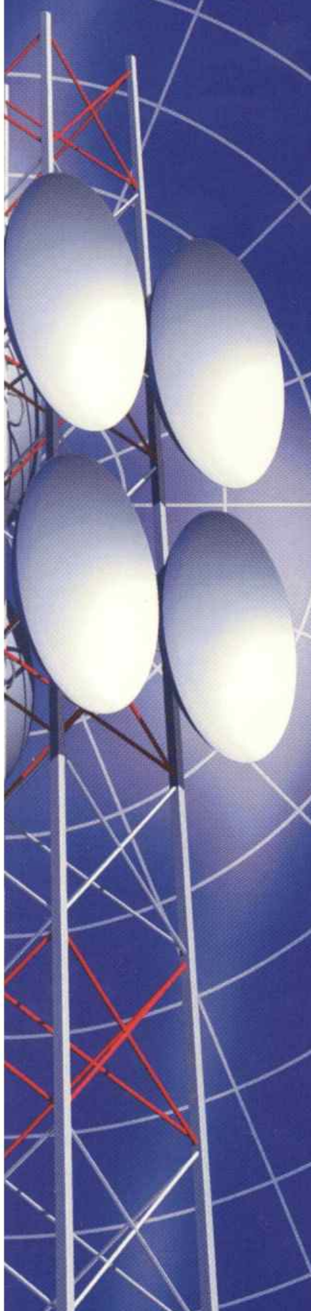
The Primer of Public Safety Telecommunication Systems



J. Rhett McMillian Jr.

APCO International
Association of Public-Safety Communications Officials

For Vivian,
the first employee
of the APCO International office.

The Primer Of Public Safety Telecommunication Systems

THIRD EDITION

By J. Rhett McMillian Jr.

Published by
APCO International, Inc.
Association of Public-Safety Communications Officials, Inc.
351 North Williamson Boulevard
Daytona Beach, Florida 32114
888-APCO-911
www.apco911.org

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Publisher's Note

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Transferring the relics of an old generation into the soil of a new generation enriches future harvests.
• *J. Rhett McMillian Jr.*

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Prologue

Public Safety Telecommunication Goals

During his farewell address at the 1976 Annual Conference, retiring Executive Director J. Rhett McMillian Jr. proposed APCO establish a set of national goals for the public safety telecommunication community. The goals, as later adopted by the Board of Officers, are as follows:

Goal No. 1
Every citizen should have available ready access to public safety emergency resources at all times.

Goal No. 2
All public safety employees engaged in high-risk activities should be able to intercommunicate in like telecommunication systems of the community, and on an emergency basis with other such systems in contiguous communities.

Goal No. 3
Every law enforcement officer should, in accordance with established security requirements and in the proper discharge of duties, be able to immediately access criminal justice and related data wherever stored in the United States.

***

Application

APCO is dedicated to the principles of the goals. They guide the association, keep it on track, keep purpose and belief in mind and in the final analysis, measure effort and accomplishment. This book bears witness to that dedication. It is a small step, but it is a step, one of many APCO takes in tireless pursuit of the goals. This primer, being concerned with systems, is rooted in all three goals.

Those who practice the art of public safety telecommunications would do well to post the goals in a prominent place. Any worthy public safety telecommunication activity, proposed or accomplished, springs from them. Elements of all the goals can be found in almost any public safety telecommunication endeavor. However, to illustrate their individual applications, in a few sections of the primer the key symbols (Gl), (G2), (G3), for each of the goals, will be found.

Foreward

1. Merits and Ancestry

The merits of this book, and its source, are well documented. The Primer is based upon and follows closely the product of Project Three, Phase Three of the APCO Project Series Foundation, as authorized by President Bernard Flood and delivered in 1971. Titled "POLICE TELECOMMUNICATION SYSTEMS," the report was prepared by the Illinois Institute of Technology Research Institute (IITRI) under the management of Bernie Epstein. The APCO Project Director was Otto Rhoades of the Illinois State Police and the Phase Three Committee was chaired by Frank D. Campbell of the Indianapolis Police Department. J. Rhett McMillian Jr., the author of this book, served on the committee.

2. Credits

All of the above-mentioned APCO members, except Bernie Epstein, have been presidents of the association. McMillian established and was the first director of the national office of the association as well as the founder of the APCO Project Series. Rhett set the stage when he wrote the APCO Standard Public Safety Communications Operating Manual which has been in production since 1965. APCO has sold more than 50,000 copies of the manual, as updated, which is now in its 21st edition. All of these works have been accomplished with the dedicated help of APCO members who have been or are currently active in the fields addressed.

3. Relationships

This book advances proven tax-supported telecommunication principles from the age when police communications were the bastion of emergency communications to the current era of centralized 9-1-1 Public Safety Answering Points. APCO was an early advocate and long-term participant in these matters. The primer relates particularly well with other modern APCO educational and training materials and programs. It is a privilege to take part in these needed efforts, to recommend all of our services as listed in the Appendix to the reader and, above all else, to be a member of, and to serve, the Association of Public-Safety Communications Officials, Inc.

Robert E. Tall
Executive Director, APCO
January 1984 to January 1992

Chapter I

Introduction to Text

Purpose

The art of public safety telecommunications is ably supported by technology and the modern disciplines of direct emergency response. Even so, the impact upon human resources has been formidable. As a result, an increasing demand for an introductory tool that can build a bridge between those looking, the newcomer, and the experienced telecommunicator.

Raw talent appears in a telecommunication system from two major directions. The first are those coming externally from the market place in search of careers. The second is that coming internally from different levels and positions due to changes in job status,

The requirement, therefore, is to provide a bird's eye view of the field with a handbook that combines layman's language with career terminology.

The audience for such a book is larger than may be first expected. In the system, employees frequently transfer between known and unknown jobs. They must learn about where they are going. The middle manager, the generalist in particular, caught between whom he reports to and whom he reports from, needs to know this in accordance with the quickest and most reliable prescription. Then, too, growing categories of planners, local, state and federal agency officials, frequency coordinators, processors, licensors and licensing firms, suppliers and consultants must be brought up to speed.

The Primer therefore, does not necessarily include material for professional communicators as did its parent police text. Rather, it is written for the lay person who must transact with them. However, the Primer will serve well in this important regard. It usefully illustrates to professionals the difficulties they must expect to encounter in communicating needs to others at all levels.

Scope

The word "telecommunication" limits consideration to systems and their components that involve the transfer of information over a distance, utilizing electrical and/or electronic means. Although this book refers often to police functions, as may be expected, it is not, however, about any one public safety radio service. It is, instead, a text for all in these services.

The table of contents illustrates the topical approach. Emphasis is given to the radio system component inasmuch as it and its usage are not generally as well understood as are other system elements. Also, public communication services such as telephone networks are typically owned and operated by others rather than, as is the usual case with public safety telecommunication systems, the using governmental agency. It is here the quasi-technical and quasi-regulatory aspects of the Primer are of singular importance.

The Primer concentrates on equipment, its characteristics and its place in systems. It does its best to steer clear of procedures, as was included in the Police text, and training as is carried on extensively by other APCO programs. Such tight-rope walking is difficult at best. Some tilting may be discerned in a few areas. Please be assured such inroads were unavoidable in rounding out subject matters in the scoped area.

Principal Readers

This book is intended for use by those in, or preparing for employment in, public safety telecommunications and related fields.

Chapter II

User's Guide to the Text

II.1. Topical Approach

The chapters of the text lead the reader through the elements of public safety telecommunication systems beginning with the more fundamental aspects of the subject and ending with the technical jargon of the initiated.

Those new to the field may be tempted to disagree wiPrincipally, every reader is treated as a beginner and glossary terms are defined and explained as used in the text. Next, the chapter explores what a system is and why it is a necessary adjunct to the department it serves as well as system components and the basic functions of an emergency tax-supported telecommunication system. The importance of standards and requirements are stressed. The chapter also lists the categories of public safety radio services.th such a statement when they immediately encounter unfamiliar terms among the chapter headings. Believe it or not, these are indeed terms the non-technical person will become accustomed to, but not required to learn in a purely technical application sense.

Instead, the level addressed herein is intended only to permit the newcomer to better understand and participate in matters under consideration in telecommunications. If the reader is able to do this to the point that all concerned are mutually comfortable in their relationships, the Primer will have satisfied its purpose.

II.2 Chapter Summaries

To placate apprehensions and demonstrate these are not fearsome arenas, please lean back now and read the following capsuled chapter summaries as you would a novel about strange encounters of which you know little but were intrigued enough to have bought the book.

III Introduction to Basic Systems – Principally, every reader is treated as a beginner and glossary terms are defined and explained as used in the text. Next, the chapter explores what a system is and why it is a necessary adjunct to the department it serves as well as system components and the basic functions of an emergency tax-supported telecommunication system. The importance of standards and requirements are stressed. The chapter also lists the categories of public safety radio services.

Chapter IV: Elements of Systems: Part 1 – The elements of systems are divided into two parts: Part 1 in this chapter and Part 2 in Chapter V. Basic hardware elements are reviewed in each chapter, and other subjects are progressively added. It is a common error to know how to operate "things" without knowing what the "things" are. As we advance through the text, the Primer strives to approximate reality as closely as possible.

This chapter removes more of the mysteries from radio frequencies, how they are generated and transmitted and the channels they occupy. We end up introducing the real "buzz" words of telecommunication: effectiveness, reliability and evaluation, cautioning how these matters affect not only operation but tax dollars as well.

Chapter V: Elements of Systems: Part 2 – This chapter opens with base stations and enters into detailed explanations of their components. Different categories of fixed stations are discussed, such as point-to-point microwave as are security measures. The chapter also addresses mobile and personal portable units as well as special devices used in base and mobile systems.

It then revisits the mystical subjects of frequencies, channels, propagation and networks. The chapter ends by recognizing the importance of the personnel who, in the final analysis, make the whole concept work.

Chapter VI: Description and Function of Systems – This chapter enlarges our view from single systems to the universe of all public safety radio services systems. To understand their commonalties, despite their disparate responsibilities, we again visit needs and functions. Then, descriptions are given of all the public safety radio services pool.

In the process, differences in licensing eligibility requirements between the individual services can, quite often, become difficult to discern. Thus, we introduce the role of the Federal Communications Commission. Finally, we examine the reflected importance of the various radio service frequency coordinators, their local advisors, and the license application processes.

Chapter VII: Public Safety Telecommunication Networks – This chapter is dedicated mainly to drawings that picture the different types of radio networks. Although designs of networks are used to some extent as illustrations in earlier chapters, they are all concentrated here as a complete separate reference resource.

Chapter VIII: Conclusion – Here we provide a summary, directed to the reader who has completed the Primer, and offer suggestions for further study.

Chapter IX: Appendix A – Introduces the reader to APCO and to educational material available from the APCO Institute and other sources.

Chapter X: Appendix B – The best way to learn a new job is to have a ready reference to interpret its foreign language. That help is here, clear and complete.

Now, let us communicate.

Chapter III
Introduction to Basic Systems

III.1 Prelude
So, you don't know anything (much) about public safety telecommunication systems. Where'd you come from? A patrol car, an ambulance, fire truck, conservation office, highway maintenance outfit, etc.?

Or are you totally new in the field and now selling communication gear, or in a center learning to be a telecommunicator, or employed in a regulatory agency or a consultant's office or working as a frequency coordinator? Or, perhaps you're just considering public safety telecommunications as a career. Welcome!

It doesn't matter. We're all starting at the same place. And a funny sort of place it is, too. We're going to define and work with a lot of the glossary terms right at the beginning. This is unusual in a text but, as you're now in a strange country, you've got to learn the language first, right? Otherwise, it'll be confusing, having to switch back and forth from the beginning of the text to the concluding glossary as you read.

With these thoughts in mind, let's start with the title of the primer. "Public safety" sets the boundary of our concerns, particularly as the Federal Communications Commission defines the term. This label limits our considerations to the functions of those who use tax dollars to provide direct response to the citizen's needs. You will be introduced to the departments that carry out these functions.

"Emergency" is a descriptive often encountered in connection with these services, denoting a serious situation, developing suddenly and unexpectedly, demanding immediate attention.

"Telecommunication" is transmitting messages via electronic or electrical means over distance. You'll be learning about this act, or as we like to call it, "art", in this book. Message means signal or information.

"System" describes a group of interacting, interrelated or interdependent elements forming a collective entity bound together for a particular purpose

We go into systems before elements, which will be discussed later. We do this for the same reason we learn to drive an automobile before we learn about all the

elements that make it go. The automobile should begin to provide a service the minute you buy it. How it performs depends upon how well you use it. How well you use it depends upon your skill in operating and maintaining it. That skill depends upon experience and knowledge of the elements involved. The same idea applies to you and your duties in the public safety telecommunication field.

"Public safety telecommunication" is the tax-supported application of these means for the purpose of expediting the delivery of protective and emergency services to the general public.

But hold it. Is an automobile, or a public safety telecommunication system, necessary in the first place? One question, here, is as bad the other. However, it ought to get your attention. And, if we're going to talk about everything, we have to start at the beginning.

III.2 Concepts
What's it all about? What's meant by communication? What's a radio? What's a radio system? What are its elements? Who needs to talk and how often? How fast can messages be sent? What are the costs? What federal and local government bodies are involved?

Communication is the act of exchanging information by means of speech, writing, or signals. Speech we know. Writing we know. What's a signal? In our work it means a pulsed, or a fluctuating, electrical quantity, such as a voltage or current or electrical field. The variations and periods of these quantities represent information.

The word "signal" is important in communication. It will get to be second-nature knowledge to you before long. The word "exchange" is also important. No communication occurs when a signal is broadcast unless the sender receives affirmation it has been received. Whether or not the receiver understands the information opens up a whole new ball game called training. See the Appendix A for information in this field.

A radio, in our basic terms, is a consolidated package of electronic gear containing a source of power, a transmitter and a receiver. A transmitter is an electronic unit capable of converting its electrical source into a radio frequency and then broadcasting information on that frequency. That source can be powerline (house) current, a power generator or a battery. A receiver is an electronic package capable of receiving a selected radio frequency broadcast and recovering information from it. A power supply common to both the transmitter and receiver distributes power to them.

Radio is the primary means of communication between a public safety department and its mobile personnel. Radio is defined as the means of transmitting (sending) information via electromagnetic waves without physical connections between sender and receiver.

"Electromagnetic" has two components: electrical and magnetic. The earth (a magnet) is surrounded by the natural phenomena of an electromagnetic field. An electromagnetic wave is a periodic (having a frequency) disturbance of the electromagnetic field. The disturbance we are concerned about here is the radiation from a transmitted signal.

What is a frequency? A frequency is the number of times a unit of electricity varies (cycles) from zero to maximum and minimum peaks in one second. Pure direct current (DC) is so called because it doesn't vary at all. The battery in your automobile produces direct current at 12 volts. It stays at its given peak all the time (we hope). House current, called 60 cycle current, varies at the rate of 60 times each second. A one megacycle (1 MHz [megahertz]) radio signal varies at the rate of 1 million times each second.

Think of bicycle: 'bi" (two) "cycle" (wheel). Two wheels. A wheel is a circle. A circle (cycle) has no beginning or end. Draw a circle on a piece of paper. (See Fig. 1 1 1-2 below). Draw a line through the middle of it. Label the top half "a" and the bottom half "b." Cut the circle into two equal halves at the midline. Slide the bottom half forward along the middle line until the two halves join again. You still have all the elements of the circle, but it now looks more like an electrical cycle.

You can see the "cycle" alternately increases in magnitude (height) both above and below the line. These variations, voltages in this example, are called alternations, or alternating current. A true electrical cycle, or sine wave, is also shown for comparison purposes. Alternating current has a frequency.

Along this line, it is important to know alternating current causes radiation. "Radiation" here means an alternating current makes a disturbance (produces a wave) in the electromagnetic spectrum. If this radiation is unwanted it is called "noise", or "interference." If the radiation is deliberately made by a transmitter, it is called a radio signal.

Radio frequencies radiate from an antenna into space as "waves." A useful analogy is to visualize spectrum as the water in a swimming pool, and a radio antenna as a vertical rod in the water. When the rod is struck, the resulting water waves radiate away from the rod in all directions at certain frequencies, or wavelengths. The wavelengths (distance from crest to crest) will vary in accordance with the speed of the rod movement. When waves are radio frequencies, receivers can be tuned to select one or more radio waves and reject all others.

Frequencies make up the radio spectrum. Spectrum is a basic nonreplenishable resource (there are just so many useable radio frequencies) that can be applied to radio communication. It is formed of a series of radiant energies (frequencies) arranged in order of wavelength. The entire range of electromagnetic radiation extends from the longest known radio waves to the shortest known cosmic rays.

