequencies which cause interference.

Possible exceptions to this general rule are hard-wired connections to the transmitter capable of conducting inputs into transmitter circuitry. These may include microphone cables, other audio or telephone lines, and power lines. Depending on the manner in which they are filtered, these wired connections can pick up signals at various frequencies and route them to nonlinear transmitter stages, where they can combine with the transmitter signal.

C.2.3 Environmental Nonlinearity

There are many physical objects in the operating environment of transmitters and receivers. Some of these objects can display nonlinear behavior. If the metal objects are in fact rods or wires, radio frequency signals can be picked up efficiently and the nonlinear voltages which are generated in the contact can be re-radiated. The classic case is the slack guy wire, broken by eyes or a turnbuckle. Other demonstrated problem areas have involved coaxial feed lines touching towers, screens on ventilator shafts which are not adequately fastened, roof gutters with corroded joints, and even rusty tin cans lying on metal roofs.

The most severe interference generation can take place in loose or corroded connections in the antennas themselves or in antenna coupling or duplexing networks.

Another type of nonlinearity comes about from the use of steel center pins in coaxial cable connectors, of the hermetic type. Also, steel wires with copper plating are used as the center conductors of some kinds of coaxial cable. These too can generate nonlinear interference, because of the magnetic properties of steel. A small magnet may be used to identify these steel components.

C.3 Identifying Sources of Interference

In most practical situations, identification of the sources of interference is a difficult problem. It has two phases; identifying the transmitter or transmitters which are contributing to the interference, and locating the nonlinearity in which the transmitter signals are combining to form the interfering signal. Each will be discussed separately.

C.3.1 Identifying the Transmitters Involved

To tackle the problem of transmitter identification, one starts with some knowledge about the possible frequency relationships (from general nonlinear theory) and the fact that the interference signal will contain components of all of the modulations on all of the contributing signals. The manner in which an interference comes and goes will yield some information about its sources—especially if a test can be arranged in which possible sources can be turned on and off. (Obviously this is easier to accomplish if the sources are cooperating public-safety services than if they are continuously broadcasting stations.)

The modulations may or may not be recoverable from the receiver being interfered with. However, specialized receivers can be of help in recovering all modulation, when necessary. It is usually possible to obtain some clues about the interference source from its "sound". For one thing, all broadcasters are required to identify themselves periodically. Regular identification by all units is thus an invaluable aid in trouble shooting interference problems.

In the absence of such identification, there are other clues that can be used to determine which of hundreds of possible radio transmitters are contributing to an interference situation. There is the content of the message being transmitted. In addition there are other clues in the modulation. Some transmitters use tone squelch modulations or selective calling signals. There may be some hum or noise which characterizes a given transmitter. The dispatcher or operator may be in the same room with other people, teletypewriters or radio receivers used to monitor other services. These "background noises" can help to identify sources of interference.

Interference which occurs intermittently is almost certainly the result of intermodulation involving two or more transmitters. Bits and pieces of detected intelligence, such as conversation, is a prime identifying symptom. The transmitters are most likely to be of the communications type rather than of the broadcast type, since these latter may cause continuous interference. Ideally, one would like to run tests to verify interference sources but in practice this is often not possible.

C.3.2 Locating the Nonlinearities Involved

When the transmitters have been identified and the significant frequency relations determined, it is still necessary to pin down the physical nonlinearity causing the interference. Only when this latter task has been accomplished is it possible to determine how best to reduce the interference. It has been explained that nonlinearities can appear in transmitters, receivers, or the environment. The first clue as to which is responsible can be obtained by observing whether the interference is being heard equally on all receivers tuned to a channel. If so, the source is probably the transmitter, or an environmental nonlinearity near the transmitter. If not, the source is logically within the receiver which has the interference problem, or in the environment near that receiver.

Once this determination has been made, the problem becomes more difficult. Various equipment adjustments and substitutions will sometimes yield an insight into nonlinearity location. Attenuators can be inserted in transmission lines feeding receivers and transmitters. Attenuator pads, if used carefully, are a valuable tool for the identification of nonlinearity location. This is true because the amplitude of a nonlinear product is generally *not* directly proportional to the amplitudes of the signals which cause it. Nonlinear products can be proportional to the square, the cube, etc. of the various signals which generate them. This knowledge can be used to determine whether a linear attenuating pad is attenuating either the nonlinear product, or the signals which caused it, or even both.

In general, the amplitude of the nonlinear product, in decibels, will be proportional to the integer multipliers of the term in the frequency relationships. In more concrete terms, a fifth order product of the form $3f_1 - 2f_2$ would be proportional to the cube of the f_1 signal and the square of the f_2 signal. The net effect of the 10 dB pad ahead of the nonlinearity would be a 50 dB reduction in this fifth order product. Thus, the attenuating pad can be used as a valuable tool for nonlinear interference identification and location, if the user understands the amplitude relationships and signal paths which are involved.

If an environmental problem is suspected, there are two general approaches to its location. The first is to use a well shielded portable receiver and directional antenna to search out the point of strongest interference. This approach is straightforward but the receiver is expensive. A highly linear receiver of the field effect transistor (FET) type is desirable. As an alternative to the use of a portable receiver, it may be possible to use the system receiver with a length of flexible coax and a portable antenna to "sniff out" nonlinearities.

The second approach is to listen to the interference on existing receivers while an assistant mechanically disturbs various possible interference sources, typically by using a rubber mallet to strike various guys, screens, and other metal objects. One begins with items closest to the antennas of interest and works progressively farther away. Also, significant nonlinearities may be hidden behind nonmetal walls or below roofs on decking that are transparent to radio signals. These can often be located by pounding or hammering on the walls in question.

C.4 Remedies for Interference Situations

There are several remedies that have found widespread acceptance in interference situations. These include the rather common use of cavity filters ahead of receivers in congested environments, and the increasing use of ferrite isolation devices (along with cavities) at transmitter outputs when several transmitters must be located together. These cavities, incidentally, are made of a low temperature coefficient, ferrous alloy (Invar) that is potentially nonlinear at high current densities!

The trend toward locating a number of transmitters together is unfortunate from an interference point of view. It is usually motivated by a desire to operate from the tallest building in an area. However, this is not always necessary. Interference problems can often be avoided by separating transmitters. In other situations, the best remedy might be to move transmitters which are located in close proximity.

Out-of-band pickup of conventional monopoles can be avoided by using folded monopoles ("trombone" antennas) or shunt fed antennas. These antennas have a DC path from active element to ground that eliminates low frequency pickup. Array antennas have several elements that are sometimes enclosed in a weather-tight package so that it is not possible to determine the configuration by visual examination. An ohmmeter can be used to determine whether or not a DC path is present in such an antenna. If it is not, one can be inserted in the system by using a filter with a DC path to ground or a loop-fed cavity—preferably close to the antenna. It may be advisable to update the antenna itself where low frequency pickup is suspected. It has now been generally recognized that a DC path will also reduce induced pickup from nearby lightning strokes, so that most new antenna designs are of the type that incorporate such a path.

When an environmental nonlinearity has been positively identified, the remedy consists of removing it, or (if that is not practical) shunting it with a good low impedance conducting path. A short, wide, flexible strap is ideal. It has become common practice to weld joints in and around antenna towers and systems to prevent nonlinearities from developing. Similarly, feedlines should be insulated completely through the use of jacketed cables and nylon ties.

Where one of the unwanted signals is entering a system through a power or telephone line, a suitable filter must be obtained and installed to eliminate it. In some instances, replacing tubes in transmitters has reduced nonlinear interference. In other cases, returning or switching to a spare transmitter has had a noticeable effect. In cases like this, there are two possible attitudes. One is to do something to reduce the interference, and stop at that point. The second is to determine the exact cause of interference and follow up by letting appropriate people know about the problem, i.e., service personnel, manufacturers, etc. Obviously the latter approach is preferable as interference proliferates. In fact, specialized study programs may prove effective in identifying common interference causes and focusing attention on them.

The user and system planner must be aware of the potential interference problems in his sytem. This includes the forms of interference discussed here, in addition to co-channel interference examined in Sections V.2.3.1 and V.2.3.2 of Chapter V. Consideration of this potential at the planning stage can reduce these problems by incorporating sound engineering practices in specifications for new equipment and overall system design. Many interference problems can be prevented more effectively before they occur than they can be remedied afterward.

APPENDIX D

FACSIMILE SYSTEMS

Facsimile is a form of communication that reproduces graphic copy at a remote point by electronic means. A facsimile system systematically converts a picture on other fixed graphic copy into electrical signals which are transmitted by wire or radio to a receiving point where they are converted back into a replica of the original. Although the time it takes to transmit a complete copy can vary from as little as 7.5 seconds to as long as ten minutes, this system of sending graphic material is superior to other time consuming methods such as mail or courier. This savings of time along with new technical developments that have provided reliable, low cost equipment, have aided in the rapid growth of this means of communication. Table D-1 is an outline of current capabilities of facsimile equipment.

D.1 Copy Parameters

To make optimum use of the facsimile system, the equipment capabilities should be matched to the copy parameters of the majority of material to be transmitted. If the equipment capabilities exceed that required for faithful reproduction of the copy, the equipment and transmission link costs will be excessive.

D.1.1 Copy Size

Commercial equipment is available which spans the range of copy sizes indicated in Fig. D-1 plus 16 mm microfilm, 35 mm aperture cards, and 105 mm or 8" x 10" positives. Some transmitters allow folding the copy. Copy wider than the specified width can be transmitted in a number of passes.

D.1.2 Copy Resolution

The resolution, or density, of the transmitted copy is usually specified in lines per inch. This indicates the number of scans of the copy made by the facsimile scanner per inch of copy travel. The greater the density in lines per inch the finer will be the detail of the transmitted copy. Densities ranging over 48, 75, 80, 90, 96, 100, 120, 135, 166, 192, 1,000, and 1,460 lines per inch are currently available in commercial equipment. The majority of commercially available scanners for transmitting typewritten material and graphic material use 90 to 100 lines per inch resolution. Equipment manufactured specifically for transmitting fingerprints uses 200 lines per inch resolution. It must be noted that increasing the facsimile density not only increases the complexity and cost of the equipment, but either the band-

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Table D–1
Capabilities of Facsimile

CAPABILITY	REMARKS
Permanent Copy Record	The durability of the copy is, in general, quite good for office use, however, carbon copy facsimilies are susceptible to smudging and some light sensitive papers lose contrast after prolonged exposure to light.
Minimum Clerical Handling	No encoding is required as in the case of a teleprinter application where written data must be typed.
Transmission of any Message Format	Typed material, handwritten, maps, or photographs may be transmitted.
Fast Transmission	The transmission time ranges from 7.5 seconds to ten minutes per page depending upon copy parameters.
Base Station and/or Mobile Operation	Equipment is available which is compatible with police car power and radio systems. Size and weight are of the order of one cubic foot and 50 pounds.
Automatic Remote Access to Microfilm Data	Equipment is available to access stored data remotely via telephone links.
Automatic Graphic Generation	The weather bureau presently employs a system which generates weather maps from information gathered from several sources.

width of the transmission link or transmission time required is also increased. For example, the bandwith or transmission time increases by a factor of four when the density is doubled.

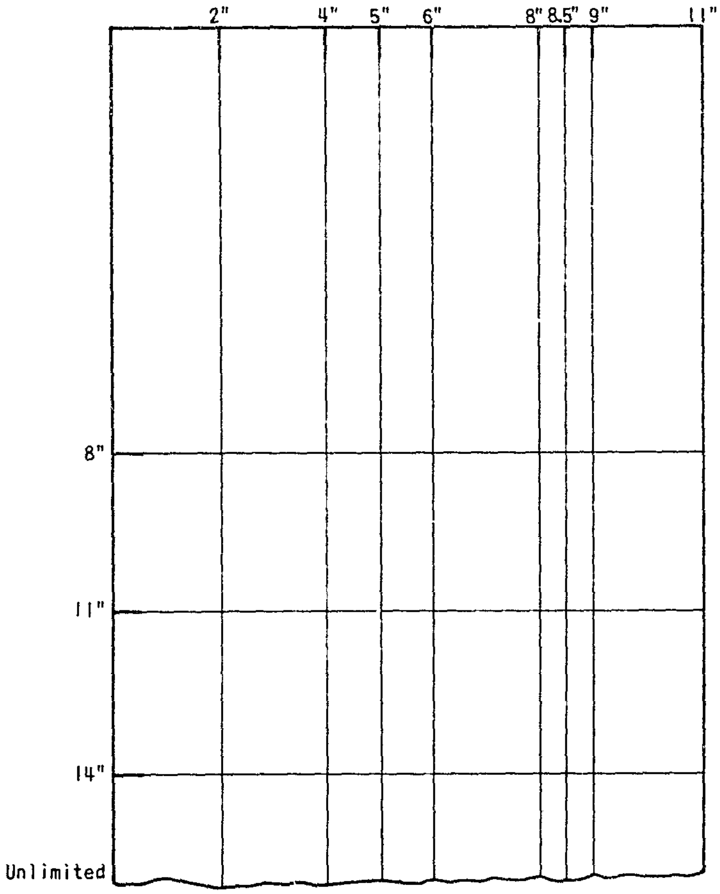


Fig. D-1 Facsimile Copy Sizes

D.1.3 Grey Scale

The grey scale indicates the number of tones or shades of grey from black to white which are to be distinguished in the received copy. The number of grey scale transmitted is limited by the transmission link and the receiver. In general, if the number of grey scale exceeds 10, a photographic recording is used for obtaining sharpness and the best fidelity of the picture grey scale. The most severe limitations on the grey scale is imposed by the transmission link, since a high signal-to-noise ratio is required for a large grey scale. For this reason the majority of commercially available equipment operating over standard telephone lines is high contrast or black and white recording. However, commercial equipment is currently available with grey scales of 4, 8, 10, 14, 16, and 32.

D.2 Facsimile Equipment Characteristics

A large variety of optical scanning, modulation and recording techniques are used in commercial facsimile systems. The major differences in the equipment are discussed here relative to their influence on system design and performance.

D.2.1 Scanning Systems

Most common scanning systems use a very small incandescent lamp which is focused in a small spot on the surface of the copy. This spot, which covers a distinct area, is often referred to as an element. The spot is uniformly scanned across the copy at a constant scan rate as the copy is being advanced, or transported across the scanning system. A phototube, mounted close to the copy, picks up light reflected from the copy and converts it into electrical signals proportional to the brightness. These signals may be either DC voltages or amplitude modulated signals. Many different scanning systems are available, however, copy quality stability, ease of maintenance, and reliability provide the best evaluation of the scanning technique used. There are two basic types of copy transport mechanisms.

- *Drum scanner:* requires clamping the copy to a cylinder which rotates as the copy is scanned. This type limits the copy dimensions to that of the drum area or smaller.
- *Flat bed scanner:* allows a continuous feed copy with any width up to the specified width, if the receiver will permit this type of operation. Depending upon the transport design, the copy may be folded for transmission of wide copy using several passes through the scanner.

D.2.2 Signal Characteristics

Depending on the copy to be transmitted and the transmission link used, two types of electrical output signals are available. First, if the output signal is a voltage proportional to the copy reflectivity (or transmission in the case of film), it is called the video or baseband output. This type of output is desirable for the following systems:

- *With equipment* which performs the desired modulation; e.g., radio transmitters in police vehicles and the Bell System Data Phone
- *For very short dedicated phone lines* where the line bandwidths and linear phase characteristics must extend to DC

Secondly, amplitude modulation is used for transmission on telephone lines, since the lines have the same characteristics as the transmitting and receiving equipment.

A double sideband amplitude modulated (AM) output doubles the bandwidth required for the signal but removes the requirement for transmitting DC. For example, a signal whose resolution is 100 lines per inch, with a line width of 8.5 inches, and a scan rate of 80 lines per minute can be transmitted on normal telephone lines with amplitude modulation. Single-sideband or vestigal-sideband amplitude modulation, requiring a bandwidth approximately equal to that of the video signal, can be used. With this improvement in bandwidth, speed of transmission or resolution can also be improved. For example, a scan rate of 360 lines per minute could be employed in the above system. However, this modulation is as susceptible to noise as double sideband AM and in general requires a telephone line with better characteristics.

In addition to amplitude modulation, various frequency and phase modulation systems are available which are more immune to noise. These are used to transmit high contrast copy over the telephone lines, since a large grey scale requires either a very long transmission time or a wide bandwidth transmission link.

D.2.3 Phasing

Phasing refers to a control signal generally sent to the receiver prior to copy transmission. This signal is needed to position, or phase, the two drums together, thereby centering the recorded image on the film. Thus, the write mechanism is always in phase with the read mechanism of the transmitter. In some high speed, high resolution facsimile systems a continuous phasing signal is sent during the copy transmission. However, in most commercial facsimile systems the phasing signal is sent for a period of 10 to 20 seconds prior to copy transmission. The phasing mechanism may be mechanical or electrical in the receiver. The electrical phasing systems are, in general, more reliable and may be preferred to the older mechanical types.

D.2.4 Synchronization

A synchronizing signal is needed at each end to keep the speed of the two drums almost exactly the same. As the transmitted copy and the received copy are being scanned, skewing of the received copy will occur if the speed of the two drums is not in step. Three types of synchronization are employed in present day facsimile systems.

- *Continuous during transmission:* A synchronizing pulse, positioned at the beginning of each scan line, is used to control drum speed. This system is not normally employed over normal ordinary telephone lines.
- *Power line:* In the eastern portion of the United States, where a large inter-connected power system is used, this system will operate with the 60 Hz power signal. If, however, the transmitter and receiver are in separate power systems the frequency drift between the systems may cause a skew in the recorded copy.
- *Frequency standard:* A fork or crystal oscillator is employed in both the transmitter and receiver. The stability of these oscillators is sufficient to prevent a detectable skew over the duration of the copy transmission.

D.2.5 Record Medium

Conversion of the received electrical signal in the recorder to a facsimile of the transmitted copy is accomplished b the methods listed in Table D-2. The facsimile quality for a given printing technique may vary considerably due to the paper and mechanical differences between equipments.

D.2.6 Pressure Sensitive Printouts

The pressure sensitive system consists of a drum with a wire wrapped in a single helical turn around it, along with a blade placed parallel to the axis of the drum with recording paper passing between them. The recording is made with pressure sensitive techniques usually employing carbon paper for the copy. This system has the advantage of low cost paper although the copy is susceptible to smudging.

D.2.7 Electrosensitive and Electrolytic Printout

The electrosensitive and electrolytic printout system uses a helical drum and blade similar to that used in the pressure sensitive system. This system, though, employs a moist paper which utilizes a chemical change due to current passing through the paper. Current passing between the blade and the helical wire prints the image on the paper. This system is capable of providing a high quality, durable record and is more reliable than the carbon paper system. However, the electrolytic paper is more expensive than carbon and the writing blades require periodic replacement.

Table D–2
Facsimile Printout Methods

Printout	Print Densities Lines Per Inch	Observations
Pressure Sensitive	up to 100	High contrast with limited grey scale
Electrosensitive) Electrolytic)	up to 200	Grey scale up to 10— Requires moist paper
Electrostatic	up to 200	Limited Grey scale— Humidity may be a problem
Photo-Sensitive	up to 1400	Largest Grey scale (32) Highest transmission speed

D.2.8 Electrostatic Printout

In the electrostatic system an electrostatic charge pattern resembling the transmitted copy is placed on the paper or a transfer medium. Charged carbon particles are then attracted to the paper or transfer medium and subsequently fused into the paper providing a permanent record. High quality copy is provided with low paper costs. Also, unless an optical screen is employed in the transmitter, large black areas will tend to wash out in the received copy.

D.2.9 Photo Sensitive Printout

The photo sensitive technique uses a modulated light source in the receiver. The received signal controls the brightness of the light which is focused in a small spot (approximately identical to the size in the transmitter) on photo sensitive film. This sytem alleviates many of the electromechanical wear and adjustment problems encountered with other systems. The paper costs are high and the paper exposure method and wet development of the copy may be undesirable. To end this problem, an alternative photosensitive paper is used in some systems which is developed thermally or with ultraviolet light. The copy quality, however, is much poorer than the normal wet developed photographic paper.

D.3 Transmission Link

Phase and frequency nonlinearities, narrow bandwidth and low signal to noise ratio of the transmission link can effect the transmission time and copy quality of facsimile. While facsimile equipment is available for use with voice radio communication systems, two factors must be considered before using facsimile on this transmission link.

- *The transmitting* and receiving equipment should have linear phase characteristics over the 3 kHz passband. Even though this characteristic is not important in voice communications it can be a problem with facsimile since it causes envelope delay distortion.
- *If a video* or baseband output from the facsimile is used, the modulation and demodulation equipment in the radio transmitter and receiver must have a bandwidth which extends from DC to 3 kHz. If however, the facsimile has a normal amplitude modulated output, which usually extends from 300 Hz to 3 kHz for telephone applications, it can be used directly with voice communications equipment.

The signal-to-noise ratio (voice quality) of the channel should be satisfactory for high contrast facsimile if problems are not encountered with voice communications. Legible copy will usually be received even when voice communications are marginal. Most people appear to be better oriented visually than aurally due to factors such as accents, choice of words, etc. Facsimile, by its nature, is more immune to noise.

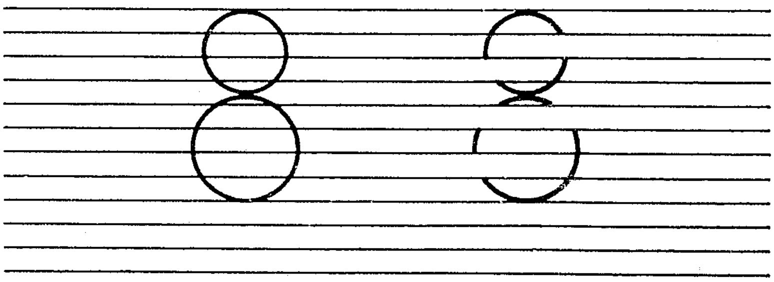


Fig. D-2 Facsimile Transmission with Errors

Figure D-2 considers numerals 0.080 inches (typing normally runs 0.100 inches) high with 100 lines per inch facsimile density. The numeral on the right contains five missing resolution elements due to noise pulses and is still clearly legible. A corresponding transmission to a digital type printer would probably have generated a message with errors.