The frequencies (wavelengths) where we work are typically between 30 MHz (30 million cycles per second) and the microwave (millions of MHz) regions. Million in

radio is "mega." 30 MHz=30 megahertz. Hertz means cycle and is named after Hertz, the German physicist who first discovered alternating current.

Frequencies are a regulated commodity, nationally and internationally. In the United States, the Federal Communications Commission (FCC) provides this regulatory function by means of allocation, licensing, and rule-making for all allocations except federal government. The National Telecommunications and Information Administration (NTIA), a division of the U.S Department of Commerce, administers the federal government allocations. Some frequencies are shared by agreement between NTIA and the FCC, and between federal government and non-federal government services.

To send a message by radio, a radio frequency is needed. In other words, some specific frequency, sometimes called a channel, must be used. (See V.2.3.) In fact,

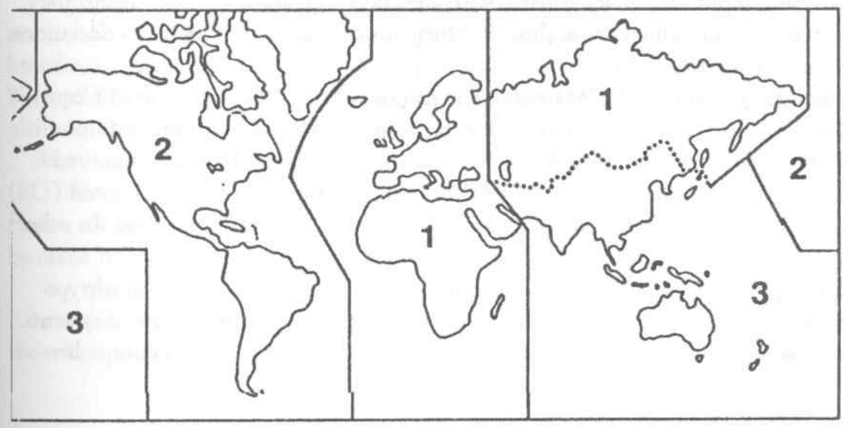


Fig. III-3 International Frequency Planning Regions

a channel may be comprised of a number of frequencies, each of which plays some role in the overall radio system. The radio equipment (transmitter) for sending messages must generate a precise signal on one channel, or frequency. The receiving equipment must select this signal without being disturbed by signals on nearby channels.

A highway, which is a "spectrum" of pavement, has lanes (channels) for vehicles. A river, a "spectrum" of water, has channels for boats. These channels can be narrow or wide. So can a radio channel for messages be narrow or wide. The narrower the frequency the narrower the channel and the more channels that can be placed in a given section of a highway, river, or radio spectrum. As radio channels are added and made narrower, "spill over" becomes more likely and what is on one channel will interfere with what is on another. Therefore, under these conditions, it is necessary for the associated radio equipment to be more sophisticated and costly.So, what is "information" as used here? This is the bottom line, the alpha and omega, of communication. Everything in this text, regarding our work, is about the means of conveying information. The transfer of knowledge.

In the old days, before radio, police officers transmitted information by rapping their night sticks on the sidewalk. Then came bells, lanterns and whistles. With the advent of electricity, street lamps were used. Then came the telephone. When a lamp was lit at a corner phone booth the police officer ran to get the message.

The first radio used dots and dashes in certain sequences. This, being an agreed-upon code, was information. The transmission of voice was made possible by the development of amplitude modulated (AM) radio. This means, for example, when the microphone is spoken into (audio), the transmitted frequency (carrier) is varied in strength (amplitude) in accordance with the audio. "Carrier" simply means the frequency itself, on which the audio, or information, is carried. Frequency variations (FM) are undesired in AM.

In frequency modulated (FM) radios the reverse is true. The transmitted frequency varies in frequency in accordance with, for example, the audio impressed upon it by whatever the microphone picks up. Amplitude variations (AM) are undesired. FM radio is principally used in public safety telecommunications in the United States because it is less sensitive to surrounding noise in the operating area. In other words, its "signal-to-noise" ratio is better.

Other types of information besides voice are carried on radio systems, such as teletypewriter, facsimile, tones, computer data, etc. Before progressing, here is a review of systems.

A system is a group of interacting, interrelated elements that form a comprehen-

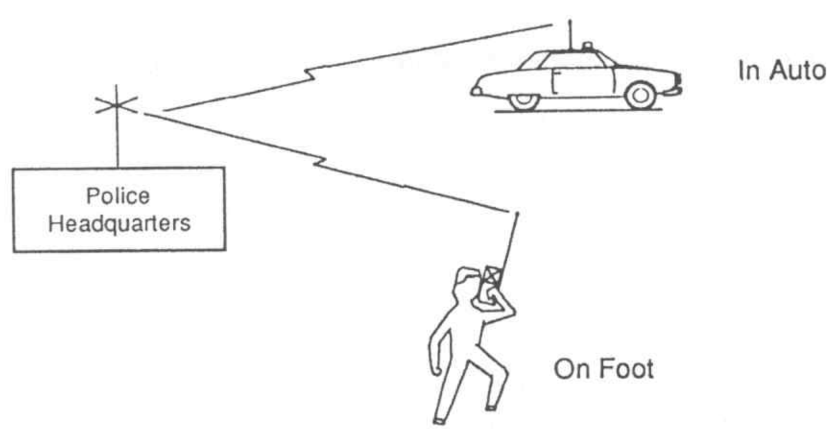


Fig. III-8 The Radio System

sive group working for a common purpose. An automobile has many systems: an electrical system made up of lights, ignition, dash -instruments, etc. The brake system consists of pedal, hydraulics, shoes, drums, etc. The fuel system includes gas tank, lines, carburetor, pump, etc.

All these systems are complete within themselves. Linked into a coordinated assemblage in a specified manner, and placed on wheels, we have an automobile: a system of systems.

When, for our purposes, the elements are radios, and we have at least two radios capable of communicating with each other, we have a radio system.

Why is a communication system necessary in a public safety function? The answer: to aid in increasing the speed, coordination and reliability of emergency resources (personnel and material) delivered to the general public

How fast is fast? Well, radio signals travel at the speed of light, or 186,000 miles per second. As fast as information in a public safety telecommunication system is broadcast, it is received. As long as the equipment holds up, the spectrum is infallibly available. The speed that counts down where we work is how fast we use that phenomenon. We will talk about that later.

What about the telephone? Believe it or not, the regular old telephone system (ROTS), including cellular phones in private autos, is the primary communication system for the public safety services. Citizen contact with emergency resources must be made by means universally understood and readily available.

In addition to its main purpose of providing citizen-public safety services contact, the telephone system within and between departments gives a back-up means of

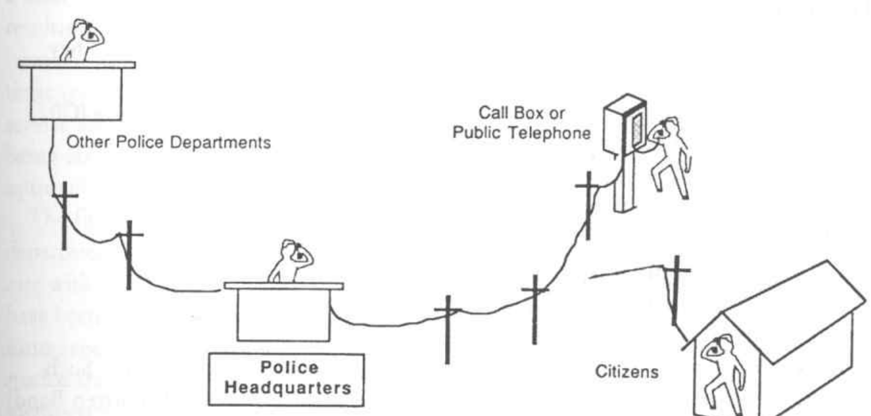


Fig. III-9 The Telephone System

communication in case of radio failure. This is an important way of passing lengthy or confidential information that may not be appropriate for radio transmission. Call boxes and hotlines fall within this category.

The telephone portion of a public safety telecommunication system usually consists of several trunk (multiple) lines. The number of lines depends on the size of the department, which is a reflection of the size and population of the area it serves.

In smaller departments, the telephone is often answered by the radio operator. In larger departments, the work load is divided between telecommunicators who are calltakers and others who operate the radio systems and dispatch resources. Large areas are usually divided into zones, each with its own telecommunication system or control points, which divide the telecommunication and resource demand load into more manageable units.

There are at least two significant operational differences between radio and telephone systems. The radio system is usually owned by the using department, while the telephone system is a commercially owned public utility whose services are leased by the department. The telephone lets anyone talk to anyone, while a public safety radio system limits communication to specific people. These differences gain prominence when such issues as reliability, control, delay and costs are examined.

Computers, data bases and facsimile operations are also major users of the telephone networks. Computers are usually used to input and extract information by and for the telecommunicator. Data bases can be internal, such as Computer Aided Dispatch (CAD) systems in operating centers, and external, such as the National Crime Information Center (NCIC) database, which is accessible by law enforcement agencies nationwide.

III.3 Functions

Public safety telecommunications functions fall into four broad categories. They provide communications:

1. Between the public and the Public Safety Radio Services (PSRS) department (Gl),
2. Within the department (G2),
3. Among like departments (G2),(G3),
4. Between departments and other agencies (G2),(G3)

In Category 1, communications revolve around several areas:

a. Calls from citizens for assistance
b. Calls from citizens giving or requesting information
c. Calls from departments to citizens

Emergency calls from citizens have to be handled quickly and efficiently. Such calls usually come in over the telephone system. Some come over CB (Citizen Band) monitors. You are now getting into the crux of what a telecommunicator's job is all about: decisions. Is this call about an emergency, or not? Priorities (classes of calls)

have to be established. A message from someone wanting to know if Corporal Kazinsky is on duty (administrative) is quite different from someone reporting a fire (emergency). Corporal Kazinsky's return call to find out who wants to know he is on duty (administrative) is quite different from the telecommunicator coming back and wanting know more details of the fire (emergency).

The second category of communication, between members of the department, is probably the largest in terms of the amount of information time consumed. The messages may involve the radio system telecommunicator at the control point and field personnel in radio-equipped vehicles or with hand-held radios. The telephone network handles a large portion of such traffic between non-mobile personnel.

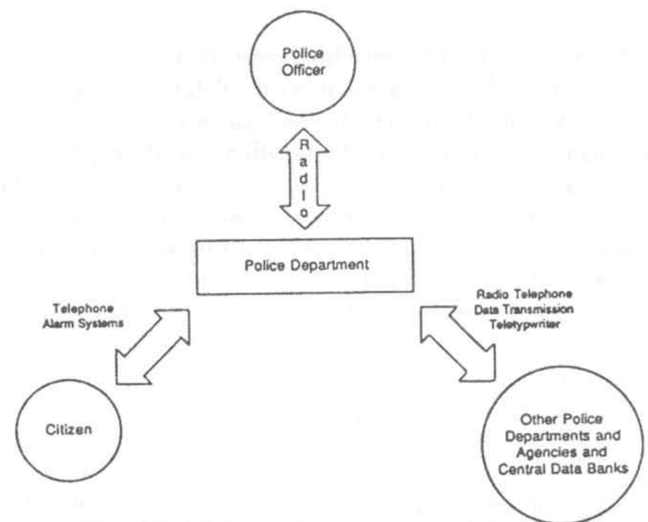


Fig. III-12 Intradepartmental Calls

The third category of communication occurs between departments. It may concern status checks or personnel assignments. It may concern wide-spread disaster. It may be a theft and resulting chase between jurisdictions (political or service area boundaries). One of the most desired capabilities in a radio system is being able to hear what is going on in the system, whether participating or not and, optimally, being able to communicate with anyone in times of need.

The final function of a communication system is passing messages between PSRS departments and supporting departments. This is really when the ability to communicate with all units at the scene of a disaster is most neccessary. Critical area networks have been established for these purposes, such as the ISPERN (Illinois State Police Emergency Radio Network) system. APCO, in early recognition of this need, persuaded the FCC to establish a national emergency channel for this purpose. APCO members were also leaders in the formation of a National Public Safety Plan which is used for assignments in the 821-824/866-869 MHz bands across the country.

III.4 Standards And Requirements

Why is it necessary for you to be concerned with such things? Well, public safety telecommunication systems, as do all other forms of endeavor, strive to operate in certain ways for certain purposes. Those "ways" are determined by "standards" and "requirements." They are included in this text because they are too often not.

1. Based on current or actual needs
2. Known
3. Understood
4. Met

Operating standards derive from external needs. Standards usually originate in requirements. Requirements are the capabilities necessary for a system to meet the needs. A police department, for example, is an enforcement agency. It is required to maintain law and order. To do this effectively, the department will, among other considerations, determine the response time necessary to deploy units in answering calls for service. This time interval becomes a standard for the department. The telecommunication system of a police department must contribute its part in meeting this response time standard.

For example, during the APCO Project Three study, it was found that the Chicago Police Department overall average standard for responding to a call was three minutes. Allowing for a field response of half this time, the average communication center response time was set at less than 90 seconds.

Since priorities are always given to types of calls, purely emergency call response time in the communication center can be 10 to 20 seconds.

Thus, the department standard becomes a requirement on the telecommunication system. The telecommunication system then establishes standards of its own in this regard. Two of the most important operating standards are: the maximum time a telecommunicator was to respond to a telephone call, and, the maximum waiting time allowed to acquire a radio channel (get on the air).

Regulatory considerations outside the parent department form the bulk of telecommunication system external requirements. These include the application Rules and Regulations of the Federal Communications Commission (FCC) and the Federal Aviation Administration (FAA). You will have to know them in order to comply with them. This text is not designed to go into the details of these matters, but course material covering these subjects is available through the APCO Institute.

Legal requirements are chiefly concerned with state and local government laws and ordinances, particularly regarding system-installation phases. Among these are erection of towers, phone and power lines, building permits and codes, etc. Also, regional agreements may bind governmental signatories into joint planning and

operational efforts. Significant among such agreements are those involving use of radio channels and sharing of telecommunication systems. Also, a knowledge of liability laws is important.

It is important to know the value of maintaining good records. Court cases arising from incidents that violate laws often depend heavily on matters involving time, place and circumstance. Communication center records and logs may be introduced as evidence.

Cost is certainly a requirement. Cost is the anchor of planning and design. No matter how good the design or how well the system meets its standards and requirements, all such things have roots in a common source: a budget. Everything must be cost-effective. One system can handle 1,000 calls per day and another 2,000 calls per day. But, the cost per each call in each system had better be somewhere reasonably in the same ball park or the bean counters (fiscal people) will come after you.

A discussion of economic requirements always begins with "how much does it cost?" That, coupled with "how well will it work?" begins the process of analysis which relates cost, performance and need associated with each function. Balance is a key word here. A "perfect" communication system has little value if its exorbitant cost seriously limits the number of vehicles which carry the mobile units. Economic considerations vary from place to place. However, many maxims of everyday business economics can be applied to emergency telecommunications. As examples, the possibility of increased direct or indirect cost occurs at each

- Additional function or service.
- Increase in flexibility.
- Adoption of different modes of operation.
- Improvement made in intercommunication with other departments.
- Increase made in automation (does not always lower labor costs).
- Increase in the area of coverage.
- Reduction in waiting time.
- Increase in the capability to handle busy and routine periods alike.

III.5 User Categories

We have talked a lot about public safety radio services. Who are the main users of PSRS? For our purposes, the best source for answering these questions is the FCC rules and regulations. Let's list them alphabetically.

1. Fire
2. Forestry-Conservation
3. Highway Maintenance
4. Local Government
5 Police

Why isn't EMS (Emergency Medical Services) listed here? EMS operations are often profit-motivated, rather than always being solely and directly tax supported. Sometimes the differences are difficult to determine, as is mentioned later.

In 1998, the FCC introduced refarming. Among other drastic changes, which will be discussed later in this text, was the consolidation of radio services. All public safety frequencies were grouped into one pool and all industrial/business frequencies were placed into another, eliminating the need for multiple radio services. This change was thought to make the application process easier for the end user.

Although the FCC now recognized the public safety pool as a group of frequencies from which any public safety agency can apply, the certified are each responsible for coordinating a unique allocation. In other words, the public safety pool is frequency specific rather than radio service specific.

We will go into more details in these matters a little later in the text, such as giving you examples of what agencies, provide these services. We will also mention other operations, such as EMS, not directly responsible for PSRS functions, that have important support facilities. Right now, though, it's important you remember the above-mentioned list. You either do, or will, work for or in one of them, or you may be in a support or supply function, such as a consultant, vendor or frequency coordinator, etc.

Chapter IV

Elements of Telecommunication Systems
Part 1

IV.1 Base Station Radio Equipment

Base station radio equipment is the "home base" of systems. It is usually at a headquarters facility, or at least at a control point of mobile units. In simplest form, the equipment consists of

- A transmitter.
- A receiver.
- A control console, or at least a microphone input and a speaker output.
- An antenna.
- An antenna support structure (tower).
- A transmission line.

The antenna, antenna support structure and transmission line are shared by the transmitter and receiver. The receiver is attached to the antenna during nontransmit periods and isolated during transmit periods. The control console controls the station functions. Essentially, it makes the station transmit, receive, select frequencies, etc. (See V.1.3).

This is the minimum base-station equipment which, together with mobile equipment, provides two-way communication. Many smaller departments have only this basic collection of equipment. A larger department might have several transmitters, receivers and antennas and a complex control console. Nevertheless, the basic equipment works along the same principles as the smaller department's equipment.

This is true even in the newest configuration known as automated trunked systems. A basic system and a trunked system are fundamentally the same. Operationally, they are quite different. The number of basic radio systems required to perform the same tasks as one automated trunked system would be prohibitive in any sense. A trunked system is much more flexible and therefore more efficient, particularly in terms of better response, spectrum utilization and broad front command of multiple functions.

To field units, an automated trunked radio system seems almost like a telephone system insofar as users don't know what channel or routing is being used for its transmission. The trunked radio system automatically selects the best frequency (circuit) and the best equipment location (exchange). Call numbers are assigned to exchanges according to area and/or function (area code). By choosing the right switches (dialing) a unit can talk to one other unit (person- to person call) or to a group of units (conference call). Groups in one function (fire) can talk (area code) to groups in another function (police).

IV.2 Mobile Radio Equipment

Mobile radio equipment includes any radio equipment that can be readily moved from place to place. Mobile units primarily communicate between field units and with headquarters base stations. The equipment includes those mounted in

- Patrol cars
- Ambulances
- Fire trucks
- Highway maintenance vehicles
- Conservation vehicles
- Boats and airplanes
- Personal gear

The units consist of a power source, transmitter, receiver, and antenna system in a configuration that allows two-way communication. A pocket pager is not a true personal communication unit. It only can receive. Remember, we said communication does not exist if a sender and a receiver don't both acknowledge a transmitted message.

IV.3 Frequencies

A basic difference in public safety radio systems is the number of frequencies employed and the way they 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. The system uses only one frequency that handles messages in both directions (base-base, base-mobile. mobile-base, mobile-mobile) one at a time. This system requires the least radio-spectrum space and is the most economical two-way system to purchase and operate. In this system, the base station (main or fixed station, labeled Headquarters in Fig. IV-4 below) and its mobile (movable in vehicles, etc.) units share the same frequency.

Only one user can transmit at any one time. All receivers within range can listen to the same transmission. This feature provides some operational and psychological benefits to be explained later.

Duplex, or full duplex, systems are rarely used in public safety departments. Duplex means the sender and receiver can both talk and hear at the same time at each end of the circuit as is the case when using the ROTS. These systems are expensive and use more spectrum.

The two-frequency simplex system is similar to the single-frequency simplex system except the base station transmits to the mobile units on one frequency (frequency I, or fl) and the mobile units transmit to the base station on a different frequency (f2).

This prevents the base station broadcasts of one department (say, police in Jamestown) from interfering with the mobile unit broadcasts in another department (say, police in Elmville) when they are close together and share the same frequencies. If the Jamestown dispatcher is listening to his Officer Jones on fl, and the Elmville dispatcher is talking to Officer Schultz of his department at the same time - also on fl - then, most likely, all the Jamestown dispatcher would hear would be the Elmvillle dispatcher talking to Shultz. (Radio waves know no boundaries and the transmitter at the Elmville headquarters is more powerful than that in Jones' mobile unit).

This is undesirable. To avoid this, the two-frequency simplex system was adopted by Jamestown and Elmville. With this system, it's 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.

A disadvantage is mobile units cannot hear each other's transmissions. 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 f2. Another way to avoid this problem is to have the base station rebroadcast on its frequency (fl) everything it receives on the mobile frequency (f2) so Officer Smith can hear what Jones says. This requires the system to be half-duplex. The base station is then operating as a mobile relay.

The third 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. It differs from a full duplex system in that only at the base station end is it duplex. The base station can receive and transmit at the same time. This permits all mobile unit f2 transmissions to be simultaneously rebroadcast by the base station on f1. The base station is then said to be operating as a mobile-relay station. This makes it possible for all mobile units to hear each other's transmissions.

Mobile-relay stations are normally used to increase the coverage of the mobile units. Example, mobile unit A is 18 miles south and in range of the mobile-relay station. Mobile unit B is 15 miles north and in range of the mobile-relay station. The two mobile units can now talk to each other through the mobile-relay station for a total distance of 33 miles, far beyond the normal direct mobile-to-mobile range.

In larger cities where one radio frequency cannot handle all the necessary radio messages, it is common to use several frequencies. These may be assigned to different geographic zones, or to different functions such as in a police system: patrol, traffic, investigation. The individual frequencies may be used in any of the three modes described.

If a large geographic area, such as a county or state, is to be covered, or if obstructions like mountains divide the service area, it may be necessary to use one or more repeater stations to amplify signals and rebroadcast them. In other cases, repeater stations insure complete coverage by low-powered personal portable radios. Many variations are possible depending on geographical conditions.

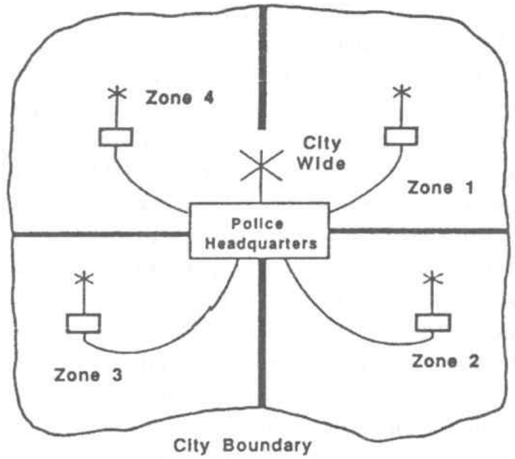


Fig IV-7 Multi-Channel Operation

IV.4 The Radio Frequency Spectrum

Radio communications are conducted through ration (electromagnetic) waves. A radio system operates on a certain radio frequency in a band of frequencies. "Frequency" is defined as the number of times per second it takes for an electrical energy to vary (cycle) from zero to its maximum and minimum peaks and back to zero. House current varies at 60 cycles per second. A 150 MHz frequency varies 150 million times per second. Figure IV-9 shows the difference in wave forms between a 1000-cycle signal (wave) and one that is

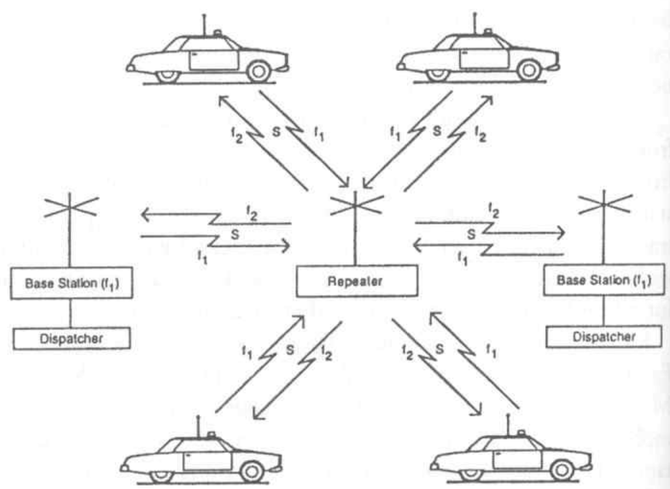


Fig. IV-8 Remote Repeater Network

1,000 times faster (1 megacycle).

The information (message) is imposed on a frequency, causing the frequency to vary in amplitude (AM) or frequency (FM). This is called "modulation" which means the frequency (carrier) is shaped or contoured by the message.

A radio "channel" can have one frequency or a pair of frequencies. When all useable radio frequencies possible are discussed, the term "radio spectrum" is used.

This spectrum is a finite non-replenishable natural resource that, unlike most other resources, cannot be directly detected by our human senses. This resource is an invisible means to transmit energy at one point and receive it at another and, in the process, convey information. Because radio frequency energy can be transmitted without wires, it is an extremely valuable means of conveying information whenever either the sender or the receiver, or both, are in motion - as between a fire marshal and a hook and ladder truck.

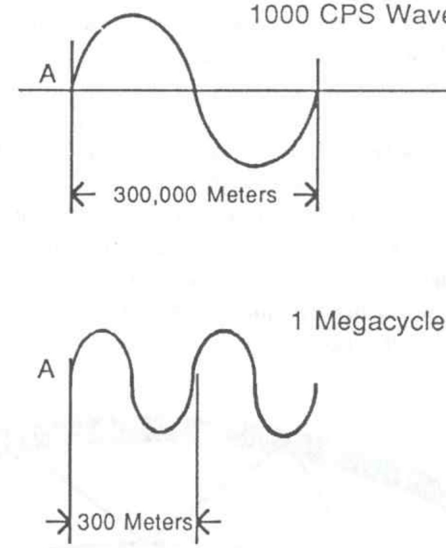


Fig. IV-9 Wave Form Differences

Picture the electromagnetic spectrum as an ocean surrounding the earth, as we picture the air and space around us. Everything is sitting there, calm and peaceful. Then we stick a couple of radio antennas up from earth near each other into the bottom of this ocean. If we "excite" one antenna with a radio transmission the electromagnetic ocean is disturbed by radio "waves." Immediately (remember, radio waves travel at the speed of light - 186,000 miles per second) the second radio antenna detects this disturbance and we have radio contact.

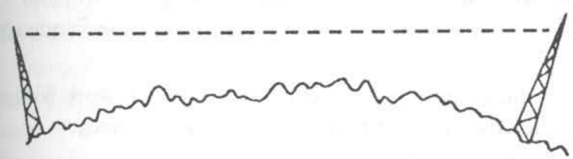


Fig. IV-10 Direct Signal Path

While we have this picture in our heads note if we move the two antennas further apart down slope, the curvature of the earth will bulge up and get between them. If the antennas are not very high, the curvature soon gets in the way and the two antennas can't "see" each other. That is when we say the stations are "out of range" and cannot communicate with each other.

A phenomenon called "skip" can cause radio signals to bounce off an ionized layer of gasses (Heaviside layer - named after the physicist who discovered it) in near space above earth. The greater the angle of radiation to the Heaviside layer the less the skip. In other words, the original signal bounces back somewhat as would light shone at an angle up into an overhead mirror. The smaller the angle of signal (the longer it stays close to earth) the farther the skipped signal can travel. This is more undesired than desired in public safety telecommunications. Skip is more prevalent at low-band frequencies and is notorious for causing undesired communication or interference.

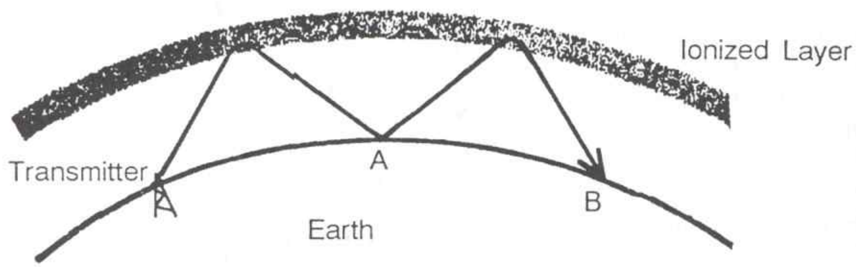


Fig. IV-11 Skip Signals

Other factors can distort a simple picture of radio frequency (RF) transmissions, such as reflection, noise, antenna height, choice of frequencies, etc. But for our purpose keep the simple picture in your mind as we go along.

Right here, however, we come to the real nub of spectrum matters. You have to know this at this point. Every radio transmission

1. Occupies a certain geographic area.
2. Occupies a certain period of time.
3. Occupies a certain portion of the radio spectrum.

From this you can now begin to understand in physical terms why no two radio users can use the system in the same area at the same time and in the same frequency of the spectrum.

Let's look deeper into each of these topics. They are the tools you will work with if you are in or related to a public safety telecommunication system, no matter whether you are an engineer, manager, supervisor or telecommunicator.

These matters are equally important to those who support public safety telecommunication functions, including vendors, licensing agents, frequency coordinators, etc.

A little reflection will tell you we are speaking here again, but in different terms,

about coverage, message length, waiting times, and interference. These concerns are shared by everybody, in or related to public safety telecommunication systems.

The primary geographic concerns are

- Antenna height (above ground)
- Antenna gain (apparent increase in power)
- Antenna directivity (beamed in one direction)
- Transmitter power (watts),
- Distance between stations (airline mileage)
- Noise (ambient [surrounding] or system)

The primary time factors are

- Deliberate simultaneous transmissions (interference)
- Deliberate staggered transmissions (breaking in)
- Ignorant interfering transmissions (untrained)
- Excessive transmissions (lengthy/unnecessary)

The primary and only spectrum concern is frequencies.

Radio waves in the VHF and UHF frequencies have the most desirable "propagation" characteristics. Propagation simply means the radio waves can spread in the electromagnetic spectrum most efficiently. These describable characteristics include better penetration in difficult areas and more pronounced deterioration at the edges of coverage areas. This deterioration, believe it or not, allows the frequencies to be more readily used again in a given area. This provides better spectrum efficiency and causes less interference to other systems.

To transmit information a certain amount of frequency spectrum is required. The amount needed increases as more information transmits simultaneously. For example, a television picture uses several hundred times as much spectrum as does voice. The amount of spectrum occupied by a transmission is termed the band-width of the transmission, where "band" means group, package, etc.

Each spectrum user is assigned a certain amount of spectrum (channel width). For public safety systems, the center frequency assignments are anywhere from 12.5 to 25 kHz (12,500 to 25,000 cycles) apart, although new standards are reducing these numbers. These variations occur according to the band used, i.e., low band, VHF band, UHF band, and the 806-960 MHz bands. The transmitted signal does not occupy all of the channel width, thus leaving guard bands on each side of center frequency.

Guard bands are just that. They are empty spectrum that guards against interference from adjacent channel signals. Visualize an assigned frequency and its guard bands as a piece of coaxial cable. The wire in the middle is the occupied space, or bandwidth, (center assigned frequency plus modulation). The insulation (cover) around the center wire represents the guard bands. As said above, the width of the guard bands (thickness and number of the insulation covers) varies according to the part of the spectrum being used (VHF, UHF, etc.).

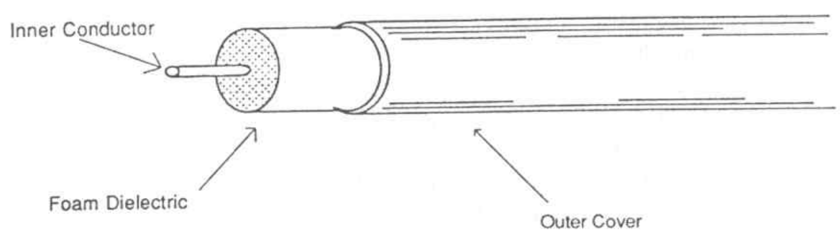


Fig. IV-13 Guard Bands As Insulation

IV.5 Effectiveness

An effective public safety department (fire, forestry-conservation, highway maintenance, police, etc.) requires an effective telecommunication system. You can have a public safety department without a serving telecommunication system but you won't have an effective public safety department.

A long accepted dogma in communication circles says while it is necessary for public safety departments to depend on leased-telephone companies for their services, it's heresy to depend on third parties for their radio systems. This belief is founded on the degree of control of emergency operations, and is currently undergoing significant review. Costs, advances in technology, experience accumulated in the 9-1-1, PSAP, and other consolidated functions, particularly when viewed in conjunction with trunked operations, may well introduce industry as more of a partner in the field. The issue of "control" then will be limited to operations and system-license retention, rather than also to hardware, its placement, maintenance, system reliability and capability, as well as ownership.

The radio, telephone and data-processing equipment, operating procedures and personnel training, must enable messages to be conveyed as quickly and reliably as a given situation requires. To provide this service requires attention to flexibility, message delay, number and length of messages, frequencies and spectrum.