A variety of transmission lines are available from telephone companies and other sources. Standard bandwidths available are 3, 4, 10, 16, 24, 48, 96 and 240 kHz. The radio link transmission requirements apply here, observing that phase distortion is often a more serious problem. The most popular leased line is the standard 3 kHz bandwidth line which can be classed into three categories shown in Fig. D-3.[1]

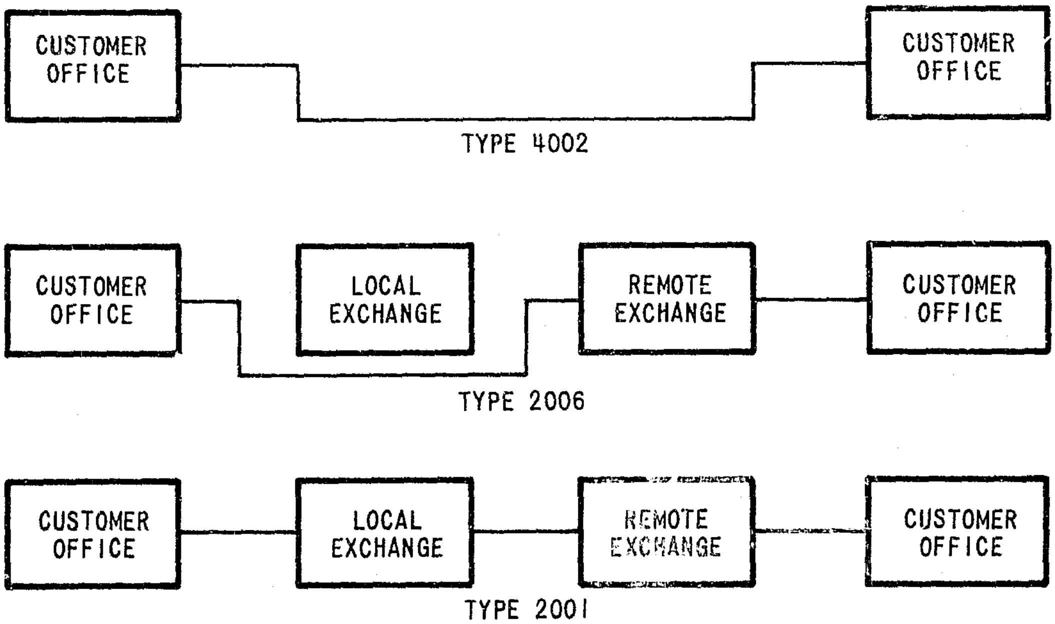


Fig. D-3 Leased Telephone Lines

Line type 4002 is a leased line conditioned to provide bandwidth and phase characteristics required by facsimile. The line extends between the transmitter and receiver directly. This is the most expensive 3 kHz line but it is capable of higher speeds. The type 2006 line is a leased line to the exchange of the facsimile receiver. Here a given long distance trunk line is leased and, as such, its characteristics can be specified. The line is switched through the remote exchange allowing access to any facsimile receiver which may tie to lines in that exchange but the attenuation and phase characteristics of the line are degraded by the switches.

The type 2001 line allows for complete flexibility since any two telephone terminals in the system can be used. This line is also the least expensive. The transmission characteristics, though, may vary considerably since different long distance trunks will be used. The line characteristics must be assumed to be equal to or better than the worst line in the telephone system between the two points.

D.4 Terminal Equipment

If 4002 line is used, telephone terminal equipment is not required since the line is available for continuous use. However, an amplitude modulated facsimile output is required since the bandwidth of telephone lines does not extend to DC. The 2006 and 2001 type lines can be used with three types of terminal equipment:

- *Data Access Telephone* allows normal dial up of the remote station. Switches at both ends of the telephone line must be switched from the talk to the data position. Then, a modulated facsimile signal (300 H to 3 kHz) can be fed directly into the telephone line.
- *Dataphone Terminal* operation is the same as the above. In this system the facsimile output signal must be a two level DC signal allowing only the transmission of high contrast copy (unless some binary coding is employed in the facsimile equipment). The terminal equipment transfers this signal into an FM signal which provides the ability to differentiate against telephone line noise.
- *Acoustic Couplers* use the normal telephone, but the facsimile signal is acoustically coupled into the head set. If an amplitude modulated facsimile signal is acoustically coupled, the phase distortion of the transmission link is increased. A frequency modulated signal can be used to eliminate this problem.

D.5 Police Applications

The primary police use of facsimile equipment has been the transmission of fingerprints. The obvious extension of this is the automatic access of police records which includes typed material, photographs and fingerprints. Equipment is commercially available to perform this function. Another application of facsimile is the base-to-mobile transmission of "wanted" photographs or search and arrest warrants, since mobile facsimile units are also commercially available. The alternate means of communication of fingerprints and photographs involves the mails or use of a courier. If speed is required, the virtually instant arrival of facsimile copies is an obvious advantage of that means of transmitting graphic materials.

APPENDIX E

AUTOMATIC VEHICLE MONITORING SYSTEMS

There are several types of automatic vehicle monitoring methods under development. All have the following characteristics in common:

- A maximum vehicle capacity
- A certain amount of error
- A limit to how frequently a given number of vehicles can be located
- A display board for the dispatcher
- A small central computer
- A certain amount of radio spectrum space
- Fairly high cost

While there are a large number of possible monitoring methods, only six appear to be feasible for police agencies where the routes taken by vehicles are not fixed, but random.[1] These six methods are more complex and costly than those for fixed-routes. Four of these methods make use of geometrical relationships to locate a vehicle.

The *triangulation* method uses the intersection of two lines at angles measured from a third line which connects two reference points as the means of location. In such a method,

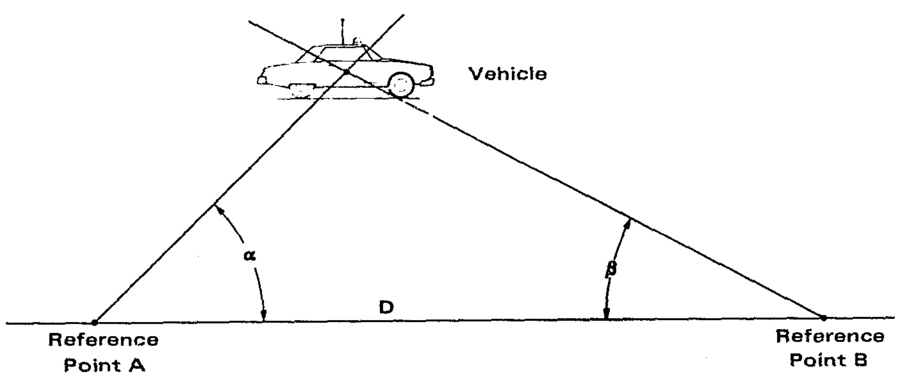


Fig. E-1 Triangulation Method

the vehicle usually emits a signal which is received by highly directional antennas at points A and B. Knowing the angles of the antennas and the fixed distance D between points A and B, the location of the vehicle can be determined. The drawback of this approach is that large antennas are required for accurate determination of the angles shown in Fig. E-1.

The *polar* method makes use of the "range and bearing" technique of location. If the location angle or bearing α and the range R relative to a reference point are found, as shown in Fig. E-2, the position is known directly. This method usually employs a radar-type system

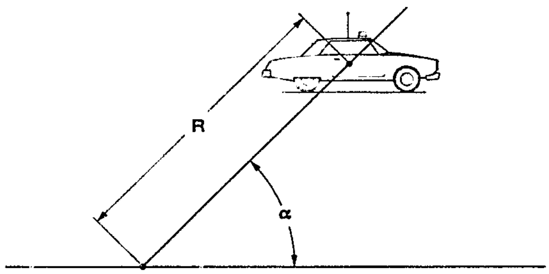


Fig. E-2 Polar Method

at the reference point for range and bearing determination. This approach also suffers from inaccuracy in determination of the angle, especially in densely populated urban areas with many buildings.

The *circular* method uses the intersection of two range measurements (by radar-type equipment) from two reference points as the means of locating the vehicle. In this system

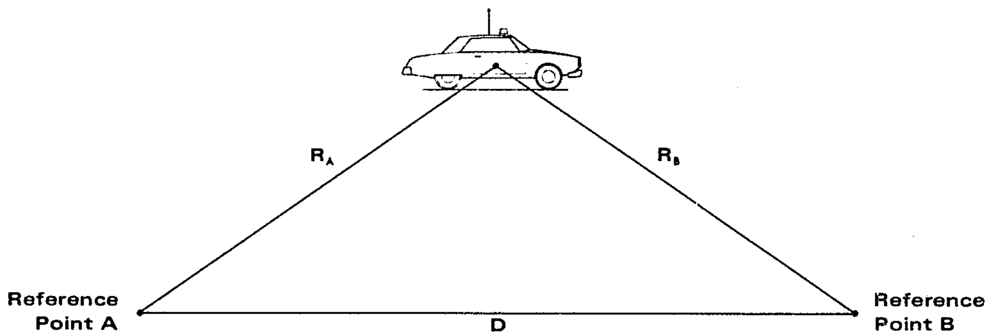


Fig. E-3 Circular Method

no angles are measured, which is a definite advantage. (See Fig. E-3.) The system does have one disadvantage, however, in that two locations for the vehicle are possible for any R_A and R_B. If the reference points A and B are on the edge of the patrol area then no problem exists, since the second possible location will lie outside of the area. (See Fig. E-4.) If the two reference points cannot be placed at the edge of the patrol area, a third reference point C can be added to eliminate the problem, as shown in Fig. E-5.

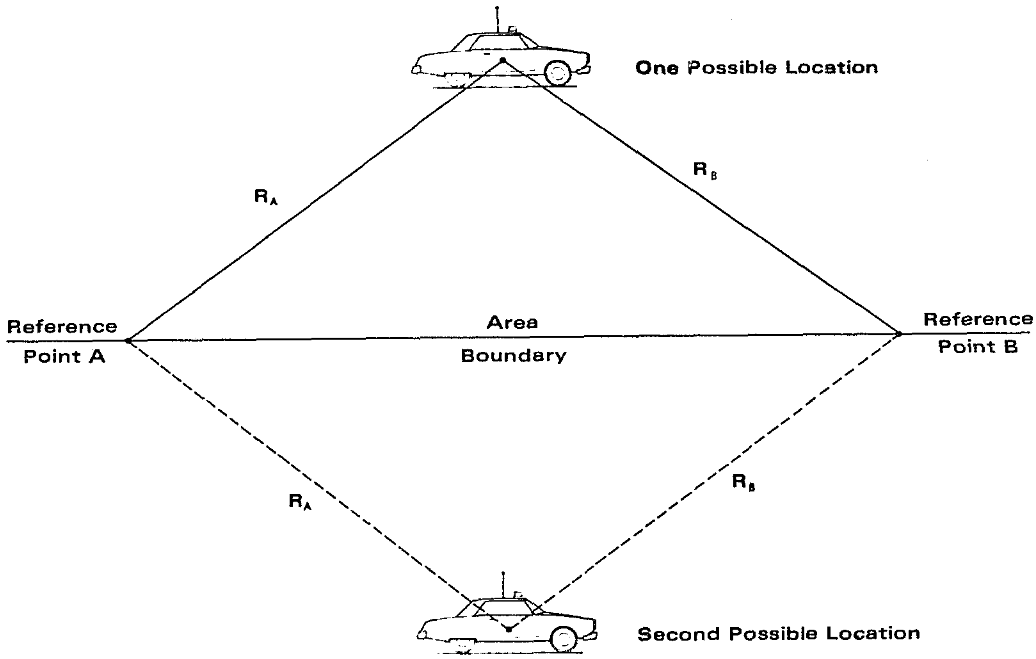


Fig. E-4 Two Possible Locations with Two Reference Points

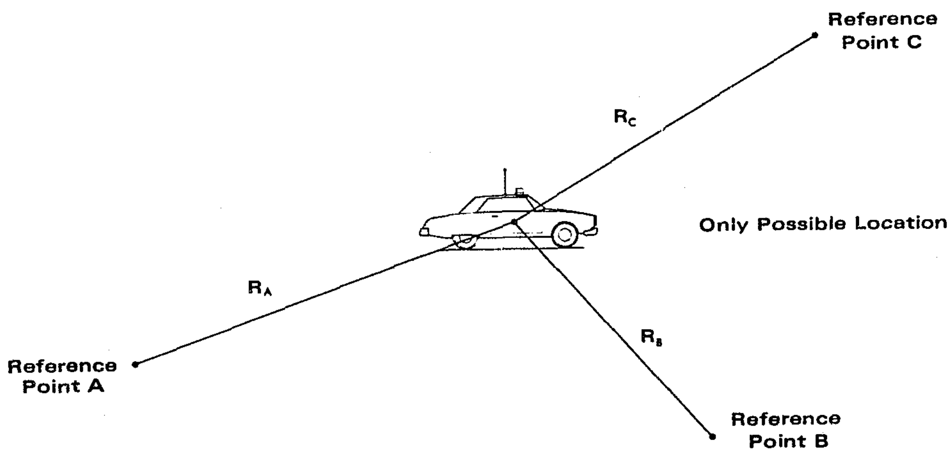


Fig. E-5 One Possible Location with Three Reference Points

The *hyperbolic* method uses the geometric notion of a hyperbola. A hyperbola is a curve for which the difference of the distances from each point on the curve to two fixed reference points is a constant. The form of this curve is shown in Fig. E-6. To locate a

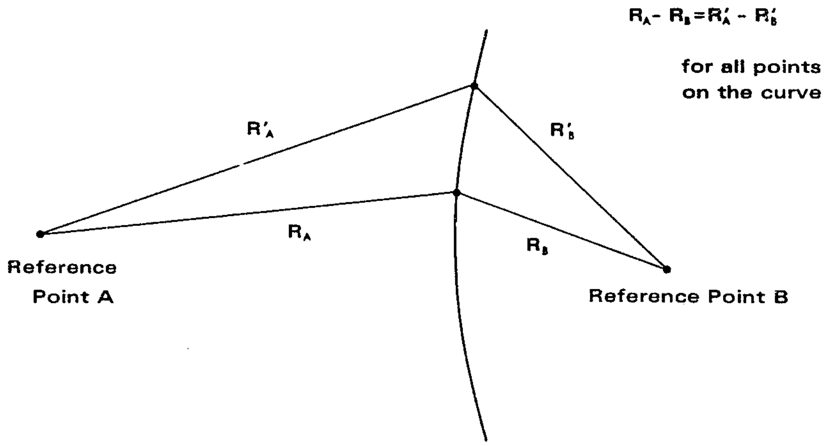


Fig. E-6 Definition of a Hyperbola

vehicle, three reference points are used, as shown in Fig. E-7. When the range difference

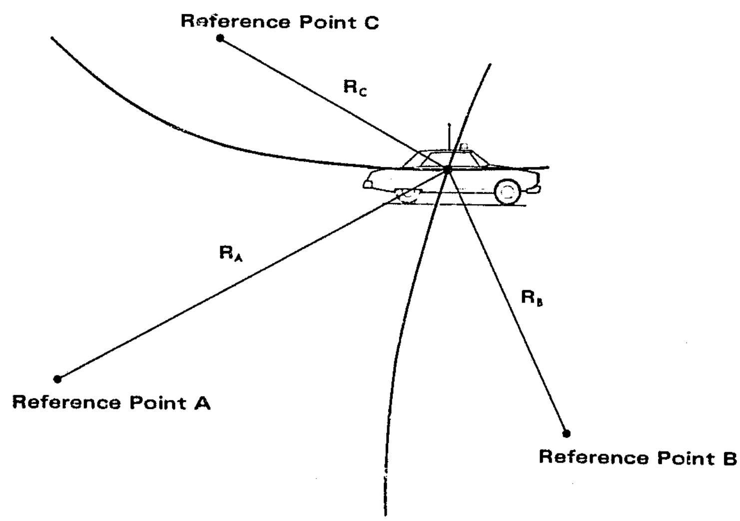


Fig. E-7 Hyperbolic Method

$R_A - R_B$ is known for points A and B and the difference $R_A - R_C$ is known for points A and C, two intersecting hyperbolas can be drawn using standard mathematical techniques. The point of intersection of the two hyperbolas thus drawn gives the location of the vehicle. This method has the advantage that no angles have to be determined; only the two range differences are required.

Two feasible methods remaining are the *check-in* or *signpost* and the *inertial navigation* methods. In the *check-in* system a grid of receivers within the beat area is established. The vehicles are equipped with transmitters which emit coded signals. These signals are monitored by the nearby receivers and relayed to a central point where the identity of the vehicle and its location are decoded and displayed. The signals can be sent to the dispatch point via telephone lines or radio links. If telephone lines are used, no radio spectrum space is needed, of course. The accuracy of this method is dependent on the number and positions of receivers used. A variation of this method is the *signpost* system. A grid of transmitters emit location codes that are received and stored by the vehicle as it passes by. When an interrogation command is received from the station, the location code and the vehicle identification code are relayed to the station. The accuracy of this system is dependent to a large extent on how far the vehicle travels from the signpost before it is interrogated.

The final method, that of *inertial navigation,* uses equipment completely contained by the vehicle to determine location. The distance and direction of travel are monitored by this equipment so that the position of the vehicle is known at any time. This information is then transmitted to a central point upon receipt of a command.

While systems using these various methods are still under development, it appears that location of a maximum of 2000 to 10,000 vehicles to an accuracy of $\pm$ 350 feet over a large area is feasible. For greater accuracy, additional reference points could be used or several successive measurements taken and averaged to reduce the error.

APPENDIX F

FCC RULES AND REGULATIONS, VOLUME V, PART 89

The Federal Communications Commission (FCC) has established a set of standards and requirements which must be met by all radio stations seeking to obtain a new license, or maintain or modify an existing one. These standards are documented in the ten volumes of the FCC Rules and Regulations, obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. A short index to these ten volumes is given in Table F-1.

In order to provide a convenient reference, several sections of the document which most directly concern police radio operation are reproduced in this appendix. Presented here are Sections 89.1 through 89.309 from Volume V, Part 89, Public Safety Radio Services. Topics considered include the filing of applications, standard forms, frequencies, operating procedure, and station limitations. In addition to the Police Radio Service regulations, those governing the Local Government Radio Service are also included, since police users may obtain assignments on Local Government frequencies. The appropriate sections of Part 89 of the Rules and Regulations, including a table of contents, are presented in the remainder of this appendix. For additional information from the FCC, write to Federal Communications Commission, Safety and Special Services Division, 1919 M Street, N.W., Washington, D.C. 20554.

439-911 O - 71 - 23

Table F-1
FCC RULES AND REGULATIONS

Notice

The FCC Rules and Regulations are grouped into ten volumes and sold in volume units by the Superintendent of Documents, Government Printing Office. The price of the volume entitles the purchaser to receive its amended pages for an indefinite period.

The ten volumes are comprised of individual Parts, as follows:

VOLUME I
- Part 0, Commission Organization
- Part 1, Practice and Procedure
- Part 13, Commercial Radio Operators
- Part 17, Construction, Marking, and Lighting of Antenna Structures
- Part 19, Employee Responsibilities and Conduct

VOLUME II
- Part 2, Frequency Allocations and Radio Treaty Matters; General Rules and Regulations
- Part 5, Experimental Radio Services (Other Than Broadcast)
- Part 15, Radio Frequency Devices
- Part 18, Industrial, Scientific, and Medical Equipment

VOLUME III
- Part 73, Radio Broadcast Services
- Part 74, Experimental, Auxiliary, and Special Broadcast and Other Program Distributional Services

VOLUME IV
- Part 81, Stations on Land in the Maritime Services
- Part 83, Stati ..s on Shipboard in the Maritime S. rvices
- Part 85, Publi Fixed Stations and Stations of the I aritime Services in Alaska

VOLUME V
- Part 87, Aviation Services
- Part 89, Public Safety Radio Services
- Part 91, Industrial Radio Services
- Part 93, Land Transportation Radio Services

VOLUME VI
- Part 95, Citizens Radio Service
- Part 97, Amateur Radio Service
- Part 99, Disaster Communications Service

VOLUME VII
- Part 21, Domestic Public Radio Services (Other Than Maritime Mobile)
- Part 23, International Fixed Public Radiocommunication Services
- Part 25, Satellite Communications

VOLUME VIII
- Part 31, Uniform System of Accounts for Class A and Class B Telephone Companies
- Part 33, Uniform System of Accounts for Class C Telephone Companies

VOLUME IX
- art 34, Uniform System of Accounts for Radiotelegraph Carriers
- Part 35, Uniform System of Accounts for Wire-Telegraph and Ocean-Cable Carriers

VOLUME X
- Part 41, Telegraph and Telephone Franks
- Part 42, Preservation of Records of Communicat on Common Carriers
- Part 43, Reports of Communication Common Carriers and Certain Affiliates
- Part 51, Occupational Classification and Compensation of Employees of Telephone Companies
- Part 52, Classification of Wire-Telegraph Employees
- Part 61, Tariffs
- Part 62, Application to Hold Interlocking Directorates
- Part 63, Extension of Lines and Discontinuance of Service by Carriers
- Part 64, Miscellaneous Rules Relating to Common Carriers
- Part 66, Applications Relating to Consolidation, Acquisition, or Control of Telephone Companies
- Part 67, Jurisdictional Separations

(Ed. 1/70) 2

Contents—Part 89

SUBPART A—GENERAL INFORMATION

§ 89.1 Basis and purpose.

(a) The basis for this part is the Communications Act of 1934, as amended, and applicable treaties and agreements to which the United States is a party. This part is issued pursuant to authority contained in Title III of the Communications Act of 1934, as amended, which vests authority in the Federal Communications Commission to regulate radio transmissions and to issue licenses for radio stations.

(b) This part is designed to provide a service of radio communication essential either to the discharge of non-Federal governmental functions or to the alleviation of an emergency endangering life or property.

§ 89.3 Definitions.

For the purpose of this part the following definitions shall be applicable. (For other definitions, refer to Part 2 of this chapter):

(a) Definitions of services:

Fire Radio Service. A public safety service of radio communication essential to official fire activities.

Fixed service. A service of radio communication between specified fixed points.

Forestry-Conservation Radio Service. A public safety service of radio communication essential to forestry-conservation activities.

Highway Maintenance Radio Service. A public safety service of radio communication essential to official highway activities.

Land mobile service. A mobile service between base stations and land mobile stations, or between land mobile stations.

Local Government Radio Service. A service of radio communication essential to official activities of states, possessions, and territories, including counties, towns, cities, and similar governmental subdivisions.

Mobile service. A service of radio communication between mobile and land stations, or between mobile stations.

Police Radio Service. A public safety service of radio communication essential to official police activities.

Public safety radio services. Any service of radiocommunication essential either to the discharge of non-Federal government functions or the alleviation of an emergency endangering life or property, the radio transmitting facilities of which are defined as fixed, land, mobile, or radiolocation stations.

Radiolocation. Radiodetermination used for purposes other than those of radionavigation. (For the purposes of this part, radiolocation will include speed measuring devices.)

Radio service. An administrative subdivision of the field of radio communication. In an engineering sense the subdivisions may be made according to the method of operation; as for example, mobile service and fixed service. In a regulatory sense, the subdivisions may be descriptive of particular groups of licensees; as for example, the groups and subgroups of persons licensed under this part.

Safety Service. A radiocommunication service used permanently or temporarily for the safeguarding of human life and property.

Special Emergency Radio Service. A public safety service of radio communication essential to the alleviation of an emergency endangering life or property.

State Guard Radio Service. A public safety service of radio communication essential to official activities of state guards or comparable organizations of states, territories, possessions, or the District of Columbia.

(b) Definitions of stations:

Base station. A land station in the land mobile service carrying on a service with land mobile stations.

Control station. An operational fixed station, the transmissions of which are used to control, automatically, the emissions or operation of another radio station at a specified location.

Fixed station. A station in the fixed service.

Fixed relay station. An operational fixed station established for the automatic retransmission of radio communications received from either one or more fixed stations or from a combination of fixed and mobile stations and directed to a specified location.

Interzone station. A fixed station in the Police Radio Service using radiotelegraphy (A1 emission) for communication with zone stations within the zone and with interzone stations in other zones.

Land station. A station in the mobile service not intended to be used while in motion.

Mobile station. A station in the mobile service intended to be used while in motion or during halts at unspecified points.