The buzz words here are "reliability," "flexibility," "delay," "evaluation" and "spectrum." In the process we will again touch on budgets and planning.

In Chapter III, we spoke of the four categories of emergency communications:

(1) between the department and the public (Gl);
(2) between members of the same department (G2);
(3) between like departments (G2), (G3); and
(4) between public safety departments and supporting (unlike) departments (G2),(G3).

Calls from category one mainly regard life and property of the public. We could break it down a little further and mention actions preserving peace and tranquility.

We should be more explicit in listing the more common of Category (2) types of calls:

(1) Between headquarters unit and field units about current working incidents.
(2) Administrative and tactical calls between all units about assignments, work status, resources deployment, logistics, etc.
(3) Coordination of efforts by command personnel.
(4) Retrieving, storing, and transmitting information.

Any of the routine situations listed in item a above can turn into an emergency situation. As soon as that happens, the patterns in the remaining categories become grossly distorted. Initial departmental energy is now aimed at the category 1 problem where the situation has changed from routine and necessary to critical. The system must be able to absorb and handle these sudden loads. This is where the "buzz" words come into play.

Messages in category 3 are fewer but important in emergencies. Routine messages between departments are like stretching muscles and checking the body. When an emergency occurs in one department it is comforting to know other departments are aware of it. Department X has like resources of Department Y, and will help when requested. Each department should not only know what resources the other has but also where they are.

Category 4 communications occur, for example, between a public safety department and public works, utilities, towing and wrecker services, railroads, hospitals, etc.

The criteria for emergency communications are clearly more stringent than for other non-military uses of the radio spectrum:

1. No excessive delays occur in sending messages to their destinations.
2. The length, style, and content of the messages are appropriate.
3. The information is not degraded by interference on the system.
4. The means of transmitting the messages is determined by their emergency nature, privacy needs and length.

When a means of communication is not heavily used, the length of time required to establish communication is usually short. However, when many messages are handled, as during an emergency, waiting time can be long. Waiting time, a true demon of effectiveness, is also called delay time. You will be wrestling with them throughout your public safety telecommunications career.

They are bred in the principle all systems of this type are shared in terms of time, area and frequency. Only a few people at the same location can use a channel at a given time.

Two good measures of efficiency are based on delay time. First the length of time it takes to get on a channel, and second, the amount of information that can be transmitted in the shortest period of time while on a channel.

In 1971, APCO, under Grant No. NI 70-091 awarded by the National Institute of Law Enforcement and Criminal Justice, made a detailed study of police waiting time. Working in conjunction with the IIT Research Institute (IITRI) of Chicago, Ill., the inquiry developed one of the better known maxims in the field:

The average length of time a radio telecommunicator should wait to get a message on the air, after the initial attempt, should not exceed Livk seconds.

This average has been accepted by public safety agencies as reasonable and useful. Some delays will be longer and some shorter. A companion standard has been developed by field experience: a telephone call to a public safety telecommunications center should be answered within three rings. This is also an average figure.

The second general requirement for an effective system concerns the length and content of messages. No rigid rule guides this. The variables are as speculative as are emergencies themselves. To say they should be long enough but not too long is to say nothing. What can be said, though, is this is where procedures and training come in.

Obviously, the average length of directly determines the average waiting time for any user of the system or shared frequency.

The third general requirement for an effective system is messages should not be degraded by interference. The two types of interference are nuisance and destructive. Nuisance (occasional and faint) interference can be lived with and is not grounds for applying to the FCC for more frequencies. Destructive interference (messages are wiped out) paralyzes the system and is considered intolerable by the FCC. The radio system is more prone to such interference than the telephone system. Radio interference can consist of

Noise from electrical devices such as auto ignition, electric motors, medical machines, neon signs, etc.

- Other radio stations on the same or nearby channels.
- Background noise from the transmitting location.
- Faulty equipment.

The final general requirement is the system provide a means of communication that is an alternative to the radio network. This is necessary because many messages are not urgent and do not require the speed that the radio system provides. Other messages may be lengthy or confidential. This is the principal domain of the public telephone system. The radio system should fundamentally be reserved for messages between and for mobile units where speed and mobility are the primary requirements.

IV.6 Reliability

It is imperative public safety telecommunication systems be both reliable and flexible. From both the operational and equipment viewpoint, the system must rarely, if ever, be unavailable.

Equipment reliability can be increased with good quality equipment, both on line and on standby, and with competent maintenance. Communication equipment is subject to breakdowns due to inadvertent or deliberate action.

Planning is an important factor. Centers should staff enough telecommunicators and complaint-takers to handle the message traffic at least during "regular" peak hours. Twenty-four hour operation is the norm. Public safety is an around-the-clock job. A failure in operations makes a system just as ineffective as a failure caused by equipment breakdown.

Public safety telecommunications systems provide for a variety of functions. One significant contribution toward improving the coordination of these functions has been the advent of the 9-1-1 national emergency telephone number. 9-1-1 (instead of 911) is used to emphasize the number is pronounced nine-one-one, rather than nine-eleven. A telephone dial doesn't have a number 11.

The 9-1-1 operation uses sophisticated dedicated telephone lines, with radio backup as required, to refer calls to the appropriate agency. Building on the success of this type of operation, the PSAP has come into prominence. In a PSAP, calls can be referred to the various public safety departments as in the 9-1-1 center, and in addition, emergency resources can be directly dispatched by the PSAP.

IV.7 Evaluation

This means to value, judge, appraise and estimate a system. Solving a small problem can uncover a larger problem. That's when a complete evaluation can occur. Evaluation also can be made on proposed systems.

An occasional evaluation of a telecommunications system is a healthy exercise. Like a medical checkup, a thorough examination of a system can serve to locate existing and potential sources of difficulty. An evaluation does not necessarily have to be a single large event. Keen observations of everyday operation and good record-keeping play a significant part.

The first step in evaluating is to find out, in detail, exactly what the system is supposed to do. In particular, an evaluation should be geared to answering the following questions:

Is the system adequate and efficient in the sense it well meets the requirements placed upon it by the department it serves? Have department goals changed since the last system modification? If so, why wasn't it known at the telecommunication level? Was the change reflected in system operation?

Have system goals wandered from departmental goals? Is the system serving more or fewer needs than it should? If so, are they are worthwhile, or should departmental goals be re-examined?

Have personnel requirements changed? Are they being met? Are personnel adequately trained? Are salaries equitable?

Does the system technical problems? If so, where? Are records adequate for documenting the need for repair or modification?

How does the system compare with state-of-the-art technology? Are future needs being addressed?

If the answers to these questions indicate problems or unanswered needs, attend to them. Difficulties in a telecommunication system are akin to illnesses in the human system. Ignore them at grave future risk. You can get over a cold faster than you can pneumonia!

The second step is to determine the requirements placed upon the system. For example:

- Have legal and regulatory requirements changed?
- Are they being met?
- Have licenses expired?
- Has the FCC been notified of modifications that may affect system authorization?
- Are forms adequate?
- Are records faithfully kept?
- Are those subject to use in legal action acceptable for that purpose?
- Is the system now, or will it be, included in a "regional" consortium of users?

The third step is concerned with identifying or getting to know the system, such as

- What equipment does the system contain?
- How is the system interconnected and operated?
- What are the characteristics of the system, ie, fast, slow, in-depth strength, peak-load capability, etc.?
- Is the system responsive to change?

The fourth step is to determine how well the system does 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 mobile unit. 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 collected information and compare the actual communication system performance to what it should be doing. From this comparison, an idea of system problems emerges. Often, quick solutions to these problems will become readily apparent.

Evaluation of an existing system can be done to an extent by department personnel on a continuing basis. In fact, in any system, an unconscious evaluation is constantly taking place. If personnel find the system has a serious shortcoming affecting their efficiency safety, they should report it and any other difficulty.

Record these in a continuing log. Particular methods of evaluation vary widely depending on the size and type of system. For small systems, evaluation tends to be semi-formal. Smaller departments often do not have the resources to make evaluations. This simple test should help make better use of the available resources.

In summary, every telecommunications system should be evaluated periodically. An evaluation will determine system efficiency and indicate the necessary improvements. The evaluation should consist of

- Outlining what the system should be doing.
- Determining the requirements of the system.
- Analyzing how equipment is used and how well it performs.
- Estimating how efficiently the entire system does its job.

Whatever changes should be made to keep a system up-to-date will be evident from the results of an evaluation. The means to accomplish the changes will also be indicated.

IV.8 Budgeting And Planning

We can't think about telecommunications without revisiting planning, specifications and funding. We can get as esoteric as we want, fly way up in the upper reaches of the spectrum, and visualize endlessly but, sooner or later, we have to plan how we are going to go about it, write specifications for it and then figure some way to pay for it all.

It is important to understand when you apply for an FCC license for a budgeted radio communication system, the commission actually expects you to meet the implementation target dates set forth in the planning document being supported by your budget. If you fail to meet the stated dates, your license may be rescinded. Budget carefully!

The primary source of revenue for public safety telecommunications system is the budget of the public safety department it serves. That department gets its money through taxes. The department, and thus the system, must compete with other municipal services for these limited funds. After that, the telecommunication system has to compete with other functions within the department itself.

This requires determinations as to what allocations of these funds will provide the needed services. Then, the funded sections must continually prove their services are indeed furnished effectively.

A public safety telecommunications system doesn't operate like a commercial business. In industry, cost and return can be measured in dollars. Public safety operations don't have a single, simple, overall measure of effectiveness. It is comparatively difficult to justify expenditures. Planning becomes an everyday task, rather than a once-a-year crisis.

Classes of expenditures compare closely business: operating expenses and capital outlays are the big factors. Capital outlays, including improvement and expansion costs, are considerations that usually require the most time in planning and writing specifications. Perhaps the most emotional cost center has to do with personnel.

Chapter V

Elements of Telecommunication Systems
Part 2

In Chapter IV we went briefly into base and mobile stations to give you a foundation for what follows. A public safety telecommunications system has three principal elements:

A. Equipment,
B. Operational,
C. Personnel.

The equipment element consists of hardware and increasingly, software. Operational elements are frequencies, propagation, networks and message flow. Personnel elements consist of qualifications, administration and training.

A thorough treatment of these elements would require a complete text for each. APCO provides manuals, training courses and seminars for this purpose. This text, being a primer, only touches upon them in a limited way telling you what they are and why they are needed. Having discussed how they interact, we're on our way to introducing you to public safety telecommunication systems.

V.1 The Equipment Elements

As in the other chapters, we begin with equipment. Fixed equipment is installed permanently in one place. A "fixed" radio station is housed in a permanent location. Basic fixed-location two-way radio equipment includes base-station transmitters, receivers, antennas, towers, transmission lines, control units, repeaters and microwave components.

Telephone equipment normally is leased from commercial sources. Computers store and retrieve information. Finally, telecommunication systems require electric power for operation. Always include an emergency primary electrical generator.

Let's look at these components.

V.1.1 Base Stations

FCC rules state a base station is the station that transmits to the mobile units. A basic base station includes a radio transmitter, receiver and antenna. These are located at a fixed location, such as a fire station.

A base station is often remotely controlled. This provides added access and increases or improves area coverage. "Remote" means the transmitter and receiver are in one location and the control console in another. The remote base station can be controlled by land-line or radio-frequency "link." If by radio, the operator controls the remote base station through a control station.

The remote transmit/receive site takes advantage of natural height for the antenna, such as tall buildings or high terrain (hills and mountains). Also, locations away from congested areas, where headquarters usually operates, often have low surrounding electrical noise levels.

The use of high sites has an important trade-off. When the signal range increases, so does the interference range, both to and from the site. This limits the reuse of the frequency, both for that site system and for other systems.

The previous chapter discussed the effect of the earth's curvature on radio coverage. The further apart the antennas are, the more the earth's curvature gets in the way. Conversely, the higher the antennas, the less the effect of the earth. Also, remember noise was one factor of system efficiency. The less the noise level, the better the reception.

The primary purpose of the base station is to provide communication between the headquarters control point and its mobile units. The base station also provides point-to-point communication with other base stations in the same or other systems.

The base station typically handles two types of messages: voice and data. Either may consist of analog or digital signals. We use "analog," in this instance, to mean electrical energy in a communication system that varies continuously in amount and/or frequency in accordance with the characteristics of a signal, such as voice into a microphone, put into the system. "Digital," means discrete (particular or specific) bits of electrical energy in a communication system that appear in accordance with the characteristics of the input signal (such as data from a computer).

Think of the difference between a rotating-hand clock (analog) and a clock which flips numbers (digital). Analog signifies gradual change, such as a light being varied by means of a rheostat, while digital would be pictured as the light being turned on and off.

Base-station equipment varies widely in physical appearance. The transmitter/receiver (T/R) components may be mounted in the same housing (cabinet) or in completely separate housings. T/R combinations range in size from cigarette packages to large refrigerators. T/R combinations normally vary in size according to power output and the number of system-required components added to the basic package.

Almost all U.S. public safety radio frequency (RF) systems employ frequency modulation (FM) equipment. Some single-side-band systems (SSB) are used. The FCC requires such systems be licensed to operate on specified frequencies as one means to minimize interference between licensees (agencies holding licenses).

Transmit/receive equipment may have multi-channel capabilities. Transmit frequencies can be changed only in fixed increments within licensed limits. A transmitter may broadcast on only one frequency at a time. A "channel" can be comprised of more than one frequency. Still, only one frequency (with appropriate guardbands) can be transmitted at one time on that channel by a given transmitter. (See Chapter IV-3.)

In a base station two-way radio designed for desktop operation, the radio cabinet holds both the transmitter, receiver and power supply A desk-stand microphone is next to the radio. The receiver loudspeaker is built into the radio cabinet. Every station requires an antenna, used by both the transmitter (while transmitting) and the receiver (between transmissions).

Base-station transmitters are manufactured with a large selection of radio-frequency power-output ratings. Limitations on transmitter power are imposed by the FCC as another means of minimizing interference. The limitations are stated in terms of the power output stage of the transmitter.

This final stage is commonly the power amplifier (low input high output) circuit whose output goes to the antenna transmission line. This is commonly called the PA (power amplifier) stage, the last of many stages in a transmitter. A "listage" is an electronic circuit where a signal develops, and thereafter is successively amplified or shaped. Examples: oscillator stage, buffer stage, modulator stage, etc. Don't worry about the meanings of these; just keep a concept of "stages," or "places" in mind.

The power figures just discussed are upper limits. Base-station transmitters are available with final RF stage power-outputs, generally, of from one watt to 500 watts. Wattages commonly found in public safety systems are from 50 to 250 watts. Watts are units of power, analogous to light bulb ratings the amount of power (heat and radiation) emitted.

Using this analogy, in a given condition the higher the wattage of a light bulb, the brighter its light will be at a given distance. This concept applies to transmitter power. The higher the power of the PA stage, the stronger the signal will be at such a distance.

Higher power also affects reliability. When more than enough power is used in a system, the more the system conditions can deteriorate and transmitter circuits can decay (fade over time) without seriously affecting system operation. These are the primary reasons why licensees usually want as much power as possible. Understand doubling the wattage of a light bulb or a transmitter PA stage will not double the distance the light can send a beam or the transmitter send a signal. In free space, for example, to double system range requires eight times as much power.

Frequency stability (how closely equipment stays right on the assigned frequency) and power output are two major factors in efficient spectrum utilization. Every applicant seeking a license to operate in the public safety radio services has to meet these measurements.

But! (There's always another "but" when dealing with regulatory agencies). The

FCC assigns (allows you to use) frequencies to base stations within a geographical area depending upon certain limitations of RF power outputs. Although you may have bought a 500-watt transmitter, the commission may rule you only need, and can use, 100 watts of it. If these levels are exceeded, the transmitted signal may be strong enough to interfere with signals in other geographical areas.

Specifically, FCC regulations state:

> *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 condition.*

To prevent interference, adherence to these regulations is imperative. Excessive power, antenna height and gain are high major arguments in licensing decisions.

These are the requirements with which not only applicants and users must comply, but also those who serve them. Chief among these are the commercial sectors: manufacturers, vendors, salesmen and consultants.

As are the frequency coordinators of the various radio services. They must take all these factors into fair consideration. They must listen to the applicant, who wants more coverage than he needs; the vendor, who wants to sell the most expensive equipment (excessive power); and the consultant who designs by brute force (ignores other users).

Among these concerns is tone-coded squelch and tone signaling. A receiver equipped with tone-squelch is activated (heard) only by signals having a specific tone or tone combination and not by other signals. This application is especially valuable in frequency-congested areas. Tone signaling is so important we will get into it again later in this chapter.