Mobile relay station. A base station established for the automatic retransmission of mobile service communications which originate on the transmitting frequency of the mobile stations and which are retransmitted on the receiving frequency of the mobile stations.

Operational fixed station. A fixed station, not open to public correspondence, operated by and for the sole use of those agencies operating their own radio communication facilities in the Public Safety, Industrial, Land Transportation, Marine, or Aviation Services.

Radiolocation mobile station. A station in the radiolocation service intended to be used while in motion or during halts at unspecified points.

Repeater station. An operational fixed station established for the automatic retransmission of radio communications received from any station in the Mobile Service.

Zone station. A fixed station in the Police Radio Service using radiotelegraphy (A1 emission) for communication with other similar stations in the same zone and with an interzone station.

(c) Miscellaneous definitions:

Antenna structures. The term "antenna structure" includes the radiating system, its supporting structures, and any surmounting appurtenances.

Assigned frequency. The frequency appearing on a station authorization from which the carrier frequency may deviate by an amount not to exceed that permitted by the frequency tolerance.

Authorized bandwidth. The maximum width of the band of frequencies, as specified in the authorizations, to be occupied by an emission.

Bandwidth occupied by an emission. The width of the frequency band (normally specified in kilohertz) containing those frequencies upon which a total of 99 percent of the radiated power appears, extended to include any discrete frequency upon which the power is at least 0.25 percent of the total radiated power.

Carrier frequency. The frequency of the carrier.

Harmful interference. Any emission, radiation or induction which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with this chapter.

Landing area. A landing area means any locality, either land or water, including airports and intermediate landing fields, which is used, or intended to be used, for the landing and take-off of aircraft whether or not facilities are provided for shelter, servicing, or repair of aircraft, or for receiving or discharging passengers or cargo.

Station authorization. Any construction permit, license, or special temporary authorization issued by the Commission.

§ 89.5 Organization and applicability of rules.

The rules in this part are divided into 9 subparts of which Subparts A and C contain rules of a general nature which apply to every station authorized under this part. Subparts E to R, inclusive, are specific and apply only to the stations authorized under the particular subpart.

§ 89.7 General limitation on use.

The radio facilities authorized under this part shall not be used to carry program material of any kind for use in connection with radio broadcasting and shall not be used to render a communications common carrier service except for stations in the Special Emergency Radio Service while being used to bridge gaps in common carrier wire facilities.

§ 89.9 General citizenship restrictions.

A station license shall not be granted to or held by:

(a) Any alien or the representative of any alien;

(b) Any foreign government or the representative thereof;

(c) Any corporation organized under the laws of any foreign government;

(d) Any corporation of which any officer or director is an alien;

(e) Any corporation of which more than one-fifth of the capital stock is owned of record or voted by: Aliens or their representatives; a foreign government or representative thereof; or any corporation organized under the laws of a foreign country;

(f) Any corporation directly or indirectly controlled by any other corporation of which any officer or more than one-fourth of the directors are aliens, if the Commission finds that the public interest will be served by the refusal or revocation of such license; or

(g) Any corporation directly or indirectly controlled by any other corporation of which more than one-fourth of the capital stock is owned of record or voted by: Aliens or their representatives; a foreign government or representative thereof; or any corporation organized under the laws of a foreign government, if the Commission finds that the public interest will be served by refusal or revocation of such license.

§ 89.11 General restrictions on transfer and assignment of station authorization.

A station authorization; the frequencies authorized to be used by the grantee of such authorization; and the rights therein granted by such authorization shall not be transferred, assigned, or in any manner either voluntarily or involuntarily disposed of, or indirectly by transfer of control of any corporation holding such authorization to any person, unless the Commission shall, after securing full information, decide that said transfer is in the public interest, and shall give its consent in writing. Requests for authority to assign or transfer control of a station authorization may be submitted in accordance with § 89.59 (b) or (d), whichever is applicable.

§ 89.13 Cooperative use of radio stations in the mobile service.

Arrangements may be made between two or more persons for the cooperative use of radio station facilities in the mobile radio service provided all persons sharing in the use of a station are eligible to hold licenses to operate the particular type of station shared. Such cooperative arrangements shall be governed by the following:

(a) *Agreements relating to control.* (1) A group of persons eligible for a license in the same public safety radio service may share the use of a base station or a base and mobile station licensed to one member of the group provided there is on file with the Commission, and maintained with the records of the station, a copy of the agreement under which such shared operation shall take place. Such agreement should provide that the licensee of the station shall be in control of the operation of the station and that all use of its facilities shall take place only under the direction and supervision of an employee of the licensee.

(2) Subscribers to such service may either obtain a separate license to cover the mobile transmitters which they use or the mobile transmitters may be included in the license of the base station from which service is rendered. In the latter case the coordinated service agreement should specifically cover use of such

mobile units and indicate that the licensee would be in control of such units.

(b) *Contributions to operating costs.* Coordinated service may be rendered without cost to subscribers or contributions to capital and operating expenses may be accepted by the licensee. Such contributions must be on a cost-sharing basis and pro-rated on an equitable basis among all persons who are parties to the cooperative arrangement. Records which reflect the cost of the service and its nonprofit, cost-sharing nature shall be maintained by the base station licensee and held available for inspection by a Commission representative.

(c) *Letter to accompany application.* Each application for a mobile station proposing to receive coordinated service shall be accompanied by a letter from the licensee of the base station concerned indicating that the proposed coordinated service will be rendered.

§ 89.14 Cooperative use of fixed radio stations.

(a) Licensees and persons eligible to become licensees of operational fixed stations under this part may make cooperative use of such licensed facilities under the conditions and subject to the limitations specified in this section.

(b) Such licensed facilities may be cooperatively used and shared only by: (1) Persons licensed or eligible to be licensed within the same radio service; or by (2) Government entities, units or subunits right-of-way companies, or enterprises whose rates and services are regulated by a governmental authority or body, regardless of whether such entities, units, subunits, companies, or enterprises are licensed or eligible to be licensed within the same radio service.

(c) The cooperative use of licensed facilities is authorized only on frequencies for which all participants would be separately eligible for assignment.

(d) Licensed facilities may be cooperatively used under this section only (1) without charge to any of the participants in its use, or (2) on a nonprofit, cost-sharing basis pursuant to a written contract between the parties involved which provides that the licensee shall have control of the licensed facilities and that contributions to capital and operating expenses are accepted only on a cost-sharing, nonprofit basis, prorated equitably among all participants using the facilities.

(e) Each licensee sharing its facilities under this section shall maintain records showing the cost of the facilities and their operation and use, the charges made to and payments made by each of those using the facilities or contributing to their capital cost or operating expense, and the information specified below, and such records shall be available for inspection by the Commission.

(f) Each licensee sharing its facilities under this section shall file a notification with the Commission 30 days prior to the use of its facilities by any other person that has not been specified in its license application or in a prior notification to the Commission containing the following information:

(1) Name and description of the licensee;

(2) Call sign of the station or stations;

(3) The radio service in which the station is licensed;

(4) The names of all prospective participants in the cooperative use of the station and a description of each participant sufficient to show its eligibility for participation under this section and its eligibility to use the frequencies assigned to the station; and

(5) A copy of the contract between the parties for the cooperative use of the facilities.

(g) The licensee may institute the service described in the notification filed pursuant to paragraph (f) of this section 30 days after filing unless the Commission during that period notifies the licensee that the information supplied is inadequate or that the proposed service is not authorized under these regulations, and the licensee shall then have the right to amend or to file another notification to remedy the inadequacy or defect and to institute service 30 days thereafter, or at such earlier date as the Commission may set upon finding that the inadequacy or defect has been remedied.

(h) Each licensee sharing its facilities under this section on a nonprofit, cost-sharing basis shall file an annual report with the Commission, using FCC Form 402-A, within 90 days of the close of its fiscal year containing:

(1) A financial statement of operations during the preceding fiscal year in sufficient detail to show compliance with the requirements of this section;

(2) The names of those who have shared the use of the facilities during the preceding fiscal year;

(3) A brief statement as to the use of the facilities made by each person sharing the use and an estimate of the approximate percentage of use by each participant during the preceding fiscal year; and

(4) Any change in the items previously reported to the Commission concerning such facilities or their use in the application for the license or in a notification under this section.

(i) When radio facilities are shared under the provisions of this section without charge and without any other consideration flowing from any of the participants, or when the facilities are shared solely by governmental entities, in lieu of the statements required to be filed by paragraph (h) of this section, the licensee shall file with the Commission within ninety days after the close of his fiscal year a statement advising the Commission of that fact.

(j) The licensee shall inform the Commission whenever the cooperative use of any of its facilities in accordance with this section is permanently discontinued.

(k) This section authorizes the sharing of facilities of fixed stations using mobile frequencies in the 25–50, 150–173, and 450–470 MHz bands on a secondary basis only by persons all of whom are licensed or are eligible to be licensed in the same radio service.

§ 89.15 Frequency coordination procedures.

(a) Except for applications from States requesting frequencies in accordance with a geographical assignment plan, applications in the Special Emergency Radio Service, and applications requesting assignment of frequencies in the 27.23–27.28 MHz band or frequencies above 470 MHz, the following applications shall be accompanied by information required by either paragraph (b) or (c) of this section:

(1) Requests for assignment of a new frequency; or

(2) Requests to change existing facilities by increasing the authorized power input, or raising the authorized height of the antenna, or moving the authorized station location (including the antenna), or by adding a base station within the licensee's existing area of operation.

(b) (1) A statement that all existing licensees located within a radius of 75 miles of the location of the station and authorized to operate on frequencies within 30 kHz of the frequency or frequencies assigned or requested have been notified of the applicant's intention to file his application; and

(2) A report, based on a field study covering the area within a radius of 75 miles of the location of the station, indicating the probable interference to existing stations authorized to operate within 30 kHz of the frequency or frequencies requested or assigned.

(c) A statement from a frequency advisory committee commenting upon the frequency or frequencies requested or the proposed changes in the authorized station and giving the opinion of the committee regarding the probable interference of the proposal to existing stations. Where the frequency or frequencies requested or assigned are within 30 kHz of a frequency which is available to another radio service, and is assignable only after coordination, the committee's statement shall affirmatively show that coordination with a similar committee for the other service has been accomplished; or, in lieu thereof, that all licensees in the other service within 75 miles of the location of the station operating on the frequency requested or assigned have been notified of the applicant's intention to file the application. The committee's statements should, where feasible, also include comments regarding technical factors such as power, antenna height, and characteristics which may serve to mitigate any contemplated interference situation. The frequency advisory committee must be so organized as to be representative of all persons who are eligible for radio facilities in the service concerned in the area the committee purports to serve. The functions of frequency advisory committees are purely advisory in character; their comments are not binding upon either the applicant or the Commission; and must not contain statements which would imply that frequency advisory committees have any authority to grant or deny applications.

(d) In addition to the provisions of paragraph (a) of this section, in order to minimize possible harmful interference at the National Radio Astronomy Observatory site located at Green Bank, Pocahontas County, West Virginia, and at the Naval Radio Research Observatory site at Sugar Grove, Pendleton County, West Virginia, any applicant for a station authorization other than mobile, temporary base, or temporary fixed seeking a station license for a new station, a construction permit to construct a new station or to modify an existing station license in a manner which would change either the frequency, power, antenna height or directivity, or location of such a station within the area bounded by 39°15′ N. on the north, 78°30′ W. on the east, 37°30′ N. on the south, and 80°30′ W. on the west shall, at the time of filing such application with the Commission, simultaneously notify the Director, National Radio Astronomy Observatory, P. O. Box No. 2, Green Bank, West Virginia 24944, in writing, of the technical particulars of the proposed station. Such notification shall include the geographical coordinates of the antenna, antenna height, antenna directivity if any, proposed frequency, type of emission, and power. In addition, the applicant shall indicate in his application to the Commission the date notification was made to the Observatory. After receipt of such applications, the Commission will allow a period of 20 days for comments or objections in response to the notifications indicated. If an objection to the proposed operation is received during the 20-day period from the National Radio Astronomy Observatory for itself or on behalf of the Naval Radio Research Observatory, the Commission will consider all aspects of the problem and take whatever action is deemed appropriate.

§ 89.17 Civil defense.

A station licensed under this part may transmit communications necessary for the implementation of civil defense activities assigned such station by the local civil defense authorities during an actual or simulated emergency, including drills and tests: *Provided*, That such communications relate to the activity or activities which form the basis of the licensee's eligibility in the radio service in which authorized.

APPLICATIONS, AUTHORIZATIONS, AND NOTIFICATIONS

§ 89.51 Station authorization required.

No radio transmitter shall be operated in the Public Safety Radio Services except under and in accordance with a proper station authorization granted by the Federal Communications Commission.

§ 89.53 Procedure for obtaining a radio station authorization and for commencement of operation.

(a) Persons desiring to install and operate radio transmitting equipment should first submit an application for a radio station authorization in accordance with § 89.59 (a).

(b) When construction permit only has been issued for a base, fixed or mobile station and installation has been completed in accordance with the terms of the construction permit and the applicable rules of the Commission, the permittee shall proceed further as follows:

(1) Notify the Engineer in Charge of the local radio district of the date on which the transmitter will first be tested in such manner as to produce radiation, giving name of the permittee, station location, call sign, and frequencies on which tests are to be conducted. This notification shall be made in writing at least two days in advance of the test date. FCC Form 456 may be used for this purpose. No reply from the radio district office is necessary before the tests are begun.

(2) After testing, but on or before the date the station is used for operational purposes, mail to the Commission in Washington, D.C., 20554, an application on FCC Form 400 or in the case of microwave station on FCC Form 402 for license or modification of license as appropriate in the particular case. The station may thereafter be used as though licensed, pending Commission action on the license application.

(c) When a construction permit and license for a new base, fixed or mobile station are issued simultaneously, the licensee shall notify the Engineer in Charge of the local radio district of the date on which the transmitter will be placed in operation, giving name of licensee, station location, call sign, and operating frequencies. This notification shall be made in writing on or before the day on which operation is commenced. FCC Form 456 may be used for this purpose.

(d) When a construction permit and modification of license for a base, fixed or mobile station are issued simultaneously, operation may be commenced without notification to the Engineer in Charge of the local radio district, except where operation on a new or different frequency results by reason of such modification, in which event the notification procedure set forth in paragraph (c) of this section must be observed.

§ 89.55 Filing of applications.

(a) To assure that necessary information is supplied in a consistent manner by all persons, standard forms are prescribed for use in connection with the majority of applications and reports submitted for Commission consideration. Standard numbered forms applicable to the Public Safety Radio Services are discussed in § 89.59, and may be obtained from the Washington, D. C., 20554, office of the Commission, or from any of its engineering field offices. Concerning matters where no standard form is applicable, the procedure outlined in § 89.61 should be followed.

(b) Any application for radio station authorization and all correspondence relating thereto shall be submitted to the Commission's office at Washington, D.C., 20554, directed to the attention of the Secretary. An application for commercial radio operator permit or license may be submitted to any of the Commission's engineering field offices, or to the Commission's office at Washington, D.C., 20554.

(c) Unless otherwise specified, an application shall be filed at least 60 days prior to the date on which it is desired that Commission action thereon be completed. In particular, applications involving the installation of new equipment shall be filed at least 60 days prior to the contemplated installation.

(d) Failure on the part of the applicant to provide all the information required by the application form or to supply the necessary exhibits or supplementary statements may constitute a defect in the application.

(e) Applications involving operation at temporary locations:

(1) When one or more individual transmitters are intended to be operated as a base station or as a fixed station at unspecified or temporary locations for indeterminate periods, such transmitters may be considered to comprise a single station intended to be operated at temporary locations. An application for authority to operate a base station or a fixed station at temporary locations shall specify the general geographic area within which the operation will be confined. The area specified may be a city, a county or counties, or a state or states.

(2) When a base station or fixed station authorized to operate at temporary locations remains at a single location for more than one year, an application for modification of the station authorization to specify the permanent location shall be filed within 30 days after expiration of the 1 year period.

(f) Applicants proposing to construct a radio station on a site located on land under the jurisdiction of the U.S. Forest Service, U.S. Department of Agriculture, or the Bureau of Land Management, U.S. Department of the Interior, must supply the information and must follow the procedure prescribed by § 1.70 of this chapter.

§ 89.57 Who may sign applications.

(a) Except as provided in paragraph (b) of this section, applications, amendments thereto, and related statements of fact required by the Commission shall be personally signed by the applicant, if the applicant is an individual; by one of the partners, if the applicant is a partnership; by an officer, if the applicant is a corporation; or by a member who is an officer, if the applicant is an unincorporated association. Applications, amendments, and related statements of fact filed on behalf of eligible government entities, such as states and territories of the United States and political subdivisions thereof, the District of Columbia, and units of local government, including incorporated municipalities, shall be signed by such duly elected or appointed officials as may be competent to do so under the laws of the applicable jurisdiction.

(b) Applications, amendments thereto, and related statements of fact required by the Commission may be signed by the applicant's attorney in case of the applicant's physical disability or of his absence from the United States. The attorney shall in that event separately set forth the reason why the application is not signed by the applicant. In addition, if any matter is stated on the basis of the attorney's belief only (rather than his knowledge), he shall separately set forth his reasons for believing that such statements are true.

(c) Only the original of applications, amendments, or related statements of fact, need be signed; copies may be conformed.

(d) Applications, amendments, and related statements of fact need not be signed under oath. Willful false statements made therein, however, are punishable by fine and imprisonment, U.S. Code, Title 18, section 1001, and by appropriate administrative sanctions, including revocation of station license pursuant to section 312(a)(1) of the Communications Act of 1934, as amended.

§ 89.59 Standard forms to be used.

(a) Except as provided in paragraph (b) of this section, a separate application shall be submitted on FCC Form 400 for the following:

(1) New station authorization for a base or fixed station.

(2) New station authorizations for any required number of mobile units (including hand-carried or pack-carried units) or any required number of units of a base station or fixed station to be operated at temporary locations in the same service.

NOTE: An application for mobile units may be combined with an application for a single base station in those cases where the mobile units will operate with that base station in a single radio communication system.

(3) License for any class of station upon completion of construction or installation in accordance with the terms and conditions set forth in the construction permit.

(4) Modification of combined construction permit and station license for changes outlined in § 89.75 (a).

(5) Modification of construction permit.

(6) Modification of station license.

Any of the foregoing applications will, upon approval and authentication by the Commission, be returned to the applicant as a specifically designated type of authorization.

(b) When the holder of a station authorization desires to assign to another person the privilege to construct or use a radio station, he shall submit to the Commission a letter setting forth his desire to assign all right, title, and interest in and to such authorization, stating the call sign and location of station. This letter shall also include a statement that the assignor will submit his current station authorization for cancellation upon completion of the assignment. Enclosed with this letter shall be an application for Assignment of Authorization on FCC Form 400 prepared by and in the name of the person to whom the station is being assigned.

(c) [Reserved]

(d) A separate application shall be submitted on FCC Form 703 whenever it is proposed to change, as by transfer of stock-ownership, the control of a corporate permittee or licensee.

(e) An application not submitted on a standard form prescribed by the Commission is considered to be an informal application. Each informal application shall be submitted in duplicate, normally in letter form, and with the original properly signed. Each application shall be clear and complete within itself as to the facts presented and the action desired.

(f) FCC Form 456 "Notification of Completion of Radio Station Construction" may be used to advise the Engineer-in-Charge of the local district office that construction of the station is complete and that operational tests will begin.

(g) Application for renewal of station license shall be submitted on FCC 405-A. All applications for renewal must be made during the license term and should be filed within 90 days but not later than 30 days prior to the end of the license term. In any case in which the licensee has, in accordance with the provisions of this chapter, made timely and sufficient application for renewal of license, no license with reference to any activity of a continuing nature shall expire until such application shall have been finally determined.

(h) Application for construction permit, license, modification or assignment thereof for an operational fixed station using frequencies above 952 MHz (a so-called microwave station) shall be submitted on FCC Form 402.

§ 89.61 Request for special temporary authority.

(a) In circumstances requiring immediate or temporary use of facilities, request may be made for special temporary authority to install and operate new equipment or to operate licensed equipment in a manner different than that authorized in the station license. Any such request may be in letter form, submitted in duplicate, and signed in accordance with § 89.57: *Provided*, That in cases of emergency involving danger to life or property or due to damage to equipment, such request may be made by telephone or telegraph under the condition that written request is submitted within 10 days from the date of such request. In the event that the Commission finds that such an emergency exists, temporary authorization may be granted for the duration of the emergency. Any such request shall be clear and complete within itself as to the action desired.

(b) Special temporary authority may also be requested for the purpose of conducting a field survey to determine necessary data in connection with the filing of formal applications for installation of a radio system under this part. In this case, the authority, if issued, will be for developmental operation only and the applicable sections of Subpart C shall also apply to the grant.

(c) Request for special temporary authority shall contain the following information:

(1) Name, address, and citizenship status of applicant.

(2) Need for special action, including a description of any emergency or damage to equipment.

(3) Type of operation to be conducted.

(4) Purpose of operation.

(5) Time and date of operation desired.

(6) Class of station and nature of service.

(7) Location of station.

(8) Equipment to be used, specifying manufacturer, model number and number of units.

(9) Frequency(s) desired.

(10) Plate power input to final radio frequency stage.

(11) Type of emission.

(12) Description of antenna to be used, including height.

(d) Except in emergencies involving safety of life or property or due to damage to equipment, request for special temporary authority shall be submitted to the Commission at least ten days prior to the date of proposed operation, or it must be accompanied by a statement of reasons for the delay in submitting such request.

§ 89.63 Supplementary information to be submitted with application.

Each application for station authorization shall be accompanied by such supplemental information listed below as may be required:

(a) Statement with respect to frequency selection and coordination:

(1) Any statements or showings, required by the applicable subpart of these rules, in connection with the use of the frequency requested.

(2) Evidence of frequency coordination as required by § 89.15.

(b) Statements justifying the need when more frequencies are desired than are normally assigned to a single applicant under the applicable subpart of this part.

(c) Statement describing the type of emission to be used if it cannot be described as "8A3," "20F3," or "40F3" pursuant to Subpart A of this part.

(d) [Reserved]

(e) A functional system diagram and a detailed description of the manner in which the interrelated stations will operate when the station is, or will be, part of a system involving two or more stations at different fixed locations.

(f) Copies of all agreements and statements which may be required under § 89.13 if operation is desired in connection with any cooperative use of the proposed radio communication facilities.

(g) Statements required by the rules in this part in connection with developmental operations. See §§ 89.203, 89.205, 89.213.

(h) Description of any equipment proposed to be used, which does not appear on the Commission's List of Equipment Acceptable for Licensing and designated for use in the Public Safety, Industrial and Land Transportation Radio Services.

(i) Any statements or other data required under special circumstances as set forth in the applicable subpart of this part, or required upon request by the Commission.

§ 89.65 Partial grant.

Where the Commission, without a hearing, grants an application in part, or with any privileges, terms, or conditions other than those requested, the action of the Commission shall be considered as a grant of such application unless the applicant shall, within 30 days from the date on which public announcement of such grant is made, or from its effective date if a later date is specified, file with the Commission a written request rejecting the grant as made. Upon receipt of such request, the Commission will vacate its original action and set the application for hearing in the same manner as other applications are set for hearing.

§ 89.67 Defective applications.