V.1.2 Base Station Antennas

A two-way base station antenna, when used by a transmitter, radiates RF energy into space. One component of space is the frequency spectrum. A transmitter "looks" at an antenna as an output "load" on its final amplifier, into which it empties (dispenses) its power. A receiver, on the other hand, being a receptor rather than a generator, looks at an antenna as a signal collector or source (input) device.

An antenna is a physical structure whose size and shape are primarily dictated by the frequency it handles. Basically, the higher the frequency, the shorter the antenna. Antenna length attempts to match a radio frequency wavelength. The higher the frequency, the shorter the length of its waves. This tells us a wavelength has measurable properties, even though you can't directly "see" a frequency with the five senses. Wavelength can be computed according to engineering formulas Also, the higher the power an antenna has to handle, and the rougher the environment it operates in, the sturdier it must be.

An exact match between wavelength and physical structure requires a cumbersome antenna. Instead, half-wave (dipole) antennas are used as references and quarter-wave matches are typically made. Example: if a wavelength is 72 inches, a quarter-wave antenna will be approximately 18 inches long. This would put the frequency in the 150 MHz band. An antenna is located (height and place) to cover as much desired area as possible.

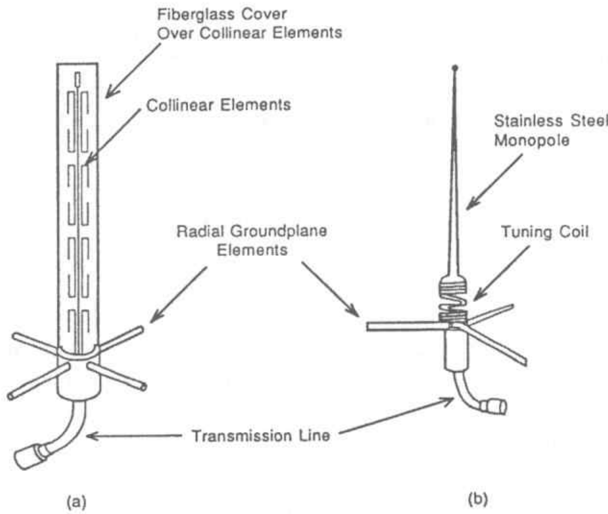


Fig. V-2 Base Station Antenna

The radiation patterns of two types of antennas are shown in Figs. V-3 and V-4. The vertical (up and down) gain is normally kept narrow (squeezed into a doughnut shape) in order to get maximum coverage in the horizontal (along the earth) direction. If the signal is to be sent in a particular direction, the antenna is made directive. This means the signal will be radiated more in one direction than another. Directive antennas protect other nearby systems from destructive interference. They also allow stations in the same system to be located farther apart in particular applications, such as point-to-point communication.

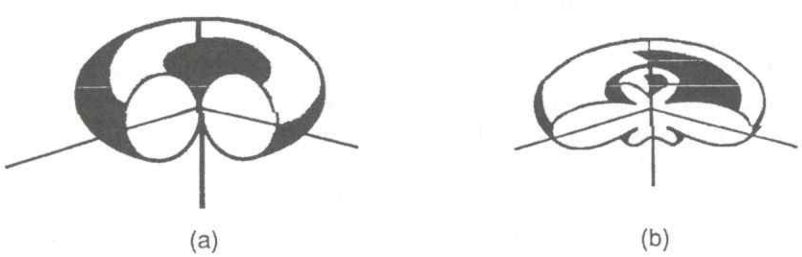


Fig. V-3 Three Dimensional Antenna Pattern

Antennas also are made to handle more than one frequency. In such instances, the design is usually around the center frequency. Thus, when the frequency used is the farthest from the center frequency, the efficiency of the antenna is correspondingly less.

Antenna height above terrain (ground) affects coverage. The higher the antenna, the greater the coverage. The transmitter must also match the transmission cable and both must match the antenna. All these system elements have matching impedances (loads) of 50 ohms.

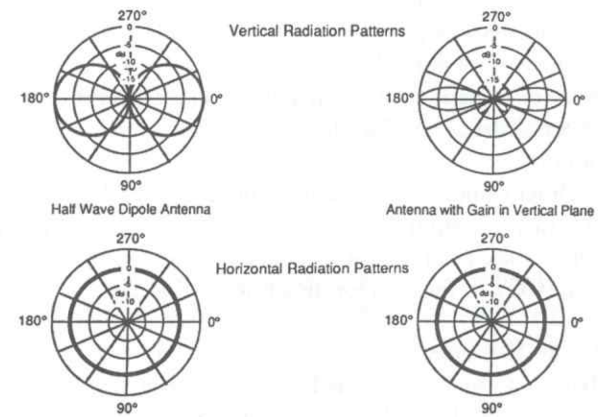


Fig. V-4 Principal Plane Radiation Patterns

Let's use an analogy and say if you have a barbell with a 50-pound weight (impedance to lifting) on one end, and you want to balance the bar, you'd put a 50-pound weight (impedance) on the other end. When electronic elements are balanced, or matched, energy flows more evenly across the junction, with less loss. We'll talk about losses later.

V.1.3 Control Equipment

Typical features of a desk-top control console are:

- Desk-stand microphone. Alternatively, a boom microphone, or a headset mike/earphone
- Speaker
- Audio volume control
- Channel-selector switch
- Transmit indicator (light or RF meter) Audio level indicator (VU meter)
- Line gain control for balancing parallel units
- Clock
- Amplifiers
- Telephone terminals

A control console's features may also include control of more than one base station control of electric locks, lights, alarms, card files, tone encoder panels and computer readout screens for data, tactical maps, etc.

If the base station were remotely controlled, the T/R cabinet would instead house the control unit. The T/R unit, tower and antenna would be at the distant location.

Several control units may be in one building. These are dispatch points. Dispatch point consoles allow people other than the responsible telecommunicator on duty at the system control point to operate the transmitter, etc. Dispatch points are under the supervisory control of the control point. In such instances, the T/R unit may be in some separate place in or next to the building, rather than distantly located.

The control point console is at the control center of the system. It's the focal point of operations. Citizen and 9-1-1-referred calls are handled here. All activities of personnel assigned to the control point are monitored, coordinated and directed from there.

Other equipment normally found in a control center are status boards, general area maps, computers for accessing national and internal data banks, CAD components, voice recorders for logging radio and telephone messages, closed circuit television (CCTV) for monitoring sensitive areas, etc.

V.1.4 Telephone

Telephone equipment may be leased or owned. Plan carefully before acquisition. Consult with local phone companies and suppliers. Equipment capabilities are sometimes limited by the telephone company and vice versa. Two major concerns are overflow and load control during emergencies.

The first national emergency telephone number, 999, was introduced in Great Britain in 1930. In 1967, APCO participated in the efforts of the President's Commission on Law Enforcement and Administration of Justice in its studies regarding a like arrangement in the U.S., recommending a single telephone number be established for reporting police emergencies. In January 1968 the American Telephone and Telegraph Company announced the three-digit number, 9-1-1, was available as the national emergency telephone number in the United States. The selection of that number, now well known as 9-1-1, (pronounced nine-one-one) took into consideration many factors. Chief among them were its impacts on the ctelephone industry in local and long distance operations, and on the public in ease of dialing and cost.

The application of 9-1-1 was an even larger task. It directly attacked the centuries-old territorial imperative of the separation of public safety services, particularly fire and police departments. The public telephone system operator behind the old "zero-emergency" dial number was no threat. But the concept of an added, separate, tax-supported function doing the same thing, and standing between the public and the individual public safety departments, was entirely different. The threat of diffusing individual departmental responsibility, if not abandoning duty and recognition as well, was real.

To their credit, those operating the public safety telecommunications systems for the most part, were, able to overcome this potential for "turf wars." Public access to public safety services through 9-1 -1 became a widespread reality and improved inter-agency radio communications also were encouraged.

This synopsis of one of the most important changes in the history of public service is an example to illustrate three maxims in the field. (1) A need, no matter its

complexity, when properly documented and accompanied by a clearly stated plan for its solution, will inevitably be resolved. (2) The larger the need the larger the number affected and therefore the larger the reaction. (3) The implementation of a solution should remain sensitive to the beliefs sacrificed to it.

The majority of calls for emergency services are directed to police. It was natural, therefore, for these departments to lead the effort in implementing 9-1 -1. How well they invoked the stated maxims is a tribute to their success.

V.1.5 Microwave Stations

Microwave refers to radio frequencies in the higher portion of the radio spectrum: typically those above 1000 MHz, where wavelengths are micro, or small. In public safety applications the most-used frequencies range from 960 MHz to about 23,000 MHz.

Microwave T/R components are typically enclosed in standing cabinets installed in air-conditioned buildings designed for and dedicated to their use. Their antennas are usually of the horn or dish types. Because of high losses at these frequencies, wave-guides or large, highly efficient cables are used to transmit signals up and down their supporting towers. Microwaves are transmitted in narrow beams, similar to light from flashlights. For this reason, because microwave antennas must "see" each other eye-to-eye, as if along narrow light beams, their towers must be very sturdy to prevent wind sway.

Microwave systems link remotely controlled transmitter sites where telephone lines would be too difficult to install or too unreliable. This would be a typical point-to-point application. Such systems are also used for inter-and intra-departmental purposes.

The desirable characteristics of microwave systems are

- Alternative use as telephone lines.
- Broad-banded: carry many simultaneous messages.
- Beamed, directional signal paths.
- Increased reliability.
- Continuous transmission.

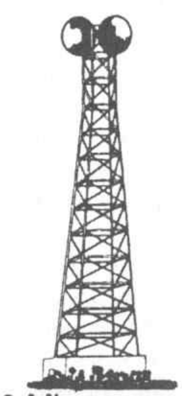


Fig. V-6 Microwave Tower

V.1.6 Physical Security, Back-up Equipment, Emergency Power

Any discussion of fixed equipment dedicated to prompt response to a citizen's request for emergency services must involve physical security, back-up equipment and emergency power. Equipment and personnel have to be protected from intervening human and natural forces. Power, central to all system functioning, must flow uninterrupted. Equipment failures happen: replacement units must be kept in working status and readily available.

These concerns speak to the importance of the telecommunication support function to the public safety agencies' primary task of the provision of their resources. The threat of terrorist activities, a growing concern in the United States, amplifies these apprehensions.

Security measures should include

- Burying telephone and power cables.
- Restricting access, including remote antenna locations.
- Using effective grounding methods.
- Installing alarm and closed circuit television surveillance systems.
- Screening personnel.
- Install underground facilities
- Preparing facilities for siege conditions.

Back-up equipment is costly. Minimum requirements should be carefully considered before outlay of funds. Old equipment may have more value here than as a trade-in. Substitution of fixed equipment with mobile equipment is a possibility. Compatibility with another agency's equipment is a consideration. Periodic testing, both of equipment and plans, is a must.

Emergency power is vital. Test stand-by plant(s) weekly. Store fuel underground and renew it at regular intervals. Your priority ranking at supply sources should be known and enforced. Standby units should start automatically when commercial power fails. Starting loads should be known.

Wiring to different facilities and their functions should be divided among several power plants according to load and need. Power plants may differ according to these requirements. Diesels are best for long hauls. Gasoline or LP units are more suited for shorter durations or smaller loads. Power plant facilities should be separate from occupied areas because of noise and fumes.

V.1.7 Mobile Station Equipment

Movable equipment, being reciprocal of fixed equipment, has a totally different application in the overall telecommunications scheme. Basic systems are designed with one base station and one or more mobiles. The base station stays in one place. Mobile units swarm around it like ants. The principal mission of the base station is to service the mobile units.

Mobile equipment is used by field personnel to communicate between themselves and with base stations. Two-way radios are perhaps the most important element of public safety telecommunication systems. When installed in vehicles they're called mobile units. When carried by the individual they're called portables or hand-carried units.

Mobile equipment is a small version of a base station in that its components are still basically a transmitter, receiver, power supply, microphone, speaker, cables and antenna. Its primary power source is its enclosed battery or the battery of a vehicle, or both. They're made to withstand weather and rough handling.

Because their geographical location varies, their operational capability varies. This is principally due to geographical signal-level differences. These variations are usually caused by changes in distance between a mobile and other stations, and signal shadowing from high terrain and buildings. Almost as detrimental are interference levels. These are very complex: ignition noise from its own and passing vehicles, traffic noise, neon signs, etc.

Vehicular units are available with various transmitter power ratings. RF power outputs usually range from one to 110 watts. Again, FM is the standard modulation used in the United States. Antennas are the flexible whip type. Some of the special types of vehicles with mobile units are aircraft, boats, fire and emergency trucks, ambulances, motorcycles, etc.

One vehicle that can be a common factor among all emergency services during large-scale events is the communications van. These special vehicles house communication equipment operating on many bands and are capable of handling large numbers of telephone lines. They can accommodate several operational personnel around the clock. Stocked with floodlights, bull horns, emergency power equipment, and practically impregnable, they become field headquarters for combined operations.

V.1.8 Personal and Portable Equipment

Base stations are becoming more accessible to mobile units today because of planning and technology. The trend, therefore, is toward the lighter and more compact lower-powered portables. A mobile unit is useless when an operator is away from the vehicle in which it is installed. Portables, on the other hand, are used both in and out of the vehicle. Adequate charging facilities are indispensable.

Enclosed batteries are used as the portables' power supply. This is the sole source of power when the field agent is on foot. In a vehicle, however, the portable is often plugged into the cigarette lighter, thus conserving the batteries in the portable. The portable is also plugged into the antenna of the vehicle, extending its range.

System design provides two principal means of extending the range of portable-to-base coverage: (1) relay of messages to other units by means of an accompanying vehicle whose mobile unit is made to operate as a mobile relay station and (2) relay of messages through fixed-surface satellite receivers at suitable locations throughout the operating area along with repeaters.

In these instances, as with base-station mobile-relay stations discussed in previous chapters, two channels are required. In fixed-satellite locations, however, one channel that to and from the base station can be a telephone or cable line.

V.1.9 Mobile Antennas

Mobile antennas are usually of the quarter-wave type because of physical limitations. Quarter-wave sections can be stacked to achieve gain. "Gain" in this sense means more signal strength because the vertical radiation pattern is compressed more into the horizontal plane (parallel the earth) where all the radios are. Therefore, we're really speaking of effective, not actual, gain.

Mobile antennas also can have some of the same characteristics of base antennas. However, mobile unit antennas are lighter and more flexible. Many are spring-mounted to survive shock and wind blast. Again, with gain given, the higher the frequency being used, the smaller the antenna. Radiation patterns are distorted by the vehicle on which the antenna is mounted. The direction of the distortion depends upon where the antenna is mounted on the vehicle. The most desired placement is in the middle of a metal roof. Therefore, the larger the antenna the more difficult the installation.

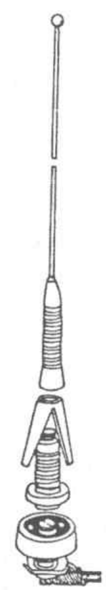


Fig. V-9 Mobile Antenna

V.1.10 Special Devices

Many problems arise in public safety telecommunication that require special devices for their solutions. A sample of the needs bred in these problems are

- Automatic logging of vehicle location and status.
- Fast retrieval of information in the field.
- Maintenance of privacy.
- Ability to exchange visual data when desired.
- Automatic selection of stations and channels.

V.1.10.1 Automatic Vehicle Location Monitoring

Automatic Vehicle Locations (AVL) technology was introduced in the 1970s. The objective was to automatically provide a continuous display of the location and movement of mobile units on a headquarters map. Several types of systems, triangulation, polar, and circular, have been tried and are in operation. Satellite-based systems are under consideration. These systems are accurate to within less than a block.

The cost-effectiveness of these systems continues to be debated. However, their usage is becoming more prevalent as costs diminish and technology improves.

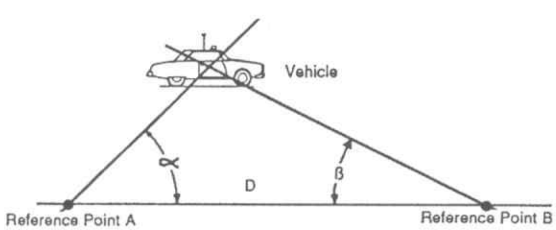


Fig V-10 AVM Triangulation Method

V.1.10.2 Fast Information Retrieval (G3)

The need for fast information retrieval is being met in the field by the growing use of computers, both in headquarters and in vehicles.

Typically, a mobile unit calls in a request for registration

and wanted information on a stopped vehicle.