(a) Applications which are incomplete with respect to completeness of answers, supplementary statements, execution or other matters of a formal character shall be deemed to be defective and may be returned to the applicant with a brief statement as to such defects.

(b) Applications will also be deemed to be defective and may be returned to the applicant in the following cases:

(1) Statutory disqualification of applicant, e. g., aliens under section 310 of the Communications Act;

(2) Proposed use or purpose of station would be unlawful;

(3) Requested frequency is not allocated for assignment for the service proposed.

(c) Applications which are not in accordance with the provisions of this chapter, or other requirements of the Commission will be considered defective and may be dismissed unless accompanied either by (1) a petition to amend any rule or regulation with which the application is in conflict, or (2) a request of the applicant for waiver of, or exception to, any rule, regulation, or requirement with which the application is in conflict. Such request shall show the nature of the waiver or exception desired and set forth the reasons in support thereof. Applications may be dismissed, if the accompanying petition for waiver or amendment of rules does not set forth reasons which, sufficient if true, would justify a waiver or change of the rules.

(d) If an applicant is requested by the Commission to file any additional documents or information not included in the prescribed application form, failure to comply with such request will be deemed to render the application defective, and such application may be dismissed.

§ 89.69 Amendment or dismissal of applications.

(a) Any application may be amended upon request of the applicant as a matter of right prior to the time the application is granted or designated for hearing. Each amendment to an application shall be signed and submitted in the same manner and with the same number of copies as required for original application.

(b) Any application may, upon written request signed by the applicant or his attorney, be dismissed without prejudice as a matter of right prior to the time the application is granted or designated for hearing.

§ 89.71 Construction period.

(a) Each radio station construction permit issued by the Commission will specify the date of grant as the earliest date of commencement of construction and installation, and a maximum of eight months thereafter as the time within which construction shall be completed and the station ready for operation, unless otherwise determined by the Commission in any particular case.

(b) In cases where the station is not ready for operational use on or before the expiration date of the construction permit, application for extension of time to construct shall be filed on FCC Form 400, or on FCC Form 402, as appropriate.

§ 89.73 License term.

(a) Licenses for stations in the Public Safety Radio Services will normally be issued for a term of 5 years from the date of original issuance, major modification, or renewal.

(1) Each station license will be issued for a term of from 1 to 5 years from the effective date of grant, the term varying as may be necessary to permit the orderly scheduling of renewal applications.

(2) Each station license normally will be renewed, upon proper application, for a term of 5 years from the effective date of renewal.

(b) Authorization for stations engaged in developmental operation will be made upon a temporary basis for a specific period of time, but in no event to extend beyond 1 year from date of grant.

[§ 89.73(a) *amended eff. 9-15-70; V(70)-2*]

§ 89.75 Changes in authorized stations.

Authority for certain changes in authorized stations must be obtained from the Commission before these changes are made, while other changes do not require prior Commission approval. The following paragraphs describe the conditions under which prior Commission approval is or is not necessary.

(a) Proposed changes which will result in operation inconsistent with any of the terms of the current authorization require that an application for modification of construction permit and/or license be submitted to the Commission and shall be submitted on FCC Form 400, or, in the case of microwave stations, on FCC Form 402, and shall be accompanied by exhibits and supplementary statements as required by § 89.63.

(b) [Reserved]

(c) Proposed changes which will not depart from any of the terms of the outstanding authorization for the station involved may be made without prior Commission approval. Included in such changes is the substitution of various makes of transmitting equipment at any station provided the particular equipment to be installed is included in the Commission's "List of Equipment Acceptable for Licensing" and designated for use in the Public Safety, Industrial, and Land Transportation Radio Services and provided the substitute equipment employs the same type of emission and does not exceed the power limitations as set forth in the station authorization.

(d) When the name of a licensee is changed (without changes in the ownership, control, or corporate structure), or when the mailing address is changed (without changing the authorized location of the base or fixed station or the area of operation of mobile stations) a formal application for modification of license is not required. However, the licensee shall notify the Commission promptly of these changes. The notice, which may be in letter form, shall contain the name and address of the licensee as they appear in the Commission's records, the new name and/or address, as the case may be, the call signs and classes of all radio stations authorized to the licensee under this part and the radio service in which each station is authorized. The notice shall be sent to (1) Secretary, Federal Communications Commission, Washington, D.C., 20554, and (2) the Engineer in Charge of the Radio District in which the station is located, and a copy shall be maintained with the license of each station until a new license is issued.

§ 89.77 Discontinuance of station operation.

In case of discontinuance of operation for a period of one year or more of a base or fixed station in these services, or in case of discontinuance for a period of one year or more of operation of all transmitter units listed in the license for a mobile station in these services, the licensee shall forward the station license to the Washington, D.C., 20554, office of the Commission for cancellation. A copy of the request for cancellation of the license shall be forwarded to the Commission's Engineer in Charge of the district in which the station is located.

§ 89.79 International police radiocommunication.

Police radio licensees which are located in close proximity to the borders of the United States may be authorized to communicate internationally. Request for such authority shall be written and signed and submitted in duplicate. The request shall include information as to the station with which communication will be conducted, and the frequency, power, emission, etc., that will be used. If authorized, such international communication must be conducted in accordance with Article 5 of the Inter-American Radio Agreement, Washington, D.C., 1940 which reads as follows:

ARTICLE 5. *Police radio stations.* When the American countries authorize their police radio stations to exchange emergency information by radio with similar stations of another country, the following rules shall be applied:

(a) Only police radio stations located close to the boundaries of contiguous countries shall be allowed to exchange this information.

(b) In general, only important police messages shall be handled, such as those which would lose their value because of slowness and time limitations if sent on other communication systems.

(c) Frequencies used for radiotelephone communications with mobile police units shall not be used for radiotelegraph communications.

(d) Radiotelephone communications shall be conducted only on frequencies assigned for radiotelephony.

(e) Radiotelegraph communications shall be conducted on the following frequencies:

2804 kHz calling	5195 kHz day calling
2808 kHz working	5135 kHz day working
2812 kHz working	5140 kHz day working

(f) The characteristics of police radio stations authorized to exchange information shall be notified to the International Telecommunication Union, Geneva, Switzerland.

(g) The abbreviations contained in Appendix 9 of the Atlantic City Radio Regulations shall be used to the greatest possible extent. Service indications are as follows: "P", priority. for messages that are to be sent immediately, regardless of the number of other messages on file. If no service indication is given, the messages are to be transmitted in the order of receipt.

(h) The message shall contain the preamble, address, text, and signature, as follows:

Preamble. The preamble of the message shall consist of the following: the serial number preceded by the letters "NR"; service indications, as appropriate; the group count according to standard cable count system; the letters "CK", followed by numerals indicating the number of words contained in the text of the message; office and country of origin (not abbreviations); day, month, and hour of filing;

Address. The address must be as complete as possible and shall include the name of the addressee with any supplementary particulars necessary for immediate delivery of the message;

Text. The text may be either in plain language or code;

Signature. The signature shall include the name and title of the person originating the message.

TECHNICAL STANDARDS

§ 89.101 Frequencies.

(a) Frequencies other than those shown in the applicable subpart of this part are not available for assignment except as provided in paragraphs (b), (d), (f), (h), and (j) of this section, and except that licensees holding a valid authorization on June 30, 1958, may, upon proper application, continue to be authorized for such operation, including expansion of existing systems, until such time as harmful interference is caused to the operation of any authorized station other than those licensed in the Public Safety Radio Services. All applicants for, and the licensees of, stations in the services in this part shall cooperate in the selection and use of the designated frequencies to minimize interference and to make effective use of the frequencies assigned. Frequencies listed in this part will not be assigned exclusively to any one applicant. The use of any frequency at a given geographical location may be denied when in the judgment of the Commission its use in that location is not in the public interest; the use of any frequency may be restricted to one or more geographical areas.

(b) Frequencies assigned to government radio stations under Executive Order of the President may be authorized for use of stations in these services upon appropriate showing by the applicant that such assignment is necessary for inter-communication with government stations or required for coordination with activities of Federal Government, and where the Commission finds, after consultation with the appropriate government agency or agencies, that such assignment is necessary.

(c) Except as provided in § 89.102, the following frequencies in the band 72-76 MHz may be authorized and used only in accordance with the criteria set forth in subparagraphs (1) to (6) of this paragraph.

[§ *89.101(c) intro text amended eff. 10-19-70; V(70)-3*]

MHz	*MHz*	*MHz*	*MHz*
72.02	72.36	72.80	75.66
72.04	72.38	72.82	75.68
72.06	72.40	72.84	75.70
72.08	72.42	72.86	75.72
72.10	72.46	72.88	75.74
72.12	72.50	72.90	75.76
72.14	72.54	72.92	75.78
72.16	72.58	72.94	75.80
72.18	72.62	72.96	75.82
72.20	72.64	72.98	75.84
72.22	72.66	75.42	75.86
72.24	72.68	75.46	75.88
72.26	72.70	75.50	75.90
72.28	72.72	75.54	75.92
72.30	72.74	75.58	75.94
72.32	72.76	75.62	75.96
72.34	72.78	75.64	75.98

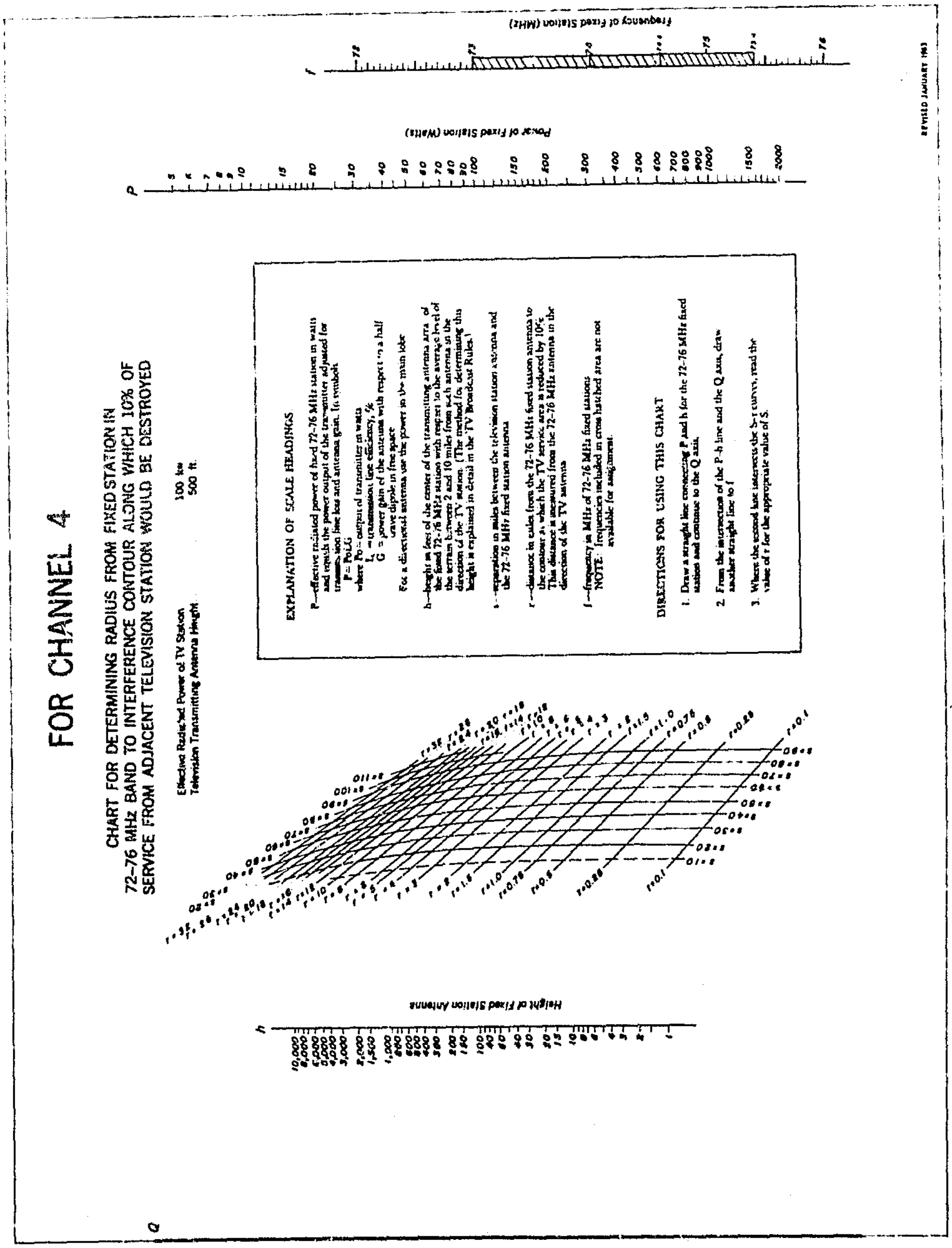
NOTE: Stations authorized for operation on or before December 1, 1961, in the frequency band 73.0-74.6 MHz may continue such operation; but no new stations will be authorized in this band, nor will expansion of existing systems be permitted.

(1) All authorizations are subject to the condition that no harmful interference will be caused to television reception on channels 4 and 5.

(2) The applicant agrees to eliminate any harmful interference caused by his operation to TV reception on either channel 4 or 5 that might develop by whatever means are found necessary within 90 days of the time knowledge of said interference is first brought to his attention by the Commission. If said interference is not cleared up within the 90-day period, operation of the fixed station will be discontinued.

(3) Vertical polarization is used.

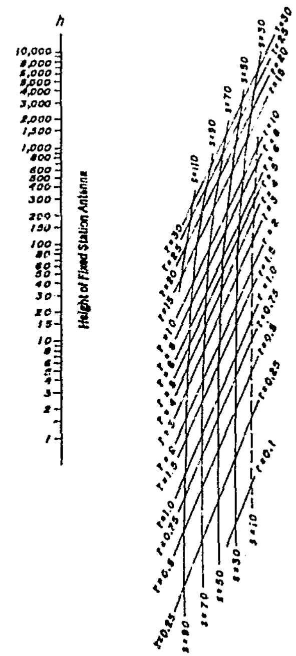
(4) Whenever it is proposed to locate a 72-76 MHz fixed station less than 80, but more than 10 miles from the site of a TV transmitter operating on either channel 4 or 5, or from the post office of a community in which such channels are assigned but not in operation, the fixed station shall be authorized only if there are fewer than 100 family dwelling units (as defined by the U.S. Bureau of the Census), excluding units 70 or more miles distant from the TV antenna site, located within a circle centered at the location of the proposed fixed station. The radius shall be determined by use of the chart entitled, "Chart for Determining Radius From Fixed Station in 72-76 MHz Band to Interference Contour Along Which 10 Percent of Service From Adjacent Channel Television Station Would Be Destroyed"; two charts are available, one for channel 4, and one for channel 5. The Commission may, in a particular case, authorize the location of a fixed station within a circle, as determined under


FOR CHANNEL 4
CHART FOR DETERMINING RADIUS FROM FIXED STATION IN 72–76 MHz BAND TO INTERFERENCE CONTOUR ALONG WHICH 10% OF SERVICE FROM ADJACENT TELEVISION STATION WOULD BE DESTROYED
Effective Radiated Power of TV Station 100 kw
Television Transmitting Antenna Height 500 ft.
EXPLANATION OF SCALE HEADINGS
P—effective radiated power of fixed 72–76 MHz station in watts and equals the power output of the transmitter adjusted for transmission line loss and antenna gain. In symbols
P = PoLG
where Po = output of transmitter in watts
L = transmission line efficiency, %
G = power gain of the antenna with respect to a half wave dipole in free space
For a directional antenna use the power in the main lobe
h—height in feet of the center of the transmitting antenna array of the fixed 72–76 MHz station with respect to the average level of the terrain between 2 and 10 miles from such antenna in the direction of the TV station. (The method for determining this height is explained in detail in the TV Broadcast Rules.)
s—separation in miles between the television station antenna and the 72–76 MHz fixed station antenna
r—distance in miles from the 72–76 MHz fixed station antenna to the contour at which the TV service area is reduced by 10%. This distance is measured from the 72–76 MHz antenna in the direction of the TV antenna
f—frequency in MHz of 72–76 MHz fixed stations
NOTE: Frequencies included in cross hatched area are not available for assignment.
DIRECTIONS FOR USING THIS CHART
1. Draw a straight line connecting P and h for the 72–76 MHz fixed station and continue to the Q axis.
2. From the intersection of the P–h line and the Q axis, draw another straight line to f
3. Where the second line intersects the S–r curves, read the value of r for the appropriate value of S.
Height of Fixed Station Antenna
Power of Fixed Station (Watts)
Frequency of Fixed Station (MHz)
REVISED JANUARY 1963

FOR CHANNEL 5

CHART FOR DETERMINING RADIUS FROM FIXED STATION IN 72–76 MHz BAND TO INTERFERENCE CONTOUR ALONG WHICH 10% OF SERVICE FROM ADJACENT TELEVISION STATION WOULD BE DESTROYED

Effective Radiated Power of TV Station . . . . 100 kw.
Television Transmitting Antenna Height . . . . 500 ft.



EXPLANATION OF SCALE HEADINGS:

P — effective radiated power of fixed 72–76 MHz station in watts and equals the power output of the transmitter adjusted for transmission line loss and antenna gain. In symbols
P = PoLG
where Po = output of transmitter in watts
L = transmission line efficiency, %
G = power gain of the antenna with respect to a half wave dipole in free space.
For a directional antenna use the power in the main lobe.

h — height in feet of the center of the transmitting antenna array of the fixed 72–76 MHz station with respect to the average level of the terrain between 2 and 10 miles from such antenna in the direction of the TV station. (The method for determining this height is explained in detail in the TV Broadcast Rules.)

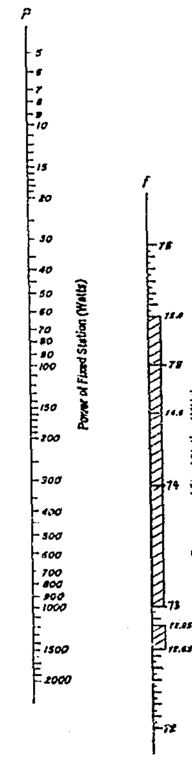
s — separation in miles between the television station antenna and the 72–76 MHz fixed station antenna.

r — distance in miles from the 72–76 MHz fixed station antenna to the contour at which the TV service area is reduced by 10%. This distance is measured from the 72–76 MHz antenna in the direction of the TV antenna.

f — frequency in MHz of 72–76 MHz fixed stations.
NOTE: frequencies included in cross hatched area are not available for assignment.

DIRECTIONS FOR USING THIS CHART:

1. Draw a straight line connecting P and h for the 72–76 MHz fixed station and continue to the Q axis.
2. From the intersection of the P-h line and the Q axis, draw another straight line to f.
3. Where the second line intersects the S-r curves, read the value of r for the appropriate value of s.



REVISED JANUARY 1963

the above conditions, containing 100 or more family dwelling units upon a showing that:

(i) The proposed site is the only suitable location.

(ii) It is not feasible, technically or otherwise, to use other available frequencies.

(iii) The applicant has a plan to control any interference that might develop to TV reception from his operations.

(iv) The applicant is financially able and agrees to make such adjustments in the TV receivers affected as may be necessary to eliminate interference caused by his operations.

(5) All applications seeking authority to operate with a separation of less than 10 miles will be returned without action.

(6) Complaints of interference to a fixed service or operational fixed receiver using wide-band equipment will not be recognized as valid if caused by a transmitter operating in accordance with the narrow-band technical standards on a frequency one or more channels removed from the frequency of the receiver affected.

(d) The frequencies 27.235, 27.245, 27.255, 27.265, and 27.275 MHz may be authorized to any eligible applicant in the Public Safety Radio Services subject to the following conditions and limitations:

(1) Notwithstanding the rule provisions relating to permissible communications, points of communication and emissions in the applicable subpart of this part, the frequencies 27.235, 27.245, 27.255, 27.265, and 27.275 MHz may be used to accomplish any radio communication requirement which is necessary to the licensee's activity: *Provided*, That all operations are otherwise in accordance with the rules in this chapter; that the bandwidth of emission does not exceed 8 kHz; and that power is limited to no more than 30 watts input to the final radio frequency stage.

(2) The frequencies 27.235, 27.245, 27.255, 27.265, and 27.275 MHz are available for assignment in the Public Safety Radio Services for use on a shared basis with stations in other services. All fixed and mobile operations on these frequencies are subject to interference from the operation of industrial, scientific, and medical devices on the frequency 27.12 MHz.

(e) Frequencies below 25 megahertz listed in the various services of this part are the frequencies normally assigned to stations in those services under the indicated conditions and limitations. In individual cases it may be impracticable to authorize the normally assignable frequencies because of potential interference to existing frequency use in the area involved. In such cases substitute frequencies, which are in accordance with the Commission's table of frequency allocations and compatible with existing United States and foreign assignments made pursuant to outstanding international agreements, may be authorized even though such frequencies are not listed in this part.

(f) The frequency bands 153.7325 to 153.7475 and 159.4725 to 159.480 MHz may be authorized for developmental operation to any eligible applicant in the Public Safety Radio Services for narrow band systems only: *Provided*, That:

(1) The band of frequencies occupied by the emission is at all times confined within the band listed;

(2) The proposed station location is removed by at least 10 miles from the station location of each other station authorized to other than the applicant on the same or adjacent channels, at the time application is made; and

(3) The application is accompanied by a signed statement that the licensees of all stations located within a radius of 75 miles of the proposed location and authorized to operate on the same or adjacent channels have concurred with such assignment, or is accompanied by a report based on a field study which indicates the probable interference to the operation of existing stations, together with a signed statement that the licensees of all stations located within a radius of 75 miles of the proposed location and authorized to operate on the same or adjacent channels have been notified of applicant's intention to request the assignment.

(g) Persons authorized pursuant to this part to operate radio stations on frequencies in the band 25–50 MHz must recognize that the band is shared with various services in other countries; that harmful interference may be caused by tropospheric and ionospheric propagation of signals from distant stations of all services of the United States and other countries operating on frequencies in this band; and that no protection from such harmful interference generally can be expected. Persons desiring to avoid such harmful interference should consider operation on available frequencies higher in the radio spectrum not generally subject to this type of difficulty.

(h) The following table indicates the bands of frequencies for microwave operation, the classes of stations to which they are normally available, and the specific assignment limitations which are developed in paragraph (i) of this section.

Frequency band—MHz	Class of station(s)	Limitations
952-960	Operational fixed	5, 6
1850-1990	...do	6
2130-2150	...do	6
2150-2160	...do	7
2180-2200	...do	6
2450-2500	Base, mobile, operational fixed and radio location	2, 4, 6
2500-2690	Operational fixed	8
2900-3100	Radiolocation	9, 10
3100-3300	...do	16
3300-3500	...do	13, 16
3500-3700	...do	16
5250-5350	...do	16
5350-5460	...do	10, 14
5460-5470	...do	10, 12
5470-5600	...do	9, 10
5600-5650	...do	10, 11
6525-6575	Base and mobile	6
6575-6875	Operational fixed	6
8100-8500	Base, mobile and operational fixed	1
8500-9000	Radiolocation	17
9000-9200	...do	10, 14
9200-9300	...do	16
9300-9500	...do	10, 12, 15
9500-10,000	...do	10
10,000-10,500	...do	13, 16, 18
10,500-10,550	...do	3, 6
10,550-10,680	Base and mobile	6
12,200-12,700	Operational fixed	6
13,200-13,250	Base, mobile and operational fixed	1
13,400-14,000	Radiolocation	16
15,700-17,700	...do	16
17,700-19,300	Base, mobile and operational fixed	1
19,400-19,700	...do	1
23,000-24,250	Radiolocation	16
27,525-31,300	Base, mobile and operational fixed	1
33,400-36,000	Radiolocation	16
38,600-40,000	Base, mobile and operational fixed	1

[§ *89.101(h) table revised eff. 12-16-70;* V(70)-3]

(i) Explanation of assignment limitations appearing in the frequency tabulation of paragraph (h) of this section:

(1) Limited to developmental operation only with the assigned frequency and particulars of operation specified in each authorization.

(2) Subject to no protection from interference due to the operation of industrial, scientific, and medical devices in this band.

(3) The band 10,500–10,550 MHz is restricted to systems using type A0 emission with a power not to exceed 40 watts into the antenna.

(4) Radiolocation land stations and radiolocation mobile stations, including speed measuring devices, may be authorized to use frequencies in the band 2450–2500 MHz on the condition that harmful interference will not be caused to the fixed and mobile services.

(5) Available for assignment in accordance with the frequency pairing plan as contained in paragraph (j) of this section.

(6) Stations authorized to operate on those frequencies above 952 MHz, which are not restricted to assignment for developmental operation only, shall be constructed and used in such a manner as to conform with all technical and operating requirements of Subpart A of this Part, unless deviation therefrom is specifically provided for in the station authorization.

(7) Available on a developmental basis only for omnidirectional operation.

(8) Only operational fixed stations employing television transmissions will be authorized in this band. The transmitting equipment for such stations must meet the technical standards for Instructional Television Fixed stations as contained in Part 74, Subpart I, § 74.901, et seq., of this chapter. Operational fixed systems authorized in this band prior to September 9, 1963, may continue to be authorized herein. Such systems may also be modified, or expanded by the addition of new stations, upon appropriate application therefor.

(9) The non-Government radiolocation service in this band is secondary to the maritime radionavigation service and to the Government radiolocation service.

(10) Speed measuring devices will not be authorized in this band.

(11) This band is allocated to the radiolocation service on a secondary basis to those services having primary status as shown in the Commission's Table of Frequency Allocations contained in § 2.106 of this chapter.

(12) The non-Government radiolocation service in this band is secondary to the radionavigation service and to the Government radiolocation service.

(13) In this band the radiolocation service is limited to survey operations using transmitters with a peak power not to exceed 5 watts into the antenna.

(14) The non-Government radiolocation service in this band is secondary to the aeronautical radionavigation service and to the Government radiolocation service.

(15) Radiolocation installations will be coordinated with the meteorological aids service, and, insofar as practicable, will be adjusted to meet the needs of the meteorological aids service.

(16) The non-Government radiolocation service in this band is secondary to the Government radiolocation service.

(17) The non-Government radiolocation service in this band is secondary to the Government radiolocation service and to airborne doppler radars at 8800 MHz.

(18) In this band harmful interference shall not be caused to the amateur radio service. Pulsed emissions are prohibited.

[§ 89.101(i)(13) *amended & (18) added eff. 12-16-70*]

(j) The frequencies between 952 and 960 MHz will be assigned as follows:

Paired frequencies (MHz)

959.9—956.3[1]	958.7—955.1	957.5—953.9
959.8—956.2[1]	958.6—955.0	957.4—953.8
959.7—956.1	958.5—954.9	957.3—953.7
959.6—956.0	958.4—954.8	957.2—953.6
959.5—955.9	958.3—954.7	957.1—953.5
959.4—955.8	958.2—954.6	957.0—953.4
959.3—955.7	958.1—954.5	956.9—953.3
959.2—955.6	958.0—954.4	956.8—953.2
959.1—955.5	957.9—954.3	956.7—953.1
959.0—955.4	957.8—954.2	9[illegible]—953.0
958.9—955.3	957.7—954.1	9[illegible]—952.9[1]
958.8—955.2	957.6—954.0	95[illegible]—952.8[1]

Unpaired frequencies (MHz)

952.7[2,3]	952.4[1,3]	952.1[1,3]
952.6[2,3]	952.3[1,3]	
952.5[2,3]	952.2[1,3]	

[1] Available on a developmental basis only for omnidirectional operation, and for other than the control of traffic signals.

[2] Available for assignment only for omnidirectional usage to control traffic signals.

[3] The maximum rated power output of transmitters for omnidirectional operations authorized to operate on this frequency is 100 watts.

(k) Operation on frequency pairs authorized prior to July 20, 1961, which are not in accordance with the above plan of frequency pairing may continue provided interference is not caused to the operation of systems which are utilizing channels in accordance with that plan.

(l) The frequency bands 31.99 to 32.00 MHz, 33.00 to 33.01 MHz, 33.99 to 34.00 MHz, 37.99 to 38.00 MHz, 39.00 to 39.01 MHz, 39.99 to 40.00 MHz, and 42.00 to 42.01 MHz may be authorized for developmental operation to any eligible applicant in the Public Safety Radio Services.

(m) [Reserved]

(n) [Reserved]

(o) [Reserved]

(p) The following frequencies may be assigned to fixed stations in the Public Safety Radio Services on a secondary noninterference basis to land mobile operations in the Industrial (except Business) and Land Transportation Radio Services. All such use of these frequencies for fixed systems is limited to locations 100 or more miles from the center of any urbanized area of 200,000 or more population, except that the distance may be 75 miles if the plate input power does not exceed 30 watts. All such fixed systems are limited to a maximum of two frequencies and must employ directional antennas with a front-to-back ratio of at least 15 dB. For two-frequency systems the separation between transmit-receive frequencies is 5 MHz. The centers of urbanized areas of 200,000 or more population are determined from the appendix, page 226, of the U.S. Commerce publication "Air Line Distance Between Cities in the United States." Urbanized areas of 200,000 or more population are defined in the U.S. Census of Population, 1960, vol. 1, table 23, page 1–50.

Frequencies (MHz)

451.025	452.150	456.425	457.650
451.050	452.175	456.450	457.675
451.075	452.200	456.475	457.700
451.100	452.225	456.500	457.725
451.125	452.250	456.525	457.750
451.150	452.275	456.550	457.775
451.175	452.300	456.575	457.800
451.200	452.325	456.600	457.825
451.225	452.350	456.625	457.850
451.250	452.375	456.650	457.875
451.275	452.400	456.675	457.900
451.300	452.425	456.700	457.975
451.325	452.450	456.725	458.000
451.350	452.475	456.750	462.200
451.375	452.500	456.775	462.225
451.400	452.625	456.800	462.250
451.425	452.650	456.825	462.275
451.450	452.675	456.850	462.300
451.475	452.700	456.875	462.325
451.500	452.725	456.900	462.350
451.525	452.750	456.925	462.375
451.550	452.775	456.950	462.400
451.575	452.800	456.975	462.425
451.600	452.825	457.000	462.450
451.625	452.850	457.025	462.475
451.650	452.875	457.050	462.500
451.675	452.900	457.075	462.525
451.700	452.975	457.100	467.200
451.725	453.000	457.125	467.225
451.750	456.025	457.150	467.250
451.775	456.050	457.175	467.275
451.800	456.075	457.200	467.300
451.825	456.100	457.225	467.325
451.850	456.125	457.250	467.350
451.875	456.150	457.275	467.375
451.900	456.175	457.300	467.400
451.925	456.200	457.325	467.425
451.950	456.225	457.350	467.450
451.975	456.250	457.375	467.475
452.000	456.275	457.400	467.500
452.025	456.300	457.425	467.525
452.050	456.325	457.450	
452.075	456.350	457.475	
452.100	456.375	457.500	
452.125	456.400	457.625	

(q) Fixed stations authorized prior to June 1, 1968, for operation on frequencies in the region 450–470 MHz, if located 100 or more miles from any urbanized area of 200,000 or more population, may continue until

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4 OF 5

POLICE TELECOMMUNICATION SYSTEMS NCJ 00341

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such time as a modification involving new facilities is proposed. At that time the system must be modified to frequencies available pursuant to paragraph (p) of this section.

§ 89.102 Radio call box operations in the 72–76 MHz band.

(a) The frequencies listed in § 89.101(c) may be assigned in the Local Government Radio Service for operation of radio call boxes to be used by the public to request fire, police, ambulance, road service and other emergency assistance subject to the following conditions and limitations.

(1) Maximum transmitter power either 2.5 watts plate input to the final stage or one watt output.

(2) Antenna gain may not exceed zero dBd [referred to a half-wave dipole] in any direction.

(3) Only vertical polarization of antennas may be permitted.

(4) The antenna and its supporting structure must not exceed 20 feet in height above the ground.

(5) A1, A2, F1, or F2 emission only may be authorized.

(6) Transmitter frequency tolerance shall be 0.005 percent.

(7) Except for test purposes, each transmission must be limited to a maximum of 2 seconds and may be automatically repeated not more than two times at spaced intervals within the following 30 seconds; thereafter, the authorized cycle may not be reactivated for 1 minute.

(8) All transmitters installed after December 10, 1970, shall be furnished with automatic means to deactivate the transmitter in the event the carrier remains on for a period in excess of 3 minutes. The automatic cutoff system must be so designed that the transmitter cannot be reactivated until manually reset.

(9) Frequency selection must be made with due regard to reception of television stations on channels 4 (66–72 MHz) and 5 (76–82 MHz) and should maintain the greatest possible frequency separation from either or both of these channels if they are assigned in the area.

(10) Until further order of the Commission, the maximum number of radio call boxes that may be authorized in any call box system is 250.

(b) Radio call box systems authorized before December 10, 1970, may continue to be authorized subject to the provisions of § 89.101(c).

[§ *89.102 added eff. 10–19–70; V(70)–3*]

§ 89.103 Frequency stability.

(a) A permittee or licensee in these services shall maintain the carrier frequency of each authorized transmitter within the following percentage of the assigned frequency:

Frequency range	All fixed and base stations	All mobile stations	
		Over 3 watts	3 watts or less
MHz	*Percent*	*Percent*	*Percent*
Below 25	0.01	0.01	0.02
25 to 50	.002	.002	.005
50 to 450	[1].0005	.0005	.005
450 to 470	[3].00025	.0005	[3].0005
470 to 950	.0005	.0005	.005
Above 950	(2)	(2)	(2)

[1] Stations authorized for operation on or before Dec. 1, 1961, in the frequency band 73.0–74.6 MHz may operate with a frequency tolerance of 0.005 percent.

[2] Radiolocation equipment using pulse modulation shall meet the following frequency tolerance: The frequency at which maximum emission occurs shall be within the authorized frequency band and shall not be closer than 1.5/T MHz to the upper and lower limits of the authorized frequency band where T is the pulse duration in microseconds. For other radiolocation equipment, tolerances will be specified in the station authorization. See also § 89.121.

[3] Effective Nov. 1, 1967. Stations authorized before Nov. 1, 1967, may continue to operate with a frequency tolerance of 0.0005 percent, 0.005 percent for mobile stations with power of 3 watts or less, until Nov. 1, 1971.

(b) For the purpose of determining the frequency tolerance applicable to a particular transmitter in accordance with the foregoing provisions of this section, the power of a transmitter shall be the maximum rated plate power input to its final radio frequency stage, as specified by the manufacturer.

§ 89.105 Types of emission.

(a) Except as provided in paragraphs (c) and (d) of this section, stations in these services will be authorized to use only A3 or F3 emission for radiotelephony. The authorization to use A3 or F3 emission is construed to include the use of tone signals or signaling devices the function of which is limited to establishing or maintaining voice communications or to actuating emergency warning devices used solely for the purpose of advising the general public or emergency personnel of an impending emergency situation.

(b) The use of F3 emission in these services will be authorized only on frequencies above 30 MHz.

(c) Zone and interzone stations will be authorized to use only A1 emission.

(d) Other types of emission not described in paragraphs (a) or (c) of this section may be authorized upon a satisfactory showing of need therefor. An application requesting such authorization shall fully describe the emission desired, shall indicate the bandwidth required for satisfactory communication, and shall state the purpose for which such emission is required. For information regarding the classification of emissions and the calculation of the bandwidth, reference should be made to Part 2 of this chapter.

§ 89.107 Emission limitations.

(a) Each authorization issued to a station operating in these services will show, as the prefix to the emission classification, a figure specifying the maximum authorized bandwidth in kilohertz to be occupied by the emission. The specified band shall contain those frequencies upon which a total of 99 percent of the radiated power appears, extended to include any discrete frequency upon which the power is at least 0.25 percent of the total radiated power. Any radiation in excess of the limits specified in paragraph (c) of this section is considered to be an unauthorized emission.

(b) The maximum authorized bandwidth of emission corresponding to the types of emission specified in § 89.105 (a) and (c), and the maximum authorized frequency deviation in the case of frequency or phase modulated emission, shall be as follows:

(1) For all type A3 emissions, the maximum authorized bandwidth shall be 8 kHz.

(2) For all F3 emission, the maximum authorized bandwidth and maximum authorized frequency deviation shall be as follows:

Frequency band (MHz)	Authorized bandwidth (kHz)	Frequency deviation (kHz)
25 to 50	20	5
50 to 150	[1] 20	[1] 5
150 to 450	20	5
450 to 470	[2] 20	[3] 5
470 to 950	40	15

[1] Stations authorized for operation on or before Dec. 1, 1961, in the frequency band 73.0-74.6 MHz may continue to operate with a bandwidth of 40 kHz and a deviation of ± 15 kHz.

[2] Effective Nov. 1, 1967. Stations authorized before Nov. 1, 1967, may continue to operate with a maximum of 40 kHz bandwidth until Nov. 1, 1971.

[3] Effective Nov. 1, 1967, for new stations. Effective June 1, 1968, for stations authorized prior to Nov. 1, 1967, if located less than 100 miles from the center of any urbanized area of 200,000 or more population. Stations authorized prior to Nov. 1, 1967, for operation outside of 100 miles of any urbanized area of 200,000 or more population, may continue to operate with a deviation of 15 kHz until Nov. 1, 1971. Such wide band systems will be required to reduce deviation at the time of any frequency change or should harmful interference be caused to stations operating on adjacent 25 kHz channels. Urbanized areas are listed in the U.S. Census of Population, 1960, vol. 1, table 23, page 1-50.

(3) For all type A1 emissions, the maximum authorized bandwidth shall be 0.25 kHz.

(c) The mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the following schedule:

(1) On any frequency removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidths: At least 25 decibels;

(2) On any frequency removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: At least 35 decibels;

(3) On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least 43 plus 10 $\log_{10}$ (mean output power in watts) decibels or 80 decibels, whichever is the lesser attenuation.

(d) When an unauthorized emission results in harmful interference, the Commission may, in its discretion, require appropriate technical changes in equipment to alleviate the interference.

§ 89.109 Modulation requirements.

(a) The maximum audio frequency required for satisfactory radiotelephone intelligibility in these services is considered to be 3000 hertz.

(b) When amplitude modulation is used for telephony, the modulation percentage shall be sufficient to provide efficient communication and normally shall be maintained above 70 percent on peaks, but shall not exceed 100 percent on negative peaks.

(c) Each transmitter shall be equipped with a device which automatically prevents modulation in excess of that specified in this subpart which may be caused by greater than normal audio level: *Provided, however*, That this requirement shall not be applicable to transmitters authorized to operate as mobile stations with a maximum plate power input to the final radio frequency stage of 3 watts or less.

(d) Each transmitter in the frequency ranges 25 to 50, 150.8 to 162, and 450 to 460 MHz shall be equipped with an audio low-pass filter. Such filter shall be installed between the modulation limiter and the modulated stage and shall meet the specifications contained in paragraph (h) of this section. The provisions of this paragraph do not apply to transmitters of licensed radiocommunications systems operated wholly within the limits of one or more of the territories or possessions of the United States, or Alaska or Hawaii.

(e) Each transmitter in the frequency ranges 72.0–73.0 and 75.4–76.0 MHz shall be equipped with a device which automatically prevents modulation in excess of that specified in this subpart which may be caused by greater than normal audio level.

(f) Each transmitter in the frequency ranges 72.0–73.0 and 75.4–76.0 MHz shall be equipped with an audio low-pass filter. The required filter shall be installed between the modulation limiter and the modulated stage and shall meet the specifications contained in paragraph (h) of this section.

(g) Each transmitter in the frequency range 73.0–74.6 MHz first authorized after July 1, 1950, must be equipped with a device which automatically prevents modulation in excess of that specified in this subpart which may be caused by a greater than normal audio level. An audio low-pass filter is not required regardless of the date of authorization.

(h) Except as provided in paragraph (i) of this section, at audio frequencies between 3 kHz and 15 kHz, the low-pass filter required by the provisions of paragraph (d) of this section shall have an attenuation greater than the attenuation at 1 kHz by at least:

$$40 \log_{10} (f/3) \text{ decibels}$$

where "f" is the audio frequency in kHz. At audio frequencies above 15 kHz, the attenuation shall be at least 28 decibels greater than the attenuation at 1 kHz.

(i) For stations authorized in the 450–470 MHz band on or after November 1, 1967, at audio frequencies between 3 kHz and 20 kHz, the low-pass filter required by the provisions of paragraphs (d) and (f) of this section shall have an attenuation greater than the attenuation at 1 kHz by at least:

$$60 \log_{10} (f/3) \text{ decibels}$$

where "f" is the audio frequency in kHz. At audio frequencies above 20 kHz, the attenuation shall be at least 50 decibels greater than the attenuation at 1 kHz. Transmitters authorized in the 450–470 MHz band before November 1, 1967, will be required to comply with the provisions of this paragraph by November 1, 1971.

§ 89.111 Power and antenna height.

(a) The power which may be used by a station in these services shall be no more than the minimum required for satisfactory technical operation commensurate with the size of the area to be served and local conditions which affect radio transmission and reception. In cases of harmful interference, the Commission may order a change in power or antenna height, or both.

NOTE: Applications for authorizations filed on or after April 17, 1967, must specify no more power than the actual power necessary for satisfactory operation.

(b) Except where the maximum power that may be used on a particular frequency is specifically designated in connection with the use of such frequency, plate power input to the final radio frequency stage in excess of the following tabulation will not be authorized:

Frequency range:	*Maximum plate power input to the final radio frequency stage (watts)*
1.6 to 8 MHz	2,000
8 to 25 MHz	1,000
25 to 100 MHz	500
100 to 460 MHz	600
Above 460 MHz	(1)

[1] To be specified in the station authorization.

(c) The plate power input to the final r. f. stage under actual operation shall not exceed by more than 10 percent the plate power input shown in the Radio Equipment List, Part C, for transmitters included in this list, or the manufacturer's rated plate power input for the particular transmitter specifically listed on the authorization.

§ 89.113 Transmitter control requirements.

(a) Each transmitter shall be so installed and protected that it is not accessible to or capable of operation by persons other than those duly authorized by the licensee.

(b) A control point is an operating position which meets all of the following conditions:

(1) The position must be under the control and supervision of the licensee;

(2) It is a position at which the monitoring facilities required by this section are installed; and

(3) It is a position at which a person immediately responsible for the operation of the transmitter is stationed.

(c) Each station which is not authorized for unattended operation shall be provided with a control point, the location of which will be specified in the license. Unattended stations may be provided with a control point if authorized by the Commission. In urban areas the location will be specified "same as transmitter" unless the control point is at a street address different from that of the transmitter. In rural areas the location will be specified "same as transmitter" unless the control point is more than 500 feet from the transmitter, in which case the approximate location will be specified in distance and direction from the transmitter in terms of feet and geographical quadrant, respectively. It will be assumed that the location of the control point is the same as the location of the transmitter unless the application includes a request for a different location described in appropriate terms as indicated in this paragraph. Authority must be obtained from the Commission for the installation of additional control points.

(d) A dispatch point is any position from which messages may be transmitted under the supervision of the person at a control point who is responsible for the operation of the transmitter. Dispatch points may be installed without authorization.

(e) At each control point, the following facilities shall be installed:

(1) A carrier operated device which will provide continuous visual indication when the transmitter is radiating; or, in lieu thereof, a pilot lamp or meter which will provide continuous visual indication when the transmitter control circuits have been placed in a condition to produce radiation: *Provided however*, That the provisions of this subparagraph shall not apply to hand-carried or pack-carried transmitters or to transmitters installed on motorcycles;

(2) Equipment to permit the person responsible for the operation of the transmitter to aurally monitor all transmissions originating at dispatch points under his supervision;

(3) Facilities which will permit the person responsible for the operation of the transmitter either to disconnect the dispatch point circuits from the transmitter or to render the transmitter inoperative from any dispatch point under his supervision; and

(4) Facilities which will permit the person responsible for the operation of the transmitter to turn the transmitter carrier on and off at will.

§ 89.115 Transmitter measurements.

(a) The licensee of each station shall employ a suitable procedure to determine that the carrier frequency of each transmitter, authorized to operate with a plate input power to the final radio frequency stage in excess of 3 watts, is maintained within the tolerance prescribed in this part. This determination shall be made, and the results thereof entered in the station records, in accordance with the following:

(1) When the transmitter is initially installed;

(2) When any change is made in the transmitter which may affect the carrier frequency or the stability thereof;

(3) At intervals not to exceed one year, for transmitters employing crystal-controlled oscillators;

(4) At intervals not to exceed one month, for transmitters not employing crystal-controlled oscillators.

(b) The licensee of each station shall employ a suitable procedure to determine that the plate power input to the final radio frequency stage of each base station or fixed station transmitter, authorized to operate with a plate input power to the final radio frequency stage in excess of 3 watts, does not exceed the maximum figure specified on the current station authorization. Where the transmitter is so constructed that a direct measurement of plate current in the final radio frequency stage is not practicable, the plate input power may be determined from a measurement of the cathode current in the final radio frequency stage. When the plate input to the final radio frequency stage is determined from a measurement of the cathode current, the required entry shall indicate clearly the quantities that were measured, the measured values thereof, and the method of determining the plate power input from the measured values. This determination shall be made, and the results thereof entered in the station records, in accordance with the following:

(1) When the transmitter is initially installed;

(2) When any change is made in the transmitter which may increase the transmitter power input;

(3) At intervals not to exceed one year.

(c) The licensee of each station shall employ a suitable procedure to determine that the modulation of each transmitter, authorized to operate with a plate input power to the final radio frequency stage in excess of 3 watts, does not exceed the limits specified in this part. This determination shall be made and the results thereof entered in the station records, in accordance with the following:

(1) When the transmitter is initially installed;

(2) When any change is made in the transmitter which may affect the modulation characteristics;

(3) At intervals not to exceed one year.

(d) The determinations required by paragraphs (a), (b) and (c) of this section may, at the option of the licensee, be made by any qualified engineering measurement service, in which case, the required record entries shall show the name and address of the engineering measurement service as well as the name of the person making the measurements.

(e) In the case of mobile transmitters, the determinations required by paragraphs (a) and (c) of this section may be made at a test or service bench; provided, the measurements are made under load conditions equivalent to actual operating conditions, and provided further, that after installation the transmitter is given a routine check to determine that it is capable of being satisfactorily received by an appropriate receiver.

§ 89.117 Acceptability of transmitters for licensing.