The telecommunicator punches this request into a computerized data-base terminal and sends the response back to the mobile unit by voice. Alternately, if the mobile unit has a data terminal installed in its vehicle, the operator can bypass the base station and access the data-base directly. This capability also satisfies the need for exchange of visual, rather than voice, information.

V.1.10.3 Voice Data Privacy

Unwanted distribution of messages constitutes a real concern in public safety telecommunications. The wide-spread sales of home and mobile monitoring receivers reveal agency operations to the general public, including potential suspects. Others, whose interest in mayhem and suffering create unwanted crowds at scenes.

The criminal element, advised of police activities, can better plan its activities. Wreckers and ambulances have been known to arrive at the scene of accidents before the appropriate public safety units. Nearly all monitors use scanning techniques wherein the receiver regularly samples all channels and locks on to those on which communication is present.

V.1.10.4 Voice Scrambler

Voice scramblers make communication unintelligible. Many are available, all with differing techniques, allowing a degree of privacy in communication. Opinions differ within public safety circles regarding the need for scramblers, particularly because of cost, the type of public safety service and the type of function within each public safety service. Meanwhile, their use continues to be widespread.

V.1.10.5 Tone Coding

Tone coding is a highly desired option. Coded squelch, recall, automatic mobile identification, mobile radio control, remote transmitter keying and channel selection are examples of tone-coding applications. Sub-audible frequencies are typically added to voice signals to achieve these results. As a result, operations are carried out faster over larger areas. Although the FCC does not require tone coding, APCO strongly encourages its use.

V.1.10.6 Computer Aided Dispatching (G3)

CAD has brought computer technology into the control point. This has increased the flow of information on the channels and also relieved the telecommunicator of many functions.

The computer may serve in three basic capacities:

- Data storage and retrieval.
- Logic device serving a complex network.
- Computational device for stored data.

A computer can supply information within seconds, particularly to and from mobile personnel. In a message switching capacity, it can serve as the exchange center for a network of terminals. As a computational device, a computer can perform many administrative tasks, such as compiling report statistics for crimes, fires, accidents, etc. It is eminently useful in evaluating operations.

V.1.10.7 Receiver Voting

Base station transmitter power is usually high enough to cover the majority of the area desired. Smaller-powered mobile and portable units, operating under more difficult circumstances, cannot match the range of the base station.

Satellite receivers are useful in equalizing these differences. When a satellite unit is receiving more than one mobile unit at a time, it needs a method of selecting one of the mobile messages. Otherwise, destructive interference occurs due to the mingling of the messages.

Three typical selection methods use, audio quality, RF signal level and quieting.

The audio method processes signals to determine level, frequency distribution, syllabic rate and noise level pauses during speech. The RF signal level method compares signal strength and selects the stronger signal. The quieting-level method compares the quieting levels on the lines from the unsquelched receivers and chooses the receiver line with the least amount of noise.

"Quieting" is a term typical of FM equipment. FM equipment circuits have high gain and thus emit strong levels of noise at the speaker terminal. A receiver squelch (meaning to shut down) circuit keeps the noise out until a signal arrives in the receiver. The strength of the signal determines how much the noise is "quieted."

Typical calling modes used are continuous, periodic or lock-on. In the continuous mode the highest quality audio signal

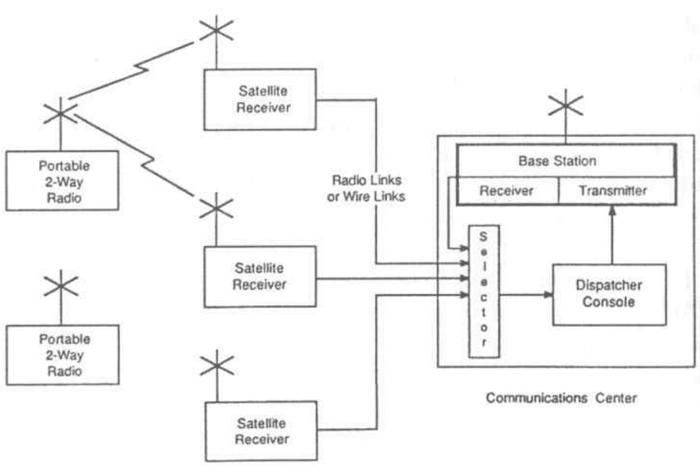


Fig. V-13 Satellite Receiver Voting System

always appears at the selector output. If the relative signal qualities change during a transmission, the selector will switch to the best signal. In the periodic mode, selection occurs only at pre set intervals. In the lock-on mode, selection occurs just once at the beginning of the transmission.

V.1.10.8 Digital Equipment

Digital equipment, because of its unique value in certain applications, is treated separately from the general genre of computers. The ability to transmit digital information in base-mobile systems offers several benefits in improved communication. One advantage is savings in time spent on the air. Another is high compatibility with automated message-processing systems, where increased speed lessens telecommunicator fatigue. A third benefit is increased privacy.

A typical system features two-way digital communication between base and mobile units, using a control point computer for automatic message processing and distribution. The digital signals are sent over a voice channel on a time-shared basis (either voice or digital). Frequently sent, or "canned" messages, can be coded into buttons in the mobile unit, such as in-service, out-of-service, message received, send ambulance, help, etc. Mobile units with digital capabilities are now common.

V.1.10.9 Facsimile Equipment

Facsimile or fax is a form of communication that graphically reproduces copy at a distant point by electronic means. The information can be in written, pictorial or graphic form.

In the simplest system, the copy is wrapped around a drum in the transmitting facsimile machine. The telephone number of the desired distant facsimile station is dialed; the copy is scanned by a bright light as the drum turns and transmitted over the phone lines. At the receiving point, the electrical signals are converted back into light and focused on special paper mounted on a receiving drum. Facsimile units suitable for mobile unit use are available.

V.2 The Operational Elements

Now let's take a look at the second public safety telecommunication element. We've seen how 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:

1. Frequencies
2. Propagation
3. Channels
4. Networks

V.2.1 Frequencies

We've seen that 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 distances. 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. The public safety telecommunication systems (Private Land Mobile) we are studying occupy only a very small part of the radio spectrum.

Frequency assignments in the low bands are not preferred for municipal and county radio systems because of their propagation characteristics. The larger physical sizes of antennas present one problem. Less penetration of signals among buildings is another. The signals in these bands are subject to "skip," resulting in strong interfering signals emanating from transmitters at great distances. Automotive ignition and other forms of electrical noise interference are common. Confining coverage to a limited area is a related problem. These frequencies are more useful in large systems, such as highway patrols, state road agencies and state forestry conservation operations.

Conversely, microwave frequencies are more like light waves. They bounce off buildings and other large objects. Their frequency characteristics require large amounts of transmitter power for general coverage. Also, good receiver sensitivity (response to low signal) is difficult to achieve. Little, if any, commercial two-way mobile radio equipment is made to operate at these frequencies. Their use has been limited mainly to fixed station, point-to-point control, microwave relay and radar speed-monitoring units.

The predominant frequencies used for two-way mobile operations are in the VHF and UHF bands. Frequencies above 800 MHz are being used more and more, particularly in trunked systems.

The combination of frequency characteristics and limited spectrum has made assignments in the land-mobile radio services a difficult task. The FCC has wisely enlisted the help of the users in these matters. Their frequency coordination groups cooperate in reviewing new license applications as a means of helping reduce interference between new and existing systems.

V.2.2 Propagation

We have touched upon this subject in previous chapters. It is repeated here in some detail because it is fundamental to any public safety telecommunications system. The basic concepts that help explain the actual transmission, propagation and reception of the radio frequency signals by which messages are sent should be well known.

In any system a certain minimum signal level must be present at the receivers. This is required independent of location within the operating area of users. Because it is neither economically nor legally permissible to use excessive transmitter power, estimates must be made of the minimum power necessary to reach the remote locations in the area.

These estimates can be made by calculating the approximate propagation losses

suffered by the signal between the transmitter and the receiver at the remote locations. The propagation loss and the minimum amount of power acceptable at the receiver can then be related to the required transmitter power.

Several methods are available to approximately determine propagation losses. In any given area, these are mainly dependent on the following:

- Frequency used
- Terrain and buildings in the area
- Heights of transmitting and receiving antennas

Calculating propagation loss can only give approximate results. In difficult cases, particularly when coordination efforts are questioned, engineering surveys may be necessary. Propagation losses are only one part of the "losses" and "gains" of power that exist in a radio system. Power gains usually occur in the following places:

- Transmitter
- Transmitter antenna
- Receiver antenna
- Power losses usually occur in the following places:
- Transmitter transmission line to the antenna
- Mismatch between transmission line and antenna
- Propagation to the receiver (path loss)
- Mismatch between receiver antenna and its line
- Receiver line from the antenna
- RF cavities, filters, duplexers, etc.

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

Transmitting and receiving antenna gain is usually specified relative to a standard antenna, a half-wave dipole. Dipole means two elements, or parts of an antenna. By focusing their ability to transmit and receive in certain directions, antennas can display an effective gain over the half-wave dipole. This is 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 rare exception). A practical limit is set for maximum achievable antenna gain because of restriction on size.

It is common to speak of the "effective radiated power" (ERP) of a radio station. This is not the same as the radio frequency power of the transmitter itself, since losses and gains occur in the antenna system. The antenna cannot have more power than the transmitter output. Gain usually occurs in the antenna itself. The propagation losses in the signal between the transmitter and a receiver can cause the signal power at the receiver to have a very small magnitude (one millionth) unless the two are practically side by side.

All receivers have a power level threshold below which their output will be unintelligible. This threshold is referred to as the receiver sensitivity (see above). Radio noise from such sources as auto ignitions, electric motors, natural sources (ambient noise) or interfering signals from other radio stations, often exist at power levels above receiver threshold sensitivities.

The receiver input signal power usually must be greater than the interfering signals for the receiver output to be intelligible. In general, a receiver rejects signals that have different frequencies than the desired signal. When the interfering signals have the same frequency, in-channel, or co-channel interference results. When the interfering signal is not on but is near the same frequency, adjacent channel interference can occur.

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

1. Change transmitter power or receiver sensitivity.
2. Change height of the base station antenna.
3. Change the gain of the base station antenna.
4. Reduce transmission line losses.
5. Move base station site.

Most 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 ways of increasing coverage. This can be accomplished by using improved antenna design or special low-loss cables.

V.2.3 Channels (G2), (G3)

We've run into this word before. It can be difficult for some to understand the relationship between channel and frequency. Let's reason together. In radio terminology, you can have a frequency and not have a channel. The first term is a thing. It can be measured. The second term is an elected concept. Try using lane, path or conduit. You choose the term for your system and elect to use it. Conversely, you cannot have a channel without a frequency. Or you can, but what good is it?

You can put a frequency in a channel but you can't put a channel in a frequency. Radio channels aren't allocated or regulated: frequencies are. The word channel, as used in public safety telecommunications, describes a useful network configuration. You can have as many channels as you want.

Here are two important relationships: first, a frequency occupies a certain, single, portion of space in the radio spectrum assigned to a licensee for his use. In truth, a frequency doesn't exist in the spectrum until someone puts it there (flips a switch or pushes a microphone button). It is the space, or slice of spectrum, authorized for use.

Second, in many base-mobile systems, one channel is used for base station transmissions and a separate channel is used for the mobile-unit transmissions. In such systems, this combination is called a channel pair.

Thus, in general, all of the slices of spectrum needed to carry on two-way communication, taken together, are called channels, places for frequencies. Ordinarily, no confusion results since the meaning intended is usually clear from the outset in a given system. It's also common to use the words frequency and channel interchangeably. If so, no harm is done because the system meaning is made clear beforehand. Channel configurations in public safety telecommunications are designated as follows:

- Single-frequency, One-Way Operation: permitting transmission of information from user A to user B, but not vice versa. This is broadcasting, not typical in the PSRS.
- Single-frequency, Simplex Operation: permitting transmission from A to B or from B to A, but not in both directions at the same time, and using the same frequency in both directions.
- Two-frequency, Simplex Operation: permitting transmission from A to Bor from B to A on two distinct frequencies, but not in both directions at the same time.
- Two-frequency, Duplex Operation: permitting transmission from A to B or from B to A on two distinct frequencies, and at the same time 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 at the same time at the mobile end.

To more clearly visualize these definitions, a diagram of a generalized base-mobile communication channel is shown in Fig. V-17. 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 of f1 and f2 are different. A single-frequency channel uses a common frequency for both the base and the mobiles. Therefore f1 and f2 are the same.

Let's be clear on one other important point here. When you are the licensee, it's your right to use your frequency. Your right in this matter does not constitute ownership. Your assigned portion of the spectrum has just been put in your care for the duration of time stated on your license. The FCC can take it back with just cause for reasons permitted under its regulatory authority. The most common ways to lose your license are to violate its rules of use and fail to renew it at the end of your license term. Also, a license can be rescinded if the system is not on the air during the time period specified in the authorization.

V.2.4 Network Configurations

We now come to the third and last operational element of public safety telecommunications systems. A network is generally 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. In the 800 MHz public safety bands, because of the architecture of trunked systems, a growing tendency to speak in terms of "talk groups" instead of channels is becoming more prevalent.

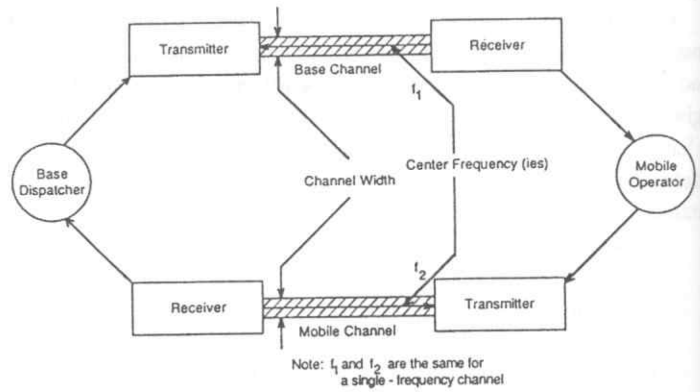


Fig. V-17 Base-Mobile Communication Channel

There are particular benefits to trunked systems which deserve specific mention:

1 .Every public safety radio can use the five common channels in these systems to talk to any other radio. This means units called in from outside a sytem during an emergency will have communication capability. These common channels are located in the 821-824/866-869 MHz bands.
2. Other-than-public safety units, such as Red Cross or the FBI, can likewise join in a concerted action.
3. Smaller systems, within a joint system, may have fewer financial burdens.
4. The number of radios in emergency vehicles are reduced.
5. Licensing and planning is simplified.

The size and degree of formal organization of networks varies widely. Many networks have been formed as the result of unstructured evolutionary growth and exhibit little cooperation between users. Others, such as intercity and interstate networks dedicated to ongoing criminal pursuit, are well planned and organized.

A network is a complex system composed of many pieces of equipment and many people working together to fulfill the communication needs of the departments within the network. Typical structures show the following general considerations:

• Location of control points
• Location of base station radio equipment

• Number of frequencies in each channel
• Number of channels in the network
• Channel operation

Each of these factors are more or less independent of each other. For each, exists a pair of trade-offs to be considered when building up a network. These are the following trade-off pairs:

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

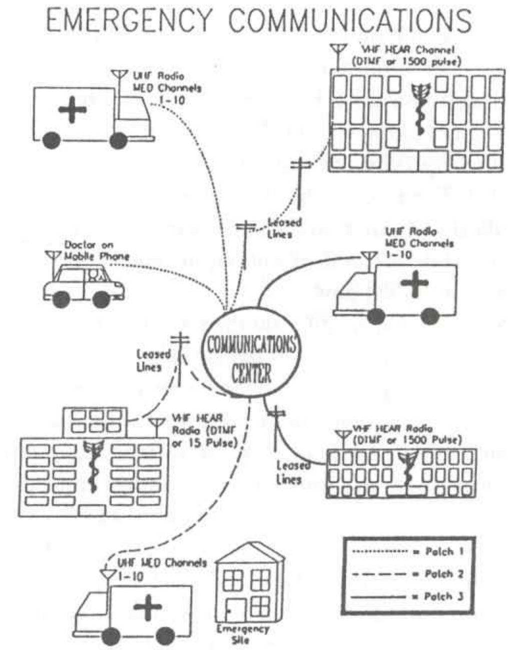


Fig. V-18 Medic Radio System Diagram Courtesy of Penta Corp.