(a) From time to time the Commission will publish a list of equipment entitled "Radio Equipment List, Part C, List of Equipment Acceptable for Licensing." Copies of this list are available for inspection at the Commission's Offices in Washington, D. C., and at each of its field offices. This list will include type approved and type accepted equipment and equipment which was included in this list on May 16, 1955. Such equipment will continue to be included on the list unless it is removed therefrom by Commission action.

(b) Except for transmitters used in developmental stations, transmitters authorized as of January 1, 1965, in police zone and interzone stations, and transmitters in radiolocation stations during the term of any license issued prior to January 1, 1973, each transmitter utilized by a station authorized for operation under this part must be of a type which is included on the Commission's current Radio Equipment List and is designated for use under this part or be of a type which has been type accepted by the Commission for use under this part.

(c) Transmitters to be operated in any of the frequency bands between 952 and 12,700 MHz, except the 8400–8500 MHz band, authorized under this part shall be type accepted if specified in an application filed after July 20, 1962, except that equipment authorized prior thereto may continue to be used provided such operation does not result in harmful interference to other stations or systems which are conforming to the microwave technical standards in § 89.121.

§ 89.119 Type acceptance of equipment.

(a) Any manufacturer of a transmitter to be built for use in this service may request "type acceptance" for such transmitter following the type acceptance procedure set forth in Part 2 of this chapter.

(b) Type acceptance for an individual transmitter may also be requested by an applicant for a station authorization by following the type acceptance procedures set forth in Part 2 of this chapter. Such transmitters, if accepted, will not normally be included on the Commission's "Radio Equipment List, Part C, List of Equipment Acceptable for Licensing" but will be individually enumerated on the station authorization.

(c) Additional rules with respect to type acceptance are set forth in Part 2 of this chapter. These rules include information with respect to withdrawal of type acceptance, modification of type accepted equipment and limitations on the findings upon which type acceptance is based.

§ 89.121 Microwave technical standards.

The technical standards indicated in the table in this section shall govern, beginning July 20, 1961, the issuance of authorizations for private microwave systems using the frequency bands above 952 MHz listed in the table. However, these standards shall not be applicable to transmitting equipment (including antennas) which were authorized to be operated on these frequencies prior to July 20, 1961, or for which an authorization is issued based on an application filed with the Commission prior to July 20, 1961. Such licensees of equipment and systems not subject to these technical standards, including their successors or assigns in business, will be permitted to utilize such equipment provided such operation does not result in harmful interference to another station or system which is conforming to these technical standards. In case of such harmful interference, such non-conforming licensee will be required to take whatever corrective measures are necessary to alleviate the interference.

Frequency band—MHz	Power [1] (watts)	Tolerance (percent)	Bandwidth [2]	Beamwidth [3] (degrees)
952-960	[8] 30	0.0005	100 kHz	[7] 20
1850-1990	18	.02	8 MHz	10
2130-2150	15	.001	800 kHz	10
2150-2160	15	.001	10 MHz	360
2160-2200	15	.001	800 kHz	10
2450-2500 [4]	12	(5)	(5)	(5)
2500-2690 [6]	12	.02	4 MHz	10
6525-6575	7	.02	25 MHz	7
6575-6875	7	.02	10 MHz	5
10550-10680	5	(5)	25 MHz	4
12200-12700	5	.05	20 MHz	4
Above 16000	5	(5)	50 MHz	(5)

[1] Maximum rated power output of transmitter. Power in excess of that shown herein will be authorized only under exceptional circumstances based upon a factual showing of need. For pulsed systems average power shall be limited to the values shown, peak power shall not exceed 5 times this limit.

[2] Maximum bandwidth (necessary or occupied, whichever is greater) which will be authorized. Except in the 2130-2160 and 2180-2200 MHz bands, consideration will be given on a case-by-case basis, to requests for additional adjacent channels based upon a complete and specific factual showing of unique or unusual circumstances, apart from economic considerations, requiring such additional channels. In the band 952-960 MHz, bandwidths up to 500 kHz may be authorized.

[3] Maximum beamwidth of major lobe between 0.5 power points in horizontal plane. Exceptions may be granted for stations in remote areas or until harmful interference is caused to other stations operating in accordance with these provisions.

[4] Subject to no protection from ISM equipment on 2450 MHz.

[5] To be specified in the station authorization.

[6] Operational fixed stations employing television transmissions in this band must utilize transmitting equipment which meets the technical requirements for Instructional Television Fixed stations as contained in Part 74, Subpart I, § 74.901, et seq., of this chapter. See also § 89.101(i)(8).

[7] Except for the frequencies 952.1, 952.2, 952.3, 952.4, 952.5, 952.6, and 952.7 MHz and the frequency pairs 950.9 and 956.3; 959.8 and 956.2; 956.5 and 952.9; and 956.4 and 952.8 MHz, where the beamwidth may be 360°.

[8] Except for the frequencies 952.1, 952.2, 952.3, 952.4, 952.5, 952.6, and 952.7 MHz, where the maximum power may be 100 watts.

§ 89.122 Interim provisions for operation of radioteleprinters in the Police and Fire Radio Services.

(a) F2 or F9 emission (audio frequency tone shift or tone phase shift) for radioteleprinter or audio passband multiplexed radiotelephony/radioteleprinter, respectively, will be authorized for base station use only in the Police and Fire Radio Services, except on mobile only frequencies, subject to the following conditions:

(1) Information is submitted with the application to establish that the minimum separation between the proposed radioteleprinter base station and the nearest cochannel base station of another licensee operating a voice system is 75 miles for the single frequency mode of operation or 35 miles for the two frequency mode of operation, or

(2) Where the minimum mileage separation that would be applicable under subparagraph (1) of this paragraph cannot be achieved, information is submitted with the application showing that agreement to the use of F2 or F9 emission for radioteleprinter operation has been received from all existing cochannel licensees using voice emission within the applicable mileage limits. If it develops that agreement was not received from an existing cochannel licensee and the radioteleprinter operation interferes with the licensee's voice operations, the licensee of the radioteleprinter system is responsible for eliminating the interference. New licensees of voice operations sharing a frequency with any established radioteleprinter operation must tolerate any interference received from the radioteleprinter operation.

(3) The application lists the manufacturer and model number of the radioteleprinter system to be employed or in lieu thereof contains a detailed technical description of the system and emitted radioteleprinter data language.

(4) The provisions in this part applicable to use of F3 emission are also applicable to use of F2 or F9 emission for radioteleprinters. The station identification required by § 89.153 shall be by voice.

(5) Frequencies will not be assigned exclusively for F2 emission for radioteleprinter.

(6) Transmitters type accepted under this part for use of F3 emission may also be used for F2 or F9 emission for radioteleprinter, provided, for each of these emissions, the audio keying signal is passed through the low pass audio frequency filter required to be provided in the transmitter for F3 emission. The transmitter must be so adjusted and operated that the instantaneous frequency deviation does not exceed the maximum value allowed for F3 emission.

OPERATING REQUIREMENTS

§ 89.151 Operating procedure.

(a) All communications, regardless of their nature, shall be restricted to the minimum practicable transmission time, and an efficient operating procedure shall be employed by each licensee.

(b) Continuous radiation of an unmodulated carrier is prohibited except when required for test purposes.

(c) Zone and interzone stations shall employ the standard operating procedure prescribed by the Commission. Copies of such procedure are available for distribution to persons having a legitimate need therefor. Requests for copies should be addressed to the Secretary, Federal Communications Commission, Washington, D.C., 20554.

(d) The Commission expects each licensee to take reasonable precautions to prevent unnecessary interference. If harmful interference develops, the Commission may require any or all stations to monitor the transmitting frequency prior to transmission.

(e) Tests may be conducted by any licensed station as required for proper station and system maintenance, but such tests shall be kept to a minimum and precautions shall be taken to avoid interference to other stations.

§ 89.153 Station identification.

(a) Except as provided in paragraph (b) of this section, the required identification for stations in these services shall be the assigned call signal.

(b) In lieu of meeting the requirements of paragraph (a) of this section, mobile units in the Police, Fire, Forestry-Conservation, Highway Maintenance, and Local Government Radio Services operating above 30 MHz may identify by means of an identifier other than the assigned call signal: *Provided*, That such identifier contain, as a minimum, the name of the governmental subdivision under which the unit is licensed; that the identifier is not composed of letters or letters and digits arranged in a manner which could be confused with an assigned radio station call signal: *And provided further*, That the licensee notifies, in writing, the Engineer in Charge of the District in which the unit operates concerning the specific identifiers being used by the mobile units.

(c) Nothing in this section shall be construed as prohibiting the transmission of additional station or unit identifiers which may be necessary for systems operation: *Provided, however*, Such additional identifiers shall not be composed of letters or letters and digits arranged in a manner which could be confused with an assigned radio station call signal.

(d) Except as indicated in paragraphs (e), (f), and (g) of this section, each station in these services shall transmit the required identification at the end of each transmission or exchange of transmissions, or once each 30 minutes of the operating period, as the licensee may prefer.

(e) A mobile station authorized to the licensee of the associated base station and which transmits only on the transmitting frequency of the associated base station is not required to transmit any identification.

(f) Except as indicated in paragraph (e) of this section, a mobile station shall transmit an identification at the end of each transmission or exchange of transmissions, or once each 30 minutes of the operating period, as the licensee may prefer. Where election is made to transmit the identification at 30-minute intervals, a single mobile unit in each general geographic area may be assigned the responsibility for such transmission and thereby eliminate any necessity for every unit of the mobile station to transmit the identification. For the purpose of this paragraph the term "each general geographic area" means an area not smaller than a single city or county and not larger than a single district of a State where the district is administratively established for the service in which the radio system operates.

(g) A station which is transmitting for telemetering purposes or for the actuation of devices, or which is retransmitting by self-actuating means a radio signal received from another radio station or stations, will be considered for exemption from the requirements of paragraph (d) of this section in specific instances, upon request.

§ 89.155 Suspension of transmission required.

The radiations of the transmitter shall be suspended immediately upon detection or notification of a deviation from the technical requirements of the station authorization until such deviation is corrected, except for transmissions concerning the immediate safety of life or property, in which case the transmissions shall be suspended as soon as the emergency is terminated.

§ 89.157 Mobile installations in vehicles not under the continuous control of the licensee.

A mobile radio station licensed in these services may not be installed or maintained in a vehicle, aircraft, or vessel, which is not at all times controlled exclusively by the licensee, unless precautions have been taken to eliminate effectively the possibility of the licensed transmitter being operated during the period that the vehicle, aircraft, or vessel is not under the control of the licensee.

§ 89.159 Emergency operation of mobile stations at fixed locations.

During an emergency requiring a local communication center, any authorized mobile transmitter may be operated temporarily as a base station at a fixed location for a period not to exceed ten days. If operation for a longer period is required, such operation must be specifically authorized.

§ 89.161 Communication with other stations.

In those cases which require cooperation or coordination of activities, stations in the Public Safety Radio Services may communicate with stations in other services and with U. S. Government stations.

§ 89.163 Operator requirements.

(a) *Operation during the course of normal rendition of service—radiotelephone.* (1) The following classes of stations transmitting on frequencies above 25 MHz may be operated by an unlicensed person, if authorized to do so by the station licensee:

(i) From a control point—a mobile, a base or fixed station.

(ii) From a dispatch point—a base or fixed station.

(2) Mobile stations transmitting on frequencies below 25 MHz may be operated by an unlicensed person when such station is associated with and under the operational control of a base station of the same licensee. Mobile stations not associated with such a base station must be operated by a person holding a com-

mercial radio operator license or permit of any class issued by the Commission.

(3) Base stations and fixed stations transmitting on frequencies below 25 MHz shall be operated as follows:

(i) From a control point, only a person holding a commercial radio operator license or permit of any class issued by the Commission shall operate a base station or fixed station.

(ii) From a dispatch point, an unlicensed person may operate a base station or fixed station after being authorized to do so by the station licensee: *Provided, however,* That such operation shall be under the direct supervision and responsibility of a person who holds a commercial radio operator license or permit of any class issued by the Commission and who is on duty at a control point meeting the requirements of § 89.113.

(b) *Operation during the course of normal rendition of service—radiotelegraph.* Only a person holding a commercial radiotelegraph operator license or permit of any class issued by the Commission shall operate a station when transmitting radiotelegraphy by any type of the Morse Code.

(c) *Maintenance or test operations.* All transmitter adjustments or tests during or coincident with the installation, servicing, or maintenance of a radio station, which may affect the proper operation of such station, shall be made by or under the immediate supervision and responsibility of a person holding a first- or second class commercial radio operator license, either radiotelephone or radiotelegraph, who shall be responsible for the proper functioning of the station equipment: *Provided, however,* That only persons holding a radiotelegraph first- or second-class operator license shall perform such functions at radiotelegraph stations transmitting by any type of the Morse Code.

(d) *Unattended operation.* No person is required to be in attendance at a station when transmitting during normal rendition of service and when either:

(1) Transmitting for telemetering purposes or

(2) Retransmitting by self-actuating means a radio signal received from another radio station or stations.

(e) *Licensed operator required.* Notwithstanding any other provisions of this section, unless the transmitter is so designed that none of the operations necessary to be performed during the course of normal rendition of service may cause off-frequency operation or result in any unauthorized radiation, and unless the transmitter is so installed that all controls which may cause improper operation or radiation are not readily accessible to the person operating the transmitter, such transmitter shall be operated by a person holding a first- or second-class commercial radio operator license, either radiotelephone or radiotelegraph as may be appropriate for the type of emission being used, issued by the Commission.

(f) *Licensee responsibility.* The provisions of this section authorizing certain unlicensed persons to operate certain stations, or authorizing unattended operation of stations in certain circumstances, shall not be construed to change or diminish in any respect the responsibility of station licensees to have and to maintain control over the stations licensed to them (including all transmitter units thereof), or for the proper functioning and operation of those stations (including all transmitter units thereof) in accordance with the terms of the licenses of those stations.

§ 89.165 Posting of operator license.

(a) The original license of each base or fixed station operator, other than an operator exclusively performing service and maintenance duties, shall be posted or kept immediately available at the place where he is on duty as an operator: *Provided, however,* That if an operator who is on duty holds a restricted radiotelephone operator permit of the card form (as distinguished from such document of the diploma form) or holds a valid license verification card (FCC Form 758-F) attesting to the existence of any other valid commercial radio operator license, he may have such permit or verification card, as the case may be, in his personal possession.

(b) Whenever a licensed operator is required for a mobile station, the original license of each such operator, other than an operator exclusively performing service and maintenance duties, shall be kept in his personal possession whenever he performs the duties of an operator at such station: *Provided,* That in lieu of an original license of the diploma form (as distinguished from such document of the card form) he may have in his personal possession a valid verification card attesting to its existence.

(c) The original license of every station operator who exclusively performs service and maintenance duties at that station shall be posted at the transmitter involved whenever the transmitter is in actual operation while service or maintenance work is being performed by him or under his immediate supervision and responsibility: *Provided,* That in lieu of posting his license, he may have on his person either his license or a valid verification card.

§ 89.167 Posting station licenses and transmitter identification cards or plates.

(a) The current authorization for each mobile station and each base or fixed station authorized to be operated at temporary locations shall be retained as a permanent part of the station records, but need not be posted. In addition, an executed Transmitter Identification Card (FCC Form 452-C) or a plate of metal or other durable substance, legibly indicating the call sign and the licensee's name and address, shall be affixed readily visible for inspection, to each of such transmitters: *Provided,* That, if the transmitter is not in view of the operating position or is not readily accessible for inspection, then such card or plate shall be affixed to the control equipment at the transmitter operating position or posted adjacent thereto.

(b) The current authorization, or a clearly legible photocopy thereof, for each base or fixed station at a fixed location shall be posted at the principal control point of the station, and a photocopy of such authorization shall also be posted at all other control points listed on the authorization. If a photocopy of the authorization is posted at the principal control point, the location of the original shall be stated on that photocopy. In addition, an executed Transmitter Identification Card (FCC Form 452-C) or a plate of metal or other durable substance, legibly indicating the call sign and the licensee's name and address, shall be affixed, readily visible for inspection, to each transmitter operated at a fixed location, when such transmitter is not in view of, or is not readily accessible to, the operator at the principal control point.

§ 89.169 Inspection of stations.

All stations and records of stations in these services shall be made available for inspection at any time while the station is in operation or shall be made available for inspection upon reasonable request of an authorized representative of the Commission.

§ 89.171 Inspection and maintenance of tower marking and associated control equipment.

The licensee of any radio station which has an antenna structure required to be painted or illuminated pursuant to the provisions of section 303 (q) of the Communications Act of 1934, as amended, and/or Part 17 of this chapter shall comply with the provisions of this section in the operation and maintenance of such tower marking as follows:

(a) Shall make an observation of the tower lights at least once each 24 hours either visually or by observing an automatic and properly maintained indicator designed to register any failure of such lights, to insure that all such lights are functioning properly as required; or alternatively.

(b) Shall provide and properly maintain an automatic alarm system designed to detect any failure of such lights and to provide indication of such failure to the licensee.

(c) Shall report immediately by telephone or telegraph to the nearest Flight Service Station or office of the Federal Aviation Agency any observed or otherwise known failure of a code or rotating beacon light or top light not corrected within 30 minutes, regardless of the cause of such failure. Further notification by telephone or telegraph shall be given immediately upon resumption of the required illumination.

(d) Shall inspect at intervals not to exceed 3 months all automatic or mechanical control devices, indicators and alarm systems associated with the tower lighting to insure that such apparatus is functioning properly.

(e) Shall exhibit all lighting from sunset to sunrise unless otherwise specified.

(f) Shall maintain a supply of spare bulbs sufficient for immediate replacement purposes at all times.

(g) Shall clean and repaint all towers as often as necessary to maintain good visibility.

§ 89.173 Answers to a notice of violation.

Any licensee receiving official notice of a violation of the terms of the Communications Act of 1934, as amended, any legislative act or treaty to which the United States is a party, or the rules and regulations of the Federal Communications Commission, shall, within 10 days from such receipt or such other period as may be specified, send a written answer to the office of the Commission originating the official notice. If an answer cannot be sent, or an acknowledgment made within such period, acknowledgment and answer shall be made at the earliest practicable date with a satisfactory explanation of the delay. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or answers to other notices. The reply shall set forth the steps taken to prevent a recurrence of improper operation.

§ 89.175 Content of station records.

Each licensee of a station in these services shall maintain records in accordance with the following:

(a) For all stations, the results and dates of the transmitter measurements required by these rules and the name of the person or persons making the measurements.

(b) For all stations, when service or maintenance duties are performed, the responsible operator shall sign and date an entry in the station record giving:

(1) Pertinent details of all duties performed by him or under his supervision;

(2) His name and address, and

(3) The class, serial number and expiration date of his license: *Provided*, That the information called for by subparagraphs (2) and (3) of this paragraph so long as it remains the same, need be entered only once in the station record at any station where the responsible operator is regularly employed on a full time basis and at which his license is properly posted.

(c) For all base and fixed stations except such stations which are authorized to be operated at temporary locations or for unattended operation, the name or names of persons responsible for the operation of the transmitting equipment each day, together with the period of their duty. Each such person shall sign, not initial, the record both when coming on and when going off duty.

(d) [Reserved]

(e) For stations whose antenna or antenna supporting structure is required to be illuminated a record in accordance with the following:

(1) The time the tower lights are turned on and off each day if manually controlled.

(2) The time the daily check of proper operation of the tower lights was made.

(3) In the event of any observed or otherwise known failure of a tower light:

(i) Nature of such failure.

(ii) Date and time the failure was observed, or otherwise noted.

(iii) Date, time and nature of the adjustments, repairs, or replacements that were made.

(iv) Identification of the Flight Service Station (FAA) notified of the failure of any code or rotating beacon light or top light not corrected within thirty minutes, and the date and time such notice was given.

(v) Date and time notice was given to the Flight Service Station (FAA) that the required illumination was resumed.

(4) Upon the completion of the periodic inspection required at least once each three months:

(i) The date of the inspection and the condition of all tower lights and associated tower lighting control devices, indicators and alarm systems.

(ii) Any adjustments, replacements, or repairs made to insure compliance with the lighting requirements and the date such adjustments, replacements, or repairs were made.

§ 89.177 Form of station records.

(a) The records shall be kept in an orderly manner and in such detail that the data required are readily available. Key letters or abbreviations may be used if proper meaning or explanation is set forth in the record.

(b) Each entry in the records shall be signed by a person qualified to do so having actual knowledge of the facts to be recorded.

(c) No record or portion thereof shall be erased, obliterated, or wilfully destroyed within the required retention period. Any necessary correction may be made only by the persons originating the entry who shall strike out the erroneous portion, initial the correction made and indicate the date of the correction.

§ 89.179 Retention of station records.

Records required to be kept by this part shall be retained by the licensee for a period of at least one year.

SUBPART B—[Reserved]

SUBPART C—DEVELOPMENTAL OPERATION

§ 89.201 Eligibility.

An authorization for developmental operation in any of the services under this part will be issued only to those persons who are eligible to operate stations in such service on a regular basis.

§ 89.203 Showing required.

(a) Except as provided in paragraph (b) of this section, each application for developmental operation shall be accompanied by a showing that:

(1) The applicant has an organized plan of development leading to a specific objective;

(2) A point has been reached in the program where actual transmission by radio is essential to the further progress thereof;

(3) The program has reasonable promise of substantial contribution to the expansion or extension of the radio art, or is along lines not already investigated;

(4) The program will be conducted by qualified personnel;

(5) The applicant is legally and financially qualified, and possesses adequate technical facilities for conduct of the program as proposed; and

(6) The public interest, convenience, or necessity will be served by the proposed operation.

(b) The provisions of paragraph (a) of this section do not apply when an application is made for developmental operation solely for the reason that the frequency requested is restricted to such developmental use.

§ 89.205 Limitations on use.

Stations used for developmental operation shall be constructed and used in such a manner as to conform with all of the technical and operating requirements of Subpart A of this part, unless deviation therefrom is specifically provided for in the station authorization.

§ 89.207 Frequencies available for assignment.

Stations engaged in developmental operation may be authorized to use a frequency, or frequencies, available for the service in which they propose to operate. The number of channels assigned will depend upon the specific requirements of the developmental program itself, and the number of frequencies available in the particular area where the station will be operated.

§ 89.209 Interference.

All developmental operation shall be subject to the condition that no harmful interference is caused to the operation of stations licensed on a regular basis under any part of this chapter.

§ 89.211 Special provisions.

(a) The developmental program as described by the applicant in the application for authorization shall be substantially followed unless the Commission shall otherwise direct.

(b) Where some phases of the developmental program are not covered by general rules of the Commission and the rules in this part, the Commission may specify supplemental or additional requirements or conditions in each case, as deemed necessary in the public interest, convenience, or necessity.

(c) The Commission may, from time to time, require a station engaged in developmental work to conduct special tests which are reasonable and desirable to the authorized developmental program.

§ 89.213 Change or cancellation of authorization without hearing.

Every application for authority to engage in developmental operation shall be accompanied by a statement signed by the applicant in which it is agreed that any authorization issued pursuant thereto will be accepted with the express understanding of the applicant that it is subject to change in any of its terms or to cancellation in its entirety at any time, upon reasonable notice but without a hearing, if, in the opinion of the Commission, circumstances should so require.

§ 89.215 Report of operation.

A report on the results of the developmental program shall be filed with and made a part of each application for renewal of authorization, or in cases where no renewal is requested, such report shall be filed within 60 days of the expiration of such authorization. Matters which the applicant does not wish to disclose publicly may be so labeled; they will be used solely for the Commission's information, and will not be publicly disclosed without permission of the applicant. The report shall include comprehensive and detailed information on the following:

(a) The final objective.

(b) Results of operation to date.

(c) Analysis of the results obtained.

(d) Copies of any published reports.

(e) Need for continuation of the program.

(f) Number of hours of operation on each frequency.

SUBPART D—[Reserved]

SUBPART E—LOCAL GOVERNMENT RADIO SERVICE

§ 89.251 Eligibility.

Authorizations for stations in the Local Government Radio Service will be issued only to territories, possessions, states, other governmental subdivisions including counties, cities, towns and similar governmental entities including districts and authorities but not including school districts or park authorities.

§ 89.253 Permissible communications.

Stations in the Local Government Radio Service are authorized to transmit communications essential to official activities of the licensee.

§ 89.255 Points of communication.

(a) Local government base stations are authorized to intercommunicate with local government mobile stations. Local government mobile stations are authorized to intercommunicate with local government base stations and other local government mobile stations.

(b) Local government base and mobile stations are also authorized to intercommunicate with other stations in the Public Safety Radio Services and to transmit to receivers at fixed locations: *Provided*, That no harmful interference will be caused to the base-mobile operations of any authorized station.

(c) Local government fixed stations are authorized to intercommunicate with other fixed stations in the Public Safety Radio Services and to transmit to receivers at fixed locations.

§ 89.257 Station limitations.

(a) Mobile relay stations in the Local Government Radio Service will be authorized only on frequencies above 150 MHz which are, pursuant to the provisions of § 89.259(f), available for base or mobile stations. Each mobile relay station authorized pursuant to the provisions of this section which is intended to be activated by signals transmitted on a frequency below 50 MHz shall be so designed and installed that:

(1) Normally it will be activated only by means of the coded signal or signals or such other means as will effectively prevent its activation by undesired signals;

(2) It will be deactivated automatically when its associated receivers are not receiving the signal on the frequency or frequencies which normally activate it; and

(3) It will be deactivated upon receipt or cessation of a coded signal or signals, or shall be provided with an automatic time delay or clock device which will deactivate the station not more than three minutes after its activation.

(b) A control station associated with one or more mobile relay stations, authorized pursuant to this section, may be assigned the mobile service frequency assigned to the associated mobile station. Use of the mobile service frequency by such control station is subject to the condition that harmful interference not be caused to stations of other licensees operating in the mobile service in accordance with the table of frequency allocations as set forth in Part 2 of this chapter.

(c) Voice, tone, or impulse signalling, for the purposes enumerated in sub-paragraph (1) of this paragraph, may be used, on a secondary basis, to the extent provided in this Subpart on the mobile service frequencies above 25 MHz in the Local Government Radio Service, provided a showing is made that such operations will not cause harmful interference to the primary operations of any co-channel licensee, and subject to the condition that harmful interference is not caused to the primary operations of any licensee. All such secondary signalling shall be subject to the following limitations:

(1) Secondary voice, tone or impulse signalling may be used only for the following purposes:

(i) Automatic indication of equipment malfunction;

(ii) Actuation of a device to indicate the presence of an intruder or fire on property under the protection of the licensee.

(2) Any one alarm or warning shall be limited to not more than five transmissions, not to exceed 6 seconds each.

(3) The bandwidth shall not exceed that authorized to the licensee for its primary operations on the frequency concerned.

(4) Frequency loading resulting from the use of secondary voice, tone or impulse signalling will not be considered in whole or in part as a justification for authorizing additional frequencies in the licensee's mobile service system.

(5) A mobile service frequency may not be used exclusively for secondary voice, tone or impulse signaling.

(6) The plate power input to the final radio frequency stage shall not exceed 50 watts.

(7) Only A1, A2, A3, F1, F2, or F3 emissions will be authorized.

(8) Automatic means shall be provided to de-activate the transmitter in the event the carrier remains on for a period in excess of 3 minutes.

§ 89.259 Frequencies available to the Local Government Radio Service.

(a) The frequencies or bands of frequencies listed herein are available for assignment to stations in the Local Government Radio Service subject to the conditions and limitations of this section.

(b) The frequencies below 450 MHz shown in paragraph (f) of this section as being available for assignment to mobile stations only may be authorized for use by base stations only after coordination with affected licensees in the area and subject to the condition that no harmful interference will be caused to the service of any mobile station using the particular frequency. Evidence of the required coordination shall be submitted with any request for such use.

(c) The amount of separation between assignable frequencies listed in paragraph (f) of this section does not necessarily indicate the amount of frequency separation required for systems operation; accordingly, grants of adjacent channel assignments in all bands shall be in the discretion of the Commission.

(d) Normally, no more than two frequencies will be assigned unless a request therefor is adequately supported by a satisfactory showing of need, provided that request for operation on the frequency 39.06 MHz will be approved upon satisfactory showing of a need even though the licensee already has been assigned two other frequencies or provided that an applicant who obtains authorization to operate on the frequency 39.06 MHz shall still be allowed to request and obtain two other frequency assignments in this service.

(e) Control and repeater stations, except as provided for by § 89.257(b), in the Local Government Radio Service will be authorized only on frequencies allocated to operational fixed stations.

(f) The following tabulation indicates the frequencies or bands of frequencies, class of stations to which they are normally available, and the specific assignment limitations, which are developed in paragraph (g) of this section:

Frequency or band	Class of station(s)	Limitations
MHz		
37.10	Base and mobile	8
37.18	do	8
37.26	do	8
39.06	Mobile	6, 8, 9
39.10	Base and mobile	8
39.18	do	8
39.50	do	8
39.58	do	8
39.82	do	8
39.90	do	8
39.98	do	8
45.08	do	------
45.12	do	------
45.16	do	------
45.20	do	------
45.24	do	------
45.28	do	------
45.32	do	------
45.36	do	------
45.40	do	------
45.44	do	------
45.48	do	------
45.52	do	------
45.56	do	------
45.60	do	------
45.64	do	------
46.52	do	------
46.54	do	------
46.56	do	------
46.58	do	------
72.00 to 76.00	Operational fixed	3
153.755	Mobile	------
153.785	do	------
153.800	do	------
153.815	do	------
153.845	do	------
153.860	do	------
153.875	do	------
153.905	do	------
153.920	do	------
153.935	do	------
153.965	do	------
153.980	do	------
153.995	do	------
154.025	Base and mobile	------
154.040	do	10
154.055	do	10
154.085	do	10
154.100	do	10
154.115	do	10
154.4525–154.460	Fixed	1, 2
154.965	Base and mobile	------
154.980	do	------
154.995	do	------
155.025	do	------
155.040	do	------
155.055	do	------
155.085	do	------
155.100	do	------
155.115	do	------
155.145	do	------
155.715	do	------
155.745	do	------
155.760	do	------
155.775	do	------
155.805	do	------
155.820	do	------
155.835	do	------
155.865	do	------
155.880	do	------
155.895	do	------
155.925	do	------
155.940	do	------
155.955	do	------
155.985	Mobile	------
156.000	do	------
156.015	do	------
158.745	Base and mobile	------
158.760	do	------
158.775	do	------
158.805	do	------
158.820	do	------
158.835	do	------
158.865	Mobile	------
158.880	do	------
158.895	do	------
158.925	do	------
158.940	do	------
158.955	do	------
453.025	Base and mobile	5, 11
453.050	do	5
453.075	do	5, 11
453.100	do	5
453.125	do	5, 11
453.150	do	5
453.175	do	5, 11

Frequency or band	Class of station(s)	Limitations
MHz		
453.200	Base and mobile	5
453.225	do	5
453.250	do	5
453.275	do	5
453.300	do	5
453.325	do	5
453.350	do	5
453.375	do	5
453.400	do	5
453.425	do	5
453.450	do	5
453.475	do	5
453.500	do	5
453.525	do	5
453.550	do	5
453.575	do	5
453.600	do	5
453.625	do	5
453.650	do	5
453.675	do	5
453.700	do	5
453.725	do	5
453.750	do	5
453.775	do	5
453.800	do	5
453.825	do	5
453.850	do	5
453.875	do	5
453.900	do	5
453.925	do	5
453.950	do	5
453.975	do	5
458.025	Mobile only	4, 11
458.050	do	4
458.075	do	4, 11
458.100	do	4
458.125	do	4, 11
458.150	do	4
458.175	do	4, 11
458.200	do	4, 5
458.225	do	4, 5, 7
458.250	do	4, 5
458.275	do	4, 5, 7
458.300	do	4, 5
458.325	do	4, 5, 7
458.350	do	4, 5
458.375	do	4, 5, 7
458.400	do	4, 5
458.425	do	4, 5, 7
458.450	do	4, 5
458.475	do	4, 5, 7
458.500	do	4, 5
458.525	do	4, 5, 7
458.550	do	4, 5
458.575	do	4, 5, 7
458.600	do	4, 5
458.625	do	4, 5, 7
458.650	do	4, 5
458.675	do	4, 5, 7
458.700	do	4, 5
458.725	do	4, 5, 7
458.750	do	4, 5
458.775	do	4, 5, 7
458.800	do	4, 5
458.825	do	4, 5, 7
458.850	do	4, 5
458.875	do	4, 5, 7
458.900	do	4, 5
458.025	do	4, 5, 7
458.950	do	4, 5
458.975	do	4, 5, 7
(For frequencies 952 MHz and above, see §89.101.)		

(g) Explanation of assignment limitations appearing in the frequency tabulation of paragraph (f) of this section:

(1) This frequency is available for assignment to fixed stations for the purpose of providing emergency call box service. The maximum power output of the transmitter is 20 watts. A1, A2, F1, or F2 emission may be authorized; however, the authorized bandwidth may not exceed 6 kHz.

(2) For FM transmitters the sum of the highest modulating frequency in Hertz and the amount of frequency deviation or swing in Hertz may not exceed 2800 Hz and the maximum frequency deviation may not exceed 2.5 kHz. For AM transmitters the highest modulating frequency may not exceed 2000 Hz. The carrier frequency must be maintained within 0.0005 percent of the center of the frequency band.

(3) The frequencies available in the band 72 to 76 MHz are listed in § 89.101(c). These frequencies, which are shared with other services, are available only in acordance with the provisions of § 89.101.

(4) Control stations associated with mobile relay stations may be authorized to operate on the land mobile service frequency assigned to the associated mobile station. However, when located less than 75 miles from the center of any urbanized area of 200,000 or more population such stations must employ directional antennas having a front-to-back ratio of at least 15 dB and may radiate a signal that, when measured at the antenna terminals of the mobile relay station receiver, does not exceed the signal strength of a mobile station operating from the control station location by more than 6 dB. To make this measurement the mobile station may be moved no more than one-quarter mile away from the control location if necessary to provide a satisfactory signal at the mobile relay receiver. An engineering statement attesting to compliance with this signal level limitation shall accompany each control station application. Urbanized areas of 200,000 or more population are defined in the U.S. Census of Population, 1960, vol. 1, table 23, page 1-50. The centers of urbanized areas are determined from the appendix, page 226 of the U.S. Commerce publication "Air Line Distance Between Cities in the United States." Control stations authorized prior to June 1, 1968, must conform to this requirement no later than November 1, 1971.

(5) For two-frequency systems, separation between base and mobile transmit frequencies is 5 MHz, however, a mobile station may be assigned the frequency of an associated base station. (Such operation may, however, subject the single-frequency system to interference that would not occur to a two-frequency system.)

(6) Available for assignment: *Provided*, That the maximum plate input power to the final radio frequency stage of any transmitter authorized to operate on this frequency shall not exceed 3 watts.

(7) This frequency will be assigned for mobile operation within normal two-way communication range of any associated base stations.

(8) This frequency is shared with the Police Radio Service.

(9) Applicants for this frequency need not demonstrate compliance with the provisions of § 89.15.

(10) This frequency is not available for assignment to stations in the Local Government Radio Service at any location in Puerto Rico or the Virgin Islands.

(11) Reserved for possible future use for communication related to safety on highways.

(h) Frequencies offset by 7.5 kHz or less from those in the 152 to 162 MHz band listed in paragraph (f) of this section may be assigned for developmental operation upon an adequate showing of the need for such irregular assignment together with an acceptable engineering report indicating that harmful interference to the operation of existing stations will not be caused.

SUBPART F—[Reserved]

SUBPART G—POLICE RADIO SERVICE

§ 89.301 Eligibility.

(a) Authorizations for stations in the Police Radio Service will be issued only to states, territories, possessions and other governmental subdivisions including counties, cities, towns and similar governmental entities.

(b) The eligibility set forth in paragraph (a) of this section includes governmental institutions in those cases where such institution is authorized by law to provide its own police protection.

§ 89.303 Permissible communications.

Stations in the Police Radio Service are authorized to transmit communications essential to official police activities of the licensee.

§ 89.305 Points of communications.

(a) Police base stations are authorized to intercommunicate with police mobile stations. Police mobile stations are authorized to intercommunicate with police base stations and other police mobile stations.

(b) Police base and mobile stations are also authorized to intercommunicate with other stations in the Public Safety Radio Services and to transmit to receivers at fixed locations: *Provided*, That no harmful interference will be caused to the base-mobile operations of any authorized station.

(c) Police fixed stations are authorized to intercommunicate with other fixed stations in the Public Safety Radio Services and to transmit to receivers at fixed locations.

(d) Police zone and interzone stations are authorized to intercommunicate in accordance with the operating procedure prescribed by the Commission. Copies of such procedure are available for distribution to persons having a legitimate need therefor. Requests for copies should be addressed to the Secretary, Federal Communications Commission, Washington, D.C., 20554.

§ 89.307 Station limitations.

(a) Mobile relay stations in the Police Radio Service will be authorized only on frequencies above 150 MHz which are, pursuant to the provisions of § 89.309(g), available for base or mobile stations. Each mobile relay station authorized pursuant to the provisions of this section which is intended to be activated by signals transmitted on a frequency below 50 MHz shall be so designed and installed that:

(1) Normally it will be activated only by means of the coded signal or signals or such other means as will effectively prevent its activation by undesired signals;

(2) It will be deactivated automatically when its associated receivers are not receiving the signal on the frequency or frequencies which normally activate it; and

(3) It will be deactivated upon receipt or cessation of a coded signal or signals, or shall be provided with an automatic time delay or clock device which will deactivate the station not more than three minutes after its activation.

(b) Subject to the provisions of § 89.157, communication units of a licensed police mobile station may be installed in any vehicle which in an emergency would require cooperation or coordination with police activities. This provision includes fire department vehicles, ambulances, emergency units of public utilities, lifeguard emergency units and rural school buses.

(c) Authorizations for interzone stations in the Police Radio Service will not be issued for more than one station within a zone. A zone is normally considered to be a single state. Any request for the rezoning of any state for the purpose of providing more than one interzone station shall be accompanied by a showing of need based either upon the volume of traffic or upon the necessity for more expeditious handling of traffic. In either event such a request shall be accompanied by comments thereon from all zone stations affected.

(d) A control station associated with one or more mobile relay stations, authorized pursuant to this section, may be assigned the mobile service frequency assigned to the associated mobile station. Use of the mobile service frequency by such control station is subject to the condition that harmful interference not be caused to stations of other licensees operating in the mobile service in accordance with the table of frequency allocations as set forth in Part 2 of this chapter.

(e) Voice, tone, or impulse signalling, for the purposes enumerated in subparagraph (1) of this paragraph, may be used, on a secondary basis, to the extent provided in this Subpart on the mobile service frequencies above 25 MHz in the Police Radio Service, provided a showing is made that such operations will not cause harmful interference to the primary operations of any co-channel licensee, and subject to the condition that harmful interference is not caused to the primary operations of any licensee. All such secondary signalling shall be subject to the following limitations:

(1) Secondary voice, tone or impulse signalling may be used only for the following purposes:

(i) Automatic indication of equipment malfunction;

(ii) Actuation of a device to indicate the presence of an intruder on property under the protection of the licensee.

(2) Any one alarm or warning shall be limited to not more than five transmissions, not to exceed 6 seconds each.

(3) The bandwidth shall not exceed that authorized to the licensee for its primary operations on the frequency concerned.

(4) Frequency loading resulting from the use of secondary voice, tone or impulse signalling will not be considered in whole or in part as a justification for authorizing additional frequencies in the licensee's mobile service system.

(5) A mobile service frequency may not be used exclusively for secondary voice, tone or impulse signalling.

(6) The plate power input to the final radio frequency stage shall not exceed 50 watts.

(7) Only A1, A2, A3, F1, F2, or F3 emissions will be authorized.

(8) Automatic means shall be provided to de-activate the transmitter in the event the carrier remains on for a period in excess of 3 minutes.

(f) Mobile stations utilizing mobile service frequencies above 37 MHz may be used for the purpose of providing extended talk back range for low-power hand-carried transmitters.

(1) Hand-carried transmitters to be automatically relayed by mobile stations may be assigned a separate frequency for this use limited to a maximum power output of 2.5 watts.

(2) Each mobile station when used for the purpose of automatically retransmitting messages originated by or destined for hand-carried units shall be so designed and installed that it will be activated only by means of a continuous tone device, the absence of which will deactivate the mobile transmitter. The continuous tone device is not required when the mobile station is equipped with a switch that must be activated to change the mobile unit to the automatic mode and an automatic time delay device to deactivate the transmitter after any uninterrupted period of transmission in excess of three minutes.

(3) Mobile stations may also be used to provide extended base station talk out range to pocket or miniature receivers, however, any additional frequencies required for this purpose may not be used with power in excess of 2.5 watts.

§ 89.309 Frequencies available to the Police Radio Service.

(a) The frequencies or bands of frequencies listed herein are available for assignment to stations in the Police Radio Service subject to the conditions and limitations of this section.

(b) The frequencies below 450 MHz listed in this section for mobile stations may be authorized for use at base stations only after coordination with other licensees in the area is effected and subject to the condition that no harmful interference will be caused to the service of any mobile station using the particular frequency. Evidence of the required coordination shall be submitted with any request for such use.

(c) (1) Normally only one base and one mobile station frequency will be assigned to a licensee for mobile service operations. Additional frequencies may be assigned provided the request therefor is adequately supported by a satisfactory showing of need.

(2) In addition, a licensee in the Police Radio Service may use, without specific authorization from the Commission, any frequency between 40 MHz and 952 MHz listed in paragraph (g) of this section, which is available to the mobile services, for communications in connection with surveillance, stakeouts, raids, and other such activities. Such use shall be on a secondary basis and shall not cause harmful interference to communications of licensees in the Public Safety Radio Services authorized on regularly assigned frequencies. The maximum power that may be used for such communications is 2 watts into the antenna. Other provisions of this part, including the requirements for station identification, shall apply.

(d) The amount of separation between assignable frequencies listed in this section does not necessarily indicate the amount of frequency separation required for systems operation; accordingly, grants of adjacent channel assignments in all bands shall be in the discretion of the Commission.

(e) In addition to the frequencies assigned for mobile service operation, one base station frequency above 152 MHz may be assigned as a common frequency to all licensees in a particular area to permit intersystem communication between base stations or mobile stations or both. This frequency use will not be authorized in any area where all available frequencies are required for independent systems.

(f) Control and repeater stations, except as provided for by § 89.307(d), in the Police Radio Service may be authorized on a temporary basis to operate on frequencies available for base and mobile stations in the region 152–150 MHz, provided an adequate showing is made why such operation cannot be conducted on frequencies allocated to the Operational Fixed Service. Such operation on base or mobile frequencies will not be authorized initially nor renewed for periods in excess of 1 year. Any such authorization shall be subject to immediate termination if harmful interference is caused to the Mobile Service, or if the particular frequency is required for mobile service operations in the area concerned.

(g) The following tabulation indicates the frequency or bands of frequencies, the class of station(s) to which they are normally available and the specific assignment limitations, which are developed in paragraph (h) of this section.