The above trade-offs can be combined to give 24 basic network configurations. See Chapter VII. Experience has shown some 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 the following considerations:

1. Means of control
2. Types of interference in the network
3. Available methods of channel "isolation" to prevent interference within the network
4. Performance under heavy message loads
5. Radio coverage characteristics
6. Degree of mobile-to-mobile and base-to-base communication in the network
7. Degree of use of special devices

V.3 The Personnel Element (G1),(G2),(G3)

The personnel element is the most important, and, at the console level, often the least appreciated in public safety telecommunications. In days past, the task of sitting long hours at the console was a catch-all job, a sink to hold the old, the odd and those needing punishment. But today, with the advent of the 9-1-1 and PSAP operations, the importance of those in telecommunications, particularly those known as telecommunicators, has come to the forefront.

The operating staff of the telecommunications system includes, but is not limited to, the supervisor, telecommunicators, complaint takers, engineers, planners and clerks. The trend is toward greater utilization of civilians in law enforcement, fire, medical and other professional operations inasmuch as the dispatching of information and resources does not require end skills. Telecommunications careers themselves are skilled jobs.

Selection and training are the really important criteria for any phase of communications work. The ability to remain calm and effective at all times is a measure of adequate screening and on-the-job training. Pure pencil-and-paper training alone is not adequate. APCO has been recognized as the leading national resource of telecommunicator training. Its standard 40-hour Basic Telecommunicators course has been adopted by many states and formal training centers in the country. This text, itself, is one of many self-help and reference materials available to the field.

To the citizen, the telecommunicator, is the department. Skillful handling of complaints and referral of calls is the mark of a good operation. The procedures required to reach a professional level of competence in telecommunications are well-illustrated by the list of appropriate material in the Appendix.

The organization of the communications function is based on the degree of specialization and size. The patterns that seem to have enjoyed success in various sized police departments, for example, are depicted in Figure V-21. 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 that must be afforded

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 treat-

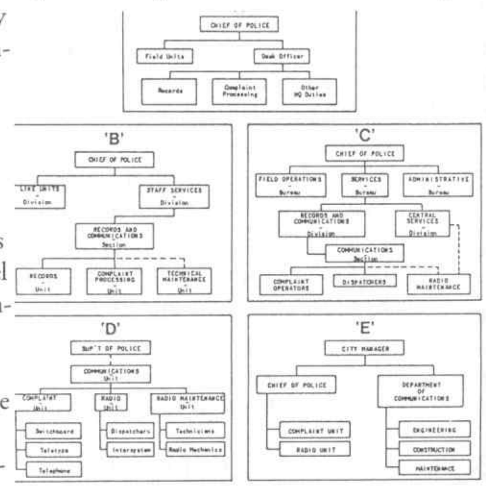


Fig.V-21 Representative Organization

ed if control is to be achieved. One exception, of course, is in a statewide organization where operations are conducted from substations. Even so, functional control still remains at headquarters staff supervision performed in the field. Microwave and other tie lines enable 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-21, is an agency that administers the telecommunications system for an entire community, or for the police and other departments of several communities. Such a centralized agency relieves the individual departments of many of the administrative details and technical aspects of a system. Control of the communications operation is achieved through adequate representation of each department on the agency's policy-making body.

V.4 Summary

In this chapter we reviewed the three major elements of a telecommunication system. Under the equipment element we discussed base and mobile equipment and special devices. Under the operational element we found frequencies, propagation, channels, and network configurations. And we emphasized the personnel element was the principal component in a system.

In the equipment category we found the principal difference between base and mobile equipment is physical size, power and mobility. The trend today, we discovered, is to install fixed equipment in such a way as to facilitate the use of hand-held equipment. This means microwave and telephone systems are being used in more imaginative ways, such as amplifying and relaying the relatively weaker signals to and from smaller field equipment. And, particularly in view of the recent threat of terrorist activities in the U.S, we know security, back-up equipment and emergency power plants are of extreme importance. Lastly, we learned something about special devices, a rapidly growing field.

Under operational elements we learned of system components that can't be directly discerned by our five senses. In fact, we really do not know what electricity is. We use it every day in our lives, and all we only know of it is its effects. Technology has made it possible for us to use even more ethereal modes of magnetic qualities. Radio seems to be so mysterious, yet in this section we found it's not so complicated in terms of how we want to use it. We even make networks for it.

The personnel element has no technical qualities, so to speak. People are the most challenging constituent in life. Given good condition, equipment always reacts in the same manner to the same stimulus, time after time; people do not. Many supervisors have muttered he wished machines could do it all. But they can't. That is why training is so important. Rote learning instills behavior patterns that can approximate mechanical reactions, and thus diminishes emotional error. No computer can supplant the human mind, especially in times of unknowns telecommunicators handle often. That's why the public has the right to ask for, receive and depend upon highly skilled telecommunicators to intelligently use the resources tax funds provide. Organizational schemes to attain this end were illustrated.

The next chapter is going to give us a larger view of public safety telecommunications systems. You'll be given the names and responsibilities of all such systems. In the process, you will see why and how they work together, and the role of the Federal Communications Commission which regulates the whole community.

Chapter VI

Descriptions and Functions Of Public Safety Telecommunication Systems

We have, to this point, been discussing public safety telecommunication systems in terms of their discrete elements. A problem in doing this is the inherent tendency to lose the whole idea of a system itself along the way. We have attempted to minimize this effect by telling you something about how and why the parts fit together, as we went. So, to clear things up, let's do a little review before we go too much further.

We need to once more look at the reasons why such systems exist, and to remind ourselves of the basic functions which are common to all such systems. Then we'll round out our view of public safety telecommunication systems by bringing an even larger picture into view. To do this, we'll have to take a look at all of the systems in the Public Safety Radio Services (PSRS). And, because every system has to be licensed, we'll talk a little about the Federal Communications Commission, and dip into the coordination process.

VI.1 Needs and Functions (G1), (G2), (G3)

The functions that follow are responsive to the elementary needs found in most of the public safety telecommunications systems, which are:

- Transferring information between prescribed individuals, groups and organizations, along "paths" of information flow.
- Storing and retrieving information for various periods in a timely manner
- Assessing, as a function of time, the condition of the information flow in order to maximally utilize the system capabilities.

Before examining the way these needs are satisfied, let's determine what a public safety telecommunications function is.

In our work, considering the function includes looking at the process. That process is the activity that must be carried out to fulfill the information handling needs of the department. A communication function, therefore, can be identified by the following:

- Function 1. Information to be conveyed

- Function 2. Path to be furnished
- Function 3. Information to be stored, and its means

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 the information. Thus, the communication path consists of all equipment, radio channels, telephone, data circuits and personnel required to convey information from an originator to a destination. As applied to our work, functions associated with the first need are divided into the following main categories:

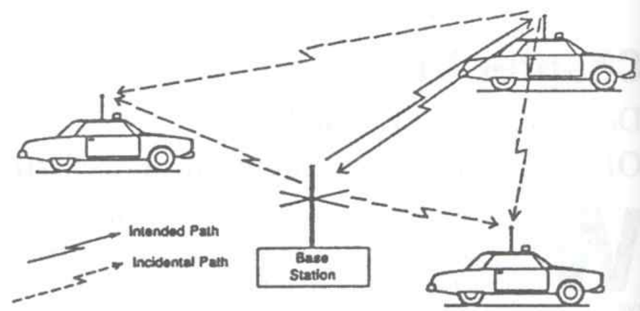


Fig VI-1 Radio Communication Paths

Category 1. Communication between the public and the department
Category 2. Communication within the department
Category 3. Communication between like departments
Category 4. Communication between the department and other agencies

The second need to store information exists in each of the above four categories. It involves the range of activities from note-taking to centralized storage of records. The telecommunication system aids in the transfer of information to and from each category, but most notably with centralized data bases and information-retrieval systems records in files or computers. The third need exists in the three latter categories, particularly for communication within the department.

VI.2 Categorical Processes

We think the categories of needs and functions should be further expanded to demonstrate the processes entailed in their executions:

Category 1: Communication between the public and a department usually can be stated as:

- Requests for assistance
- Requests for information
- Offers of information to the department
- Offers of information by the department

The topics of these communications are easily determined by the above-stated official duties of the departments in the individual radio services.

Category 2: Communication within departments are typically:

- Dispatch instructions
- Tactical commands
- Status of resources
- Dissemination of information

These communications are normally of a routine nature which involve the necessary operations of a department. During peak times of emergency, communications become terse and fast and largely involved with solving a particular problem.

Category 3: Communication between departments are mostly monitoring and clearinghouse messages. Their topics are the same as Category 2.

Category 4: Communication between public safety departments and other agencies is an extremely important process. There are times when FCC rules, which define user eligibilities in particular radio services, do not correlate so efficiently in reality. For example, medical services, such as hospitals, ambulance and rescue and volunteer fire departments are, in various ways, eligible to operate in the PSRS. On the other hand, disaster relief, rural school buses, patrols or emergency repair of communication services may not operate in the PSRS.

Yet, it is highly necessary for PSRS operations to have good communication with such other agencies, especially in time of emergency when all of these services must work together at an emergency scene. In widespread disasters, there are times when PSRS agencies must also work closely with railroads, telephone companies, tow trucks, etc., none of which can be licensed in the PSRS. This means cross-services operations.

Successful cross-services communications depend essentially upon the following factors:

- Prior planning: Working at a disaster is no time to kick options and alternatives around.
- Message volume: Alternative means for handling excessive traffic must be in place.
- Language barriers: Verbal codes are normal means of expediting messages, especially routine ones, which continue to be used during emergencies. A liaison or translation means must be at hand.
- Priorities: The "too many cooks" syndrome should be avoided. Authority between departments at their levels should be agreed upon. Priorities may change according to the nature of the emergency. Decisions in these matters may have to originate at higher administrative levels.

With these reviewed system functional components and their categories freshly in mind, let's take a look at how they are applied in individual PSRS.

It should be remembered the great distinction which separates these services from all others is the PSRS are all tax-supported. Their services are directly paid for by the public and they, in turn, directly serve the public.

VI.3 Public Safety Radio Pool

The following are eligible to hold authorizations in the Public Safety Pool. This language also can be found in 47 CFR subpart B § 90.15 through 20.

- Any territory, possession, state, city, county, town or similar governmental entity is eligible to hold authorizations in the Public Safety Pool to operate radio stations for transmission of communications essential to official activities of the licensee, including:
- A district and an authority, but not including a school district or authority or a park district or authority except as provided for in § 90.242 (travelers' information stations);
- A governmental institution authorized by law to provide its own police protection; and
- Persons or entities engaged in the provision of basic or advanced life support services on an ongoing basis are eligible to hold authorization to operate stations for transmission of communications essential for the delivery or rendition of emergency medical services for the provision of basic or advanced life support. Applications submitted by persons or organizations (governmental or otherwise) other than the governmental body having jurisdiction over the state's emergency medical service plans must be accompanied by a statement prepared by the governmental body having jurisdiction over the state's emergency medical services plan indicating that the applicant is included in the state's emergency plan or otherwise supporting the application.
- Governmental entities and governmental agencies for their own medical activities.
- Governmental entities and governmental agencies for providing medical services communications to other eligible persons through direct participation in and direct operational control of the system, such as through central dispatch service.
- Persons or organizations other than governmental entities are eligible to hold authorizations in the Public Safety Pool to operate radio stations for transmission of communications, as listed below. When requesting frequencies not designated by a "PS" in the coordinator column of the frequency table, applications must be accompanied by a statement from the governmental entity having legal jurisdiction over the area to be served, supporting the request.
- Persons or organizations charged with specific fire protection activities.
- Persons or organizations charged with specific forestry-conservation activities.
- Persons or organizations, listed below, engaged in the delivery or rendition of medical services to the public and on a secondary basis, for transmission of messages related to the efficient administration of organizations and facilities engaged in medical services operations:
- Hospital establishments that offer services, facilities, and beds for use beyond

24 hours in rendering medical treatment;
- Institutions and organizations regularly engaged in providing medical services through clinics, public health facilities, and similar establishments;
- Ambulance companies regularly engaged in providing medical ambulance services;
- Rescue organizations for the limited purpose of participation in providing medical services;
- Physicians, schools of medicine, oral surgeons, and associations of physicians or oral surgeons;
- Persons or organizations operating a rescue squad for transmission of messages pertaining to the safety of life or property and urgent messages necessary for the rendition of an efficient emergency rescue service.
- Each rescue squad will normally be authorized to operate one base station and a number of mobile units (excluding hand carried mobile units) not exceeding the number of vehicles actually used in emergency rescue operations.
- In addition, each rescue squad will be authorized to operate a number of hand carried mobile units not exceeding two such units for each radio equipped vehicle actually used in emergency rescue operations.
- Persons with Disabilities. A statement from a physician attesting to the condition of the applicant or the applicant's child (or ward in case of guardianship) must accompany the initial application from a person claiming disability eligibility.
- Any person having a hearing deficiency such that average hearing threshold levels are 90 dB above ANSI (American National Standards Institute) 1969 or ISO (International Standards Organization) 1964 levels and such other persons who submit medical certification of similar hearing deficiency.
- Any person having visual acuity corrected to no better than 20/200 in the better eye or having a field of vision of less than 20 degrees.
- Any person, who, through loss of limbs or motor function, is confined to a wheelchair, or is non-ambulatory.
- Any person actively awaiting an organ transplant.
- Parents or guardians of persons with disabilities under 18 years, or institutions devoted to the care or training of those persons.
- A veterinarian, veterinary clinic, or a school of veterinary medicine for the transmission of messages pertaining to the care and treatment of animals. Each licensee may be authorized to operate one base station and two mobile units. Additional base stations or mobile units will be authorized only on a showing of need.
- Organizations established for disaster relief purposes having an emergency radio communications plan for the transmission of communications relating to the safety of life or property, the establishment and maintenance of temporary

relief facilities, and the alleviation of the emergency situation during periods of actual or impending emergency, or disaster, and until substantially normal conditions are restored. In addition, the stations may be used for training exercises, incidental to the emergency communications plan, and for operational communications of the disaster relief organization or its chapter affiliates. The initial application from a disaster relief organization shall be accompanied by a copy of the charter or other authority under which the organization was established and a copy of its communications plan. The plan shall fully describe the operation of the radio facilities and describe the method of integration into other communications facilities which normally would be available to assist in the alleviation of the emergency condition.

- Persons or organizations operating school buses on a regular basis over regular routes for the transmission of messages pertaining to either the efficient operation of the school bus service or the safety or general welfare of the students they are engaged in transporting. Each school bus operator may be authorized to operate one base station and a number of mobile units not in excess of the total of the number of buses and maintenance vehicles regularly engaged in the school bus operation. Additional base stations or mobile units will be authorized only in exceptional circumstances when the applicant can show a specific need.
- Persons or organizations operating beach patrols having responsibility for life-saving activities for the transmission of messages required for the safety of life or property.
- Persons or organizations maintaining establishment in isolated areas where public communications facilities are not available and where the use of radio is the only feasible means of establishing communication with a center of population, or other point from which emergency assistance might be obtained if needed, for the transmission of messages only during an actual or impending emergency endangering life, health or property for the transmission of essential communications arising from the emergency. The transmission of routine or non-emergency communications is strictly prohibited.
- Special eligibility showing. The initial application requesting a station authorization for an establishment in an isolated area shall be accompanied by a statement describing the status of public communication facilities in the area of the applicant's establishment; the results of any attempts the applicant may have made to obtain public communication service, and; in the event radio communications service is to be furnished, a copy of the agreement involved must be submitted.
- Class and number of stations available. Persons or organizations in this category may be authorized to operate not more than one fixed station at any isolated establishment and not more than one fixed station in a center of population.
- Communication service rendered and received.

- The licensee of a station at any establishment in an isolated area shall make the communication facilities of such station available at no charge to any person desiring the transmission of any communication permitted.
- For the purpose of providing the communications link desired the licensee of a station at an establishment in an isolated area either may be the licensee of a similar station at another location or may obtain communication service under a mutual agreement from the licensee of any station in the Public Safety Pool or any other station which is authorized to communicate with the fixed station.
- A communications common carrier operating communications circuits that normally carry essential communication of such a nature that their disruption would endanger life or public property is eligible to hold authorizations for standby radio facilities for the transmission of messages only during periods when the normal circuits are inoperative due to circumstances beyond the control of the user. During such periods the radio facilities may be used to transmit any communication which would be carried by the regular circuit. Initial applications for authorization to operate a standby radio facility must include a statement describing radio communication facilities desired, the proposed method of operation, a description of the messages normally being carried, and an explanation of how their disruption will endanger life or public property.
- Communications common carriers for radio facilities to be used in effecting expeditious repairs to interruption of public communications facilities where such interruptions have resulted in disabling inter city circuits or service to a multiplicity of subscribers in a general area Stations authorized under this section may be used only when no other means of communication is readily available, for the transmission of messages relating to the safety of life and property and messages which are necessary for the efficient restoration of the public communication facilities which have been disrupted.
- Persons or entities engaged in the provision of basic or advanced life support services on an ongoing basis are eligible to hold authorization to operate stations for transmission of communications essential for the delivery or rendition of emergency medical services for the provision of basic or advanced life support. Applications submitted by persons or organizations (governmental or otherwise) other than the governmental body having jurisdiction over the state's emergency medical service plans must be accompanied by a statement prepared by the governmental body having jurisdiction over the state's emergency medical services plan indicating that the applicant is included in the state's emergency plan or otherwise supporting the application.