Frequency or band	Class of station(s)	Limitations
kHz		
1610	Base and mobile	6, 7, 13
1618	do	6, 7, 13
1626	do	6, 7, 13
1634	do	6, 7, 13
1642	do	6, 7, 13
1650	do	7, 13
1658	do	7, 13
1666	do	7, 13

Frequency or band	Class of station(s)	Limitations
kHz		
1674	Base and mobile	7, 13
1682	do	7, 13
1690	do	6, 7, 13
1698	do	6, 7, 13
1706	do	6, 7, 13
1714	do	7, 13
1722	do	7, 13
1730	do	7, 13
2326	do	6, 7
2366	do	6, 7
2382	do	7
2390	do	6, 7
2400	do	7
2414	do	7
2422	do	7
2430	do	7
2442	do	7
2450	do	7
2458	do	7
2466	do	7
2474	do	7
2482	do	7
2490	do	7, 13
2804	Zone and interzone	9
2808	do	9
2812	do	9
5135	do	9, 15
5140	do	9
5195	do	9, 10
7480	do	9, 11, 14
7805	do	9, 11
7935	do	9, 11
MHz		
37.02	Mobile	
37.04	Base and mobile	
37.06	do	
37.08	do	
37.10	do	18
37.12	do	
37.14	do	
37.16	do	
37.18	do	18
37.20	do	
37.22	do	
37.24	do	
37.26	do	18
37.28	do	
37.30	do	
37.32	do	
37.34	Mobile	
37.36	Base and mobile	
37.38	Mobile	
37.40	Base and mobile	
37.42	Mobile	
39.02	Base and mobile	
39.04	do	
39.06	do	17, 18
39.08	do	
39.10	do	18
39.12	do	
39.14	do	
39.16	do	
39.18	do	18
39.20	do	
39.22	Base and mobile	
39.24	do	
39.26	Mobile	
39.28	Base and mobile	
39.30	Mobile	
39.32	Base and mobile	
39.34	Mobile	
39.36	Base and mobile	
39.38	Mobile	
39.40	Base and mobile	
39.42	do	
39.44	do	
39.46	do	16
39.48	do	
39.50	do	18
39.52	do	
39.54	do	
39.56	do	
39.58	do	18
39.60	do	
39.62	do	
39.64	do	
39.66	Mobile	
39.68	Base and mobile	
39.70	Mobile	
39.72	Base and mobile	
39.74	Mobile	
39.76	Base and mobile	
39.78	Mobile	
39.80	Base and mobile	
39.82	do	18
39.84	Base and mobile	
39.86	do	
39.88	do	
39.90	do	18
39.92	do	
39.94	do	
39.96	do	
39.98	do	18
42.02	do	7, 8, 13
42.04	do	7, 8, 13
42.06	do	7, 8, 13
42.08	do	7, 8, 13
42.10	do	7, 8, 13
42.12	do	7, 8, 13
42.14	do	7, 8, 13
42.16	do	7, 8, 13
42.18	Mobile	7, 8
42.20	do	7, 8
42.22	do	7, 8
42.24	do	7, 8
42.26	do	7, 8
42.28	do	7, 8
42.30	do	7, 8
42.32	Base and mobile	7, 8, 13
42.34	do	7, 8, 13
42.36	do	7, 8, 13
42.38	do	7, 8, 13
42.40	do	7, 8, 13
42.42	do	7, 8, 13
42.44	do	7, 8, 13
42.46	do	7, 8, 13
42.48	do	7, 8, 13
42.50	do	7, 8, 13
42.52	do	7, 8, 13
42.54	do	7, 8, 13
42.56	do	7, 8, 13
42.58	do	7, 8, 13
42.60	do	7, 8, 13
42.62	do	7, 8, 13
42.64	do	7, 8, 13
42.66	Mobile	7, 8
42.68	do	7, 8
42.70	do	7, 8
42.72	do	7, 8
42.74	do	7, 8
42.76	do	7, 8
42.78	do	7, 8
42.80	Base and mobile	7, 8, 13
42.82	do	7, 8, 13
42.84	do	7, 8, 13
42.86	do	7, 8, 13
42.88	do	7, 8, 13
42.90	do	7, 8, 13
42.92	do	7, 8, 13
42.94	Base and mobile	7, 8, 13
44.62	do	7, 8, 13
44.66	do	7, 8, 13
44.70	do	7, 8, 13
44.74	do	7, 8, 13
44.78	Mobile	7, 8
44.82	do	7, 8
44.86	do	7, 8
44.90	do	7, 8
44.94	Base and mobile	7, 8, 13
44.98	do	7, 8, 13
45.02	do	7, 8, 13
45.06	do	7, 8, 13
45.10	do	
45.14	do	
45.18	do	
45.22	do	
45.26	Mobile	
45.30	do	
45.34	do	
45.38	do	
45.42	Base and mobile	
45.46	do	
45.50	do	
45.54	do	
45.58	do	
45.62	do	
45.66	do	
45.70	do	
45.74	Mobile	
45.78	do	
45.82	do	
45.86	Base and mobile	16
45.90	do	
45.94	do	
45.98	do	
46.02	do	
72.02 to 76.00	Operational fixed	3
154.650	Mobile	
154.665	Base and mobile	8
154.680	do	8
154.695	do	8

Frequency or band	Class of station(s)	Limitations
MHz		
154.710	Mobile	
154.725	Base and mobile	
154.740	do	
154.755	do	
154.770	Mobile	
154.785	Base and mobile	
154.800	do	
154.815	do	
154.830	Mobile	
154.845	Base and mobile	
154.860	do	
154.875	do	
154.890	Mobile	
154.905	Base and mobile	8
154.920	do	8
154.935	do	8
154.950	Mobile	
155.01	Base and mobile	
155.07	do	
155.13	do	
155.19	do	
155.25	do	
155.31	do	
155.370	do	
155.415	do	
155.430	do	
155.445	do	8
155.460	do	8
155.475	do	8
155.490	do	
155.505	do	8
155.520	do	
155.535	do	
155.550	do	
155.565	do	
155.580	do	
155.595	do	
155.610	do	
155.625	do	
155.640	do	
155.655	do	
155.670	do	
155.685	do	
155.700	do	
155.730	do	
155.79	do	
155.85	Mobile	
155.01	do	
155.97	do	
156.03	do	
156.00	do	
156.15	do	
156.210	Base and mobile	
158.730	do	
158.790	do	
158.850	do	
158.910	Mobile	
158.970	do	
159.030	do	
159.090	Base and mobile	
159.150	do	
159.210	do	
453.050	do	
453.100	do	
453.150	do	
453.200	do	
453.250	do	
453.300	do	
453.350	do	
453.400	do	
453.450	do	
453.500	do	
453.550	do	
453.600	do	
453.650	do	
453.700	do	
453.750	do	
453.800	do	
453.850	do	
453.900	do	
453.950	do	
458.050	Mobile	2, 4
458.100	do	2, 4
458.150	do	2, 4
458.200	do	2, 4
458.250	do	2, 4
458.300	do	2, 4
458.350	do	2, 4
458.400	do	2, 4
458.450	do	2, 4
458.500	do	2, 4
458.550	do	2, 4
458.600	do	2, 4
458.650	do	2, 4
458.700	do	2, 4
458.750	do	2, 4
458.800	Mobile	2, 4
458.850	do	2, 4
458.900	do	2, 4
458.950	do	2, 4
460.025	Base and mobile	1, 2
460.050	do	1, 2
460.075	do	1, 2
460.100	do	1, 2
460.125	do	1, 2
460.150	do	1, 2
460.175	do	1, 2
460.200	do	1, 2
460.225	do	1, 2
460.250	do	1, 2
460.275	do	1, 2
460.300	do	1, 2
460.325	do	1, 2
460.350	do	1, 2
460.375	do	1, 2
460.400	do	1, 2
460.425	do	1, 2
460.450	do	1, 2
460.475	do	1, 2
460.500	do	1, 2
465.025	Mobile only	1, 2, 4
465.050	do	1, 2, 4
465.075	do	1, 2, 4
465.100	do	1, 2, 4
465.125	do	1, 2, 4
465.150	do	1, 2, 4
465.175	do	1, 2, 4
465.200	do	1, 2, 4
465.225	do	1, 2, 4
465.250	do	1, 2, 4
465.275	do	1, 2, 4
465.300	do	1, 2, 4
465.325	do	1, 2, 4
465.350	do	1, 2, 4
465.375	do	1, 2, 4
465.400	do	1, 2, 4
465.425	do	1, 2, 4
465.450	do	1, 2, 4
465.475	do	1, 2, 4
465.500	do	1, 2, 4
(For frequencies 952 MHz and above, see § 89.101)		

(h) Explanation of assignment limitations appearing in the frequency tabulation of paragraph (g) of this section:

(1) This frequency will be assigned for mobile operation within normal two-way communication range of any associated base station.

(2) For two-frequency systems, separation between base and mobile transmit frequencies is 5 MHz, however, a mobile station may be assigned the frequency of an associated base station. (Such operation may, however, subject the single-frequency system to interference that would not occur to a two-frequency system.)

(3) The frequencies available in the band 72 to 76 MHz are listed in § 89.101(c). These frequencies, which are shared with other services, are available only in accordance with the provisions of § 89.101.

(4) Control stations associated with mobile relay stations may be authorized to operate on the land mobile service frequency assigned to the associated mobile station. However, when located less than 75 miles from the center of any urbanized area of 200,000 or more population such stations must employ directional antennas having a front-to-back ratio of at least 15 dB and may radiate a signal that, when measured at the antenna terminals of the mobile relay station receiver, does not exceed the signal strength of a mobile station operating from the control station lo-

439-911 O - 71 - 25

cation by more than 6 dB. To make this measurement the mobile station may be moved no more than one-fourth mile away from the control location if necessary to provide a satisfactory signal at the mobile relay receiver. An engineering statement attesting to compliance with this signal level limitation shall accompany each control station application. Urbanized areas are defined in the U.S. Census of Population, 1960, vol. 1, table 23, page 1-50. The centers of urbanized areas are determined from the appendix, page 226 of the U.S. Commerce publication "Air Line Distance Between Cities in the United States." Control stations authorized prior to June 1, 1968, must conform to this requirement no later than November 1, 1971.

(5) [Reserved].

(6) The use of this frequency is subject to the condition that no harmful interference will be caused to the service of any Canadian station.

(7) This frequency is available for assignment only in accordance with a geographical assignment plan.

(8) This frequency is reserved primarily for assignment to state police licensees. Assignment to other police licensees will be made only where the frequency is required for coordinated operation with the state police system to which the frequency is assigned. Any request for such assignment must be supported by a statement from the state police system concerned indicating that the assignment is necessary for coordination of police activities.

(9) This frequency is available for assignment to zone and interzone stations in the Police Radio Service for use with type A1 emission only and a maximum plate input power of 1000 watts to the final radio frequency stage of the transmitter.

(10) This frequency is authorized for use as a calling frequency; however, the transmission of operating signals or a single short radio telegram is permissible provided no harmful interference will be caused to any calling signals.

(11) This frequency may be used only during that period of time between 2 hours after local sunrise and 2 hours before local sunset.

(12) [Reserved].

(13) Subject to the restrictions contained in § 89.111(a), base stations operating on this frequency and rendering service to state police mobile units may be authorized to use a maximum plate input power to the final radio frequency stage in excess of the maximum indicated in § 89.111(b), but not in excess of 10,000 watts: *Provided*, That such operation will cause no harmful interference to the service of other stations.

(14) This frequency may be assigned to fixed stations in the Police Radio Service in Alaska for point-to-point radiotelephone communication, using type A3 emission and a maximum plate input power of 1000 watts to the final radio frequency stage of the transmitter.

(15) This frequency may be assigned to fixed stations in the Police Radio Service in Alaska for point-to-point radiotelephone communications, using type A3 emission with a maximum plate input power of 1000 watts to the final radio frequency stage of the transmitter, subject to the condition that no harmful interference is caused to the service of any police station employing type A1 emission on this frequency including any operations conducted in accordance with outstanding regional agreements and further subject to the condition that no harmful interference is caused to the service of any station, which in the discretion of the Commission may have priority on the frequency with which interference results.

(16) This frequency is reserved for assignment to stations in the Police Radio Service for intersystem operations only: *Provided, however*, That licensees holding a valid authorization to use this frequency for local base or mobile operations as of June 1, 1956, may continue to be authorized for such use.

(17) The maximum plate input power to the final radio frequency stage of any transmitter authorized to operate on this frequency, after June 1, 1956, shall not exceed three watts. Licensees holding a valid authorization as of June 1, 1956, for base or mobile station operation on this frequency, with a power in excess of three watts, may continue to be authorized for such operation without regard to this power limitation.

(18) This frequency is shared with the Local Government Radio Service.

(i) Frequencies offset by 7.5 kHz or less from those in the 152 to 162 MHz band listed in paragraph (g) of this section may be assigned for developmental operation upon an adequate showing of the need for such irregular assignment together with an acceptable engineering report indicating that harmful interference to the operation of existing stations will not be caused.

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1. General
2. Spectrum Management and Utilization
3. Network and Systems Engineering
4. Police Telecommunication Studies
5. Data Processing and Information Retrieval
6. Technical Innovations and Advanced Techniques
7. Police Department Organization—Command and Control
8. Radio Transmission, Propagation and Antennas
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ABBREVIATIONS

AC	Alternating current
AM	Amplitude modulation
APCO	Associated Public-Safety Communications Officers, Inc.
CB	Citizens' band
CCTV	Closed-circuit television
dB	Decibels
dBW	Decibels relative to one watt
DC	Direct current
EDP	Electronic data processing
EIA	Electronic Industries Association
ERP	Effective radiated power
FCC	Federal Communications Commission
FET	Field-effect transistor
FM	Frequency modulation
gHz	gigaHertz (billion Hertz or 10^9 cycles per second)
HF	High frequency
Hz	Hertz (cycles per second)
IF	Intermediate frequency
IRAC	Inter-Agency Radio Advisory Committee
ISPERN	Illinois State Police Emergency Radio Network
kHz	kiloHertz (thousand Hertz or thousand cycles per second)
LEAA	Law Enforcement Assistance Administration
LETS	Law Enforcement Teletypewriter Service
LP	Liquefied petroleum

MC	Megacycles per second (now written as "mHz", megaHertz)
MF	Medium frequency
MHz	MegaHertz (million Hertz or million cycles per second)
μV	Microvolts (10^{-6} Volts or 0.000001 Volts)
NCIC	National Crime Information Center
OTP	Office of Telecommunications Policy
PBX	Private Branch Exchange
PM	Pulse modulation
RF	Radio frequency
SINAD	Signal plus noise and distortion-to-noise and distortion
SPA	State planning agency
UHF	Ultra-high frequency
VHF	Very high frequency
VOX	Voice operated switch
VSWR	Voltage-standing-wave ratio
VU	Volume unit

GLOSSARY

The definitions of many of the following terms were obtained from FCC Rules and Regulations, Volume V, Part 89 and from two dictionaries of electronic terms:

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Graf, Rudolf F., *Modern Dictionary of Electronics*, 3rd Edition, Howard W. Sams & Co., Inc., The Bobbs-Merrill Co., Inc., New York, 1968

amplitude modulation (AM)	Modulation in which the amplitude of the carrier-frequency current is varied above and below its normal value in accordance with the audio, picture, or other intelligence signal to be transmitted.
antenna	A system of wires or electrical conductors employed for reception or transmission of radio waves. Specifically, a radiator which couples the transmission line or lead-in to space, for transmission or reception of electromagnetic radio waves. (Also known as aerial.) (See also "gain".)
attenuation	The decrease in amplitude of a signal during its transmission from one point to another. It may be expressed as a ratio or, by extension of the term, in decibels.
band	A range of frequencies between two definite limits. By international agreement, the radio spectrum is divided into nine bands. For example, the very high frequency (VHF) band extends from 30 MHz to 300 MHz. (See Table IV-1.)
bandwidth	1. The width of a band of frequencies used for a particular purpose. Thus, the bandwidth of a television station is 6 MHz.

bandwidth (continued)	2. The range of frequencies within which a performance characteristic of a device is above specified limits. For filters, attenuators, and amplifiers these limits are generally taken to be 3 decibels below the average level. Half power points are also used as limits.
bandwidth occupied by an emission	The width of the frequency band containing those frequencies upon which a total of 99 percent of the radiated power appears, extended to include any discrete frequency upon which the power is at least 0.25 percent of the total radiated power (FCC definition).
base station	A land station in the land mobile service carrying on a service with land mobile stations.
broadcast	Radio or television transmission intended for general reception.
cable	One or more insulated or non-insulated wires used to conduct electrical current or impulses. Grouped insulated wires are called a multi-conductor cable.
capture ratio	The ability of an FM radio receiver to reject unwanted signals and interference on the same frequency as a desired one, measured in decibels. The lower the figure, the better the receiver performance.
carrier	An electromagnetic wave at a specific frequency.
carrier frequency	The frequency of an unmodulated electromagnetic wave.
channel, point-to-point	A radio channel used for radio communication between two definite fixed stations.

channel, radio	An assigned band of frequencies of sufficient width to permit its use for radio communication. The necessary width of a channel depends on the type of transmission and the tolerance for the frequency of emission.
coaxial cable	A transmission line in which one conductor completely surrounds the other, the two being coaxial and separated by a continuous solid dielectric or by dielectric spacers. (Also called coaxial line, concentric line.)
communication center	The complex of equipment and personnel from which all communication activity in a particular system is controlled.
control console	A desk mounted enclosed panel which contains a number of controls used to operate a radio station.
couple	To connect two circuits so that signals are transferred from one to the other.
crystal-controlled oscillator	An oscillator in which the frequency of oscillation is controlled by a piezo-electric crystal.
crystal-controlled transmitter or receiver	A radio transmitter or receiver in which the carrier frequency is controlled directly by a crystal oscillator.
decibel (dB)	A unit which expresses the level of a power value relative to a reference power value. Specifically, the level of a power value P relative to a reference value P_R in decibels is defined as $10 \log_{10} (P/P_R)$.
directivity	The value of the directive gain of an antenna in the direction of its maximum value. The higher the directivity value, the narrower is the beam in which the radiated energy is concentrated.

distortion	Unfaithful reproduction of audio or video signals due to changes occurring in the wave form of the original signal, somewhere in the course it takes through the transmitting and receiving system. Classified as linear, frequency, and phase distortion.
duplex channel	A communication channel providing simultaneous transmission in both directions (for comparison, see simplex channel).
duplex operation	The operation of associated transmitting and receiving apparatus concurrently as in ordinary telephones without manual switching between talking and listening periods. A separate frequency band is required for each direction of transmission. (For comparison, see simplex operation.)
electromagnetic energy	The type of energy contained in any electromagnetic wave such as radio waves, visible light, x-rays, gamma rays, or cosmic rays. The frequencies of radio waves go up to about 300,000 MHz.
electromagnetic radiation	Radiation associated with a periodically varying electric and magnetic field that is traveling at the speed of light, including radio waves, light waves, x-rays, and gamma radiation.
electromagnetic wave	A wave of electromagnetic radiation, characterized by variations of electric and magnetic fields.
energy, radio frequency	See "electromagnetic energy".
fading	The variation of radio field strength caused by a gradual change in the transmission medium.
fading margin	The number of decibels of attenuation which can be added to a specified radio frequency propagation path before the signal-to-noise ratio of the channel falls below a specified minimum.

FM capture ratio	See "capture ratio".
frequency	The number of cycles per second; the reciprocal of the period.
frequency deviation	Frequency deviation of an FM signal is the change in the carrier frequency produced by the modulating signal. The frequency deviation is proportional to the instantaneous amplitude of the modulating signal.
frequency modulation (FM)	A method of modulating a carrier-frequency signal by causing the frequency to vary above and below the unmodulated value in accordance with the intelligence signal to be transmitted. The amount of deviation in frequency above and below the resting frequency is at each instant proportional to the amplitude of the intelligence signal being transmitted. The number of complete deviations per second above and below the resting frequency corresponds at each instant to the frequency of the intelligence signal being transmitted.
function	A special duty or performance required of a person or thing in the course of work or activity.
function, of a police telecommunication system	The process which must be carried out by a system to fulfill an information handling need of a police agency.
gain, of an antenna	The effectiveness of a directional antenna in a particular direction, compared against a standard (usually an isotropic antenna). The ratio of standard antenna power to the directional antenna power that will produce the same field strength in the desired direction.
generator	A device which develops either direct or alternating electrical voltage at any frequency.

guard band	A narrow band of frequencies provided between adjacent channels in certain portions of the radio spectrum to prevent interference between stations.
half-duplex channel	A communication channel providing duplex operation at one end of the channel, but not the other. Typically, the base station is operated in the duplex mode (for comparison see "simplex channel" and "duplex channel").
half-wave dipole antenna	A straight, ungrounded antenna having an electrical length equal to half the wavelength of the signal being transmitted or received.
interference	See "radio interference".
link	A transmitter-receiver system and transmission medium forming a two-way path for the transmission of information.
message delay	In a radio system, the time it takes to get a message on the air, usually the result of waiting for other radio users to finish transmitting. It is precisely the length of the time interval between the moment when an operator decides to transmit and the moment when he actually does.
microwave	A term applied to radio waves in the frequency range of 1,000 megaHertz and upward. Generally defines operations in the region where distributed-constant circuits enclosed by conducting boundaries are used instead of conventional lumped-constant circuit components.
mobile relay station	A base station established for the automatic retransmission of mobile service radio communications which originate on the transmitting frequency of the mobile stations and which are retransmitted on the receiving frequency of the mobile stations.

mobile station	A two-way radio station in the mobile service intended to be used while in motion or during halts at unspecified points.
mobile unit	A two-way radio equipped vehicle or person. Also, sometimes the two-way radio itself, when associated with a vehicle or person.
modulation	The process of modifying some characteristic of an electromagnetic wave (called a carrier) so that it varies in step with the instantaneous value of another wave (called a modulating wave or signal). The carrier can be a direct current, an alternating current (providing its frequency is above the highest frequency component in the modulating wave), or a series of regularly repeating, uniform pulses called a pulse chain (providing their repetition rate is least twice that of the highest frequency to be transmitted).
multi-channel system	A radio system which uses more than one radio channel. Also known as multi-frequency system.
multiplexer	A device which simultaneously transmits two or more signals over a common carrier wave.
network	See "radio network".
noise	Interference characterized by undesirable random voltages caused by an internal circuit defect or from some external source.
peak	The maximum instantaneous value of a quantity.
personal radio	A small portable radio intended to be carried by hand or on the person of the user.
portable radio	A completely self-contained radio which may be moved from one position to another.

propagation (electromagnetic)	The travel of electromagnetic waves through a medium, or the travel of a sudden electric disturbance along a transmission line. Also called wave propagation.
radio	The transmission and reception of signals by means of electromagnetic waves without a connecting wire.
radio-frequency power	The power associated with any signal consisting of electromagnetic radiation which is used for telecommunication.
radio interference	Undesired disturbance of radio reception. Man made interference is generated by electric devices, with the resulting interference signals either being radiated through space as electromagnetic waves or traveling over power lines or other conducting media. Radiated interference is also due to natural sources such as atmospheric phenomena (lightning). Radio transmitters themselves may interfere with each other.
radio network	A number of radio stations, fixed and mobile, in a given geographical area which are jointly administered or which communicate with each other by sharing the same radio channel or channels.
radio receiver	An instrument which amplifies radio-frequency (RF) signals, separates the intelligence signal from the RF carrier, amplifies the intelligence signal additionally in most cases, then converts the intelligence signal back into its original form.
radio transmitter	A radio-frequency power source which generates radio waves for transmission through space.
radio wave	See "electromagnetic wave".

receiver	See "radio receiver".
relay station	Radio stations that re-broadcast signals the instant they are received, so that the signal can be passed on to another station outside the range of the originating transmitter. (See also "mobile relay station" and "repeater station".)
repeater station	An operational fixed station established for the automatic retransmission of radio communications received from any station in the Mobile Service.
sensitivity of a radio receiver	The minimum input signal required in a radio receiver to produce a specified output signal-to-noise ratio. This signal input may be expressed as power or voltage at a stipulated input network impedance.
signal	The form or variation of a wave with time, serving to convey the information, message, effect, or other desired intelligence in communications.
semi-duplex	See "half-duplex".
simplex channel	A communication channel providing transmission in one direction only at any given time (for comparison see "duplex channel").
simplex channel, single-frequency	A simplex channel utilizing only one assigned band of frequencies (for comparison see "simplex channel, two-frequency").
simplex channel, two-frequency	A simplex radio system utilizing two distinct assigned bands of frequencies (for comparison see "simplex channel, single-frequency").

simplex operation	A method of radio operation in which communication between two stations takes place in only one direction at a time. This includes ordinary transmit-receive operation, press-to-talk operation, voice-operated carrier, and other forms of manual or automatic switching from transmit to receive. Also called simplex. (Compare with "duplex operation".)
spectrum	Any series of radiant energies arranged in order of wavelength or frequency. The entire range of electromagnetic radiation extending from the longest known radio waves to the shortest known cosmic rays.
station, radio	A fixed installation or mobile unit which is equipped to transmit and receive radio signals.
switchboard, telephone	A board or panel equipped with apparatus for controlling the operation of telephone circuits and routing incoming and outgoing calls.
telecommunication	Communication at a distance, as by telegraph, telephone, cable, or electromagnetic radiation.
teletype	A system of communication in which the Teletype—a trademark applied to a kind of teletypewriter—is used. (See "teletypewriter".)
teletypewriter	An electromechanical device, similar to a typewriter, such that messages typed on the keyboard of the transmitter unit are converted into electrical signals, which when conveyed to the receiver unit, are printed on paper.

transistor	[TRANSfer resISTOR] An active semiconductor device having three or more electrodes. The three main electrodes used are the emitter, collector, and base. Conduction is by means of electrons and carriers or holes. Germanium and silicon are the materials most often used as the semiconductor material. Transistors can perform practically all the functions of vacuum tubes, including amplification and rectification.
transmission line	A waveguide, coaxial line, or other system of conductors used to transfer signal energy efficiently from one location to another.
trunk line	A telephone line which terminates at a switchboard rather than a telephone.
two-way radio	A radio which is able to both transmit and receive.
vacuum tube	An electronic device used in radio, television, etc., which consists of an evacuated enclosure containing two or more electrodes between which conduction of electricity can occur.
width, channel	The difference of the upper and lower frequency limits of a channel, expressed in Hertz.

INDEX

U. S. GOVERNMENT PRINTING OFFICE : 1971 O - 439-911

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