VI.4 The Role of the FCC

We have waited until now, for obvious reasons, to go further into the part played by the Federal Communications Commission in these matters. At this time, you've indirectly and intuitively come to recognize some overall control must be placed over the allocation and assignment of frequencies and their usage. Therefore, the requirements you've seen of PSRS systems will serve as actual examples of reasons why and how the FCC exists: reasons for its rules, how they are enforced and the manner in which it conducts its business.

The statutory authority that governs communications and provides the basis for the management of electromagnetic frequencies and land lines is the Communications Act of 1934, as amended. This act 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. 20402.

The FCC apportions frequencies among commercial broadcast users, such as TV, and non-broadcast services, such as the PSRS. The commission's prime resource, the radio spectrum, is not available without prior restrictions, such as the federal government's claims upon large portions of spectrum space for its military and other operation uses. The Interdepartment Radio Advisory Committee (IRAC), in which the National Telecommunications and Information Administration (NTIA) serves as secretariat, performs functions similar to the FCC, but only for federal agencies. The NTIA, jointly with the FCC, is charged with developing national spectrum utilization policy.

Further limiting effects are the many international treaties that apportion spectrum space worldwide. These international agreements are generally given birth by the International Telecommunication Union, which is a branch of the United Nations. In the United States, these agreements require senate ratification. Bilateral agreements may also be signed, such as those which the U.S. has with Canada and Mexico.

Most of the problems that beset PSRS planners are attributable to the lack of usable frequencies. Competition for frequencies is intense, not only between broadcast and non-broadcast users, but within the land mobile groups (for example, between PSRS and business and industrial radio users).

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 into discussions with radio equipment manufacturers, the system planner must have basic knowledge of certain fundamental provisions of FCC regulations. These deal with such factors as frequency stability, type of emission, power levels and acceptable equipment. Most of these provisions, for PSRS planners, are set forth in Part 90 of the FCC Rules and Regulations.

Inquiries on specific matters pertaining to the PSRS should be addressed to the Federal Communications Commission, Private Radio Bureau, 2025 M St., N.W,

Washington D.C 20554. Also, contact APCO for a list of its frequency coordination local advisors. APCO coordinates frequencies for police and local government users, for all PSRS users in the 800 MHz bands and other public safety frequency "pools."

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 these rules are constantly observed. Violation of these rules could result in violation notices from the FCC and possible suspension of services. The basic operating rules are as follows:

- All communications, regardless of their nature except in microwave systems, are restricted to the minimum practical transmission time. Continuous radiation of an unmodulated carrier, except in microwave systems, 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, the FCC may require any or all stations to monitor the transmitting frequency before transmission.
- Tests may be conducted by an licensed station as required for proper station and system maintenance, but such tests are to be kept to the minimum.
- Precautions must be taken to avoid interference to other stations.
- Among the specific provisions that apply to the PSRS are the following:
- Eligibility (as stated above for the separate PSRS)
- Permissible communications: Stations in these Services are authorized to transmit communications essential to the official public safety activities of the licensee in accordance with the licensed service
- Types of communications: In addition to the intercommunications between their own base stations, and mobile stations and between mobile stations, stations authorized in the PSRS may also intercommunicate with each other if no harmful interference exists.

Communication units of a licensed PSRS user may normally be installed in any vehicle that may require cooperation or coordination with PSRS activities in an emergency. This includes those vehicles normally excluded as listed in Category 4 above.

VI.5 Role of the Frequency Coordinator

The responsibility for actual determination of how many and which frequencies shall be assigned to a PSRS agency rests with FCC. It is assisted in this task by frequency coordinators who if had appointed.

Each coordinator in the PSRS has a central point for providing coordination. These frequency coordination points are listed in the next section. They are typically the national headquarters of associations of members representing their individual services.

Frequency coordination is the process of selecting and recommending to the applicant and to the FCC one or more radio frequencies for use.

The object of this process is four fold:

1. To cause the least amount of interference to other radio users
2. To cause the least amount of interference to the applicant himself
3. To provide the most usable frequency(s) to the applicant
4. To allow maximum reuse of the spectrum

Thus, the function of these coordinators is essentially to minimize the likelihood of harmful interference being caused to other systems by the operation of a proposed system, and thus making the most efficient use of the spectrum allocated to their services. An application may require the coordinator to perform extensive research in determining matters such as physical separation, propagation paths and the existence of other systems licensed on the same or adjacent channels in another service.

These searches entail costs. They can also be time-consuming because of the enormous amount of data that has to be researched. Many of the frequencies available to the PSRS are also available, under specific conditions, to other users in the land mobile radio services, and vice versa. Cross-service sharing agreements must be reached when these frequencies are considered. Such sharing is scrutinized very carefully by all concerned.

Because of the importance APCO attaches to the coordination service, it begins its research in the very geographical area in which the applicant is located. This is done by volunteer local area frequency advisors. These advisors are APCO members who, as a donated public service to all PSRS users in their areas, make recommendations according to their knowledge of the area, their experience in the field and extensive use of a centralized database. Their experience is considerable. Many advisors are engineers or supervisors of large PSRS telecommunications systems, or both.

Seeking approval from a Frequency Coordinator is considered the most satisfactory method for processing an application. If a dispute arises, or other considerations merit the action, an application may be forwarded to the FCC for arbitration.

The functions of frequency coordinators are purely advisory in character, and their comments are not binding upon either the applicant or the commission. Their comments must not contain statements which would imply that they have any authority to grant or deny applications.

The requirements on an applicant by a frequency coordinator are precise and exact. If they're not known and complied with, an applicant faces unnecessary delay in processing. In fact, repetitious application errors, that cause continuous delays in processing are not unknown.

VI.6 General Coordination Practices

Private land mobile radio services users may be licensed in either the public safety pool or business/industrial pool.

APCO is the largest coordinator in the public safety radio pool. It coordinates for all

public safety 800 MHz applicants. The 420 MHz allocations for Detroit, Buffalo, and Cleveland are also handled by APCO. The organization handles applications for TV sharing (general access pool) in the 470-512 band. It also handles the 821-824/866-869 channels dedicated to the new national plan. APCO accepts all 800 MHz applications for public safety and special emergency conventional and trunked systems throughout the public safety spectrum. This includes, local government, police, fire, highway maintenance, forestry-conservation, and special emergency.

If you need assistance in locating any Part 90 frequency coordinators, please contact APCO Frequency Coordination department at 1-888-APCO 9-1-1 or visit their web site at www.apco911.org.

The eligibility rules are as specific as possible. Inevitably, "gray" areas can occur. In such circumstances, the FCC will make the final decisions.

Willful false statements made on the FCC 600 Application For License Form are punishable by fine and/or imprisonment. Public safety applications are exempt from FCC, not coordinator, fees.

VI.7 Application Processing

All of the public safety radio services coordinators have standard forms for use in processing applications. These forms have a direct relationship to the FCC Form 600 application form. One of the odd facts discovered by the coordinators is the average applicant, no matter how much experience or education, is ill-informed about how to complete forms. Inasmuch as forms are the grist of federal institutions, and because these types of errors are a major contributor to processing delays, coordinators have given much thought to remedying the matter. Below, in capsule form, are the suggestions developed by APCO:

1. Coordinators should charge a fee for their services. Fees are not included here because of their changing values and complexities. Typically, the appropriate fee in the correct amount is required to be attached to the application. There are several ways to go about this:

A. Call or write the appropriate Coordinator and ask for the appropriate form, including the FCC Form 600 and a fee schedule. After completing the forms, call the coordinator again, state what you have put on the forms and ask for a fee estimate.

B. If the coordinator has local frequency advisors, ask for the name of the advisor in your area. Then contact him prior to forwarding the forms to the coordinator.

C. Attach your agency purchase order to the application sent to the coordinator and ask for billing when the fee has been determined.

2. Coordinators normally accept purchase orders from governmental agencies as well as from vendors and other valid commercial entities.

3. Send the coordinator's form, the FCC form and the fee together as a

unit. If the Coordinators form has a space for remarks, it is strongly suggested you use it to tell the coordinator exactly what you want in the form of a general statement. Forms can fool you. You might think the filled-in spaces tell the application processor what you want, but this is often not the case. Here is a suggested example for the "remarks" space on the coordinator's form:

" (1) A new applicant (2) asking for authorization for (3) a simplex system consisting of (4) one base station (5) with a 6db gain omni antenna (6) on a new 100' supporting structure (7) serving six mobile units (8) in the police radio service (9) on a frequency of 155.01 MHz (10) with squelch tone coding as may be recommended."

Now, these are plain words a processor can refer to, especially if it is necessary to contact the applicant during the processing stage.

4. Use an original FCC Form 600 when possible. The commission will, however, accept executed copies when original forms are not available. Also, be sure the coordinator form you are using is a current version.

5. Be sure you are sending your application to the correct coordinator. If in doubt, call APCO. They'll be glad to help you. Don't mix services indiscriminately on an application (see 16 below) just for the purpose of system licensing. Mixing is allowed only in applications for interservice sharing according to specific FCC rules.

6. If your application is for "modification" or "reinstatement", be sure to attach a copy of the appropriate license affected.

7. The commission prefers typewritten entries on its Form 600 but will accept those legibly handwritten.

8. Fill every space on the 600 Form. If an item does not apply, put a dash in that space. This does two things: it helps prevent you from overlooking something and it tells the commission you did not inadvertently overlook an item.

9. Follow the item numbers on the 600 in sequence. Don't skip around. Be sure the totals of columns agree with the individual item entries, especially in the mobile spaces.

10. Do not guess in filling out geographical coordinates, terrain height or distances to airport boundaries, etc. A coordinator can check on the veracity of such entries and, the commission can, and just as the commission can and often does. So, after all the time spent in coordinator processing, if the Commission later discovers an error in these areas, the application comes to back you. The process starts all over again and you still don't have your license!

11. Be consistent! Sometimes an entry made under one Form 600 item number has to be entered again under another item number. Watch out!

12. Under some items in the 600, as many as six options may be chosen. This means you can choose only one out of the six!

13. The commission insists on correct state postal abbreviations. If you use "FLA" instead of "FL" watch out!

14. In rural areas, when giving station location, use road numbers or other

geographic marks and enter the name of the nearest town under 15 miles distant. Do not use a P.0 Box number!

15. Be sure to fill in a box that asks for a telephone number. Otherwise...... you got it! Back!

16. The address of the applicant should be that of a major office at a permanent location. Normally, it should be the address of the city manager, fire chief, etc. And don't forget, this is the address where the FCC will send your license when it is granted. Sometimes such papers get lost in large agencies. So, be sure to use the "Attn" line to help insure whoever sent in the application forms gets the license.

17. The name of the signor must be typed, no ifs, ands or buts about this. The application must be signed. The signor must be an official of the entity making the application.

18. D onot forget the date!

19. Do not forget to furnish the telephone number in the space provided for it.

20. Above all, read everything, fill in or mark every space, and be consistent in your entries.

21. Remember, coordinators cannot and do not guarantee the frequency(s) they recommend to applicants will be free of interference.

VI.8 Summary

We began this chapter by reviewing the needs and functions of public safety telecommunication systems, and then their processes,. We did this to have these concerns fresh in our minds to compare their applications to different types of responsibilities that prescribe the duties of the different radio services. We then went individually into the five different public safety radio service groups. We learned the ways each had to meet FCC license eligibility requirements. In the end we found, that the differences between these eligibilities can often become blurred, and determined how such problems can be worked out.

The role of the FCC was considered, and then the important relationship of the frequency coordinators to the commission's role. We expanded on these matters in the section on general coordination practices. Perhaps the most important section in licensing activities was on application processing.

Here, then, we've climbed the mountain together and you now can begin to look down the other side to where you're going: your destiny in public safety telecommunications. And we're really going to look, for we'll see more pictures and drawings than words in the following chapter on networks.

Chapter VII

Public Safety Radio Networks

VII.1 Introduction

A wise old Chinese gentlemen once said long ago a picture is worth a thousand words. He's right. Would you care to sit down and write out the directions for tying your shoe laces? It would be almost impossible. And, even if you did, few people would read or understand them. It's the same way with describing networks.

So, we thought we'd reserve this chapter just for the purpose of giving you pictures of some of what we've been talking about in previous chapters. You can use them as references in studying earlier chapters. You can use the table to determine what network you are in or contemplating to build. Use the networks as illustrations in your own work. Maybe you can use them in preparing requests for bids, making replies to bids, etc. If you're preparing an application for frequency coordination, they could be put to good use in describing your proposed system. Use your own imagination.

VII.2 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 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. Again, reference to previous chapters where the basic factors of networks have been discussed may be appropriate as this chapter is read. The five trade-offs the basic factors give rise to are listed as follows:

1. Dispersed or central location of dispatching points.
2. Dispersed or central location of base stations.
3. Single or multi-frequency channels.
4. Single 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 configuration shows eight of the 32 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 VII-1, in which a network number is assigned to each unique combination. The 24 networks are shown in diagrammatic form in Figs. VII-2 thru VII-25, Networks 1 thru 24. Figure VII-1 is the legend (explanation) of the symbols and notations used in the diagrams. It is assumed the dispatching centers are either in the same building as the base transmitting and receiving equipment or connected to them by land lines or RF line. It is also assumed at least two mobile units are operating on each channel.

The network configurations are generated by choosing one of the alternatives in the five areas. While it is possible to have networks with both alternatives, i.e., 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.

Possible Network Configurations for Five Trade-Offs

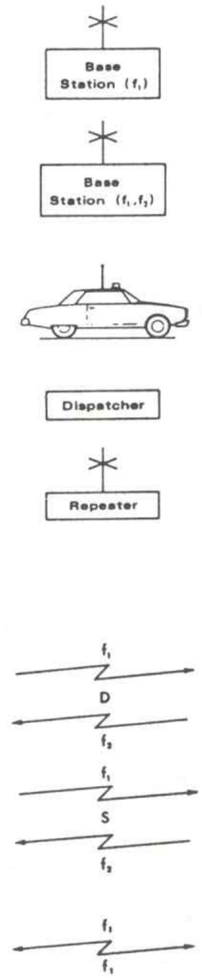
	Dispatching Personnel		Radio Equipment		Channel		Network		Operation	
Network Number	Central	Dispersed	Central	Dispersed	One-Frequency	Multi-Frequency	One-Channel	Multi-Channel	Simplex	Duplex
1		X		X		X		X		X
2		X		X		X		X	X	
3		X		X		X	X			X
4		X		X		X	X		X	
5		X		X	X			X	X	
6		X		X	X		X		X	
7		X	X			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	

VII.3 Summary

We think this chapter will be of practical use to you. It is reference material we think will stay dog-eared on your desk for as long as you have an interest in public safety telecommunications.

The entire effort of this text is displayed here: systems, systems, systems. Now that you have the still pictures, you must find yourself in them, and then make them work, work, work!

NETWORKS OF PUBLIC SAFETY RADIO SYSTEMS



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.

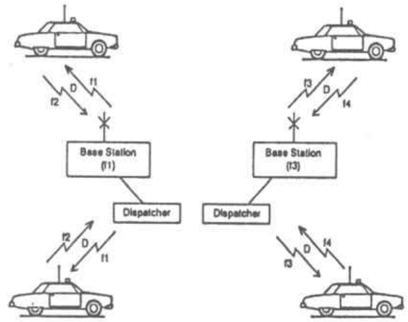
Duplex radio channel using two frequencies, f_1 and f_2.

Simplex channel using two frequencies, f_1 and f_2.

Simplex channel using one frequency, f_1.

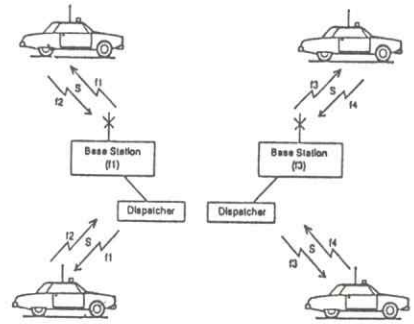
Fig. VII-1 Legend to Network Diagrams

NETWORKS OF PUBLIC SAFETY RADIO SYSTEMS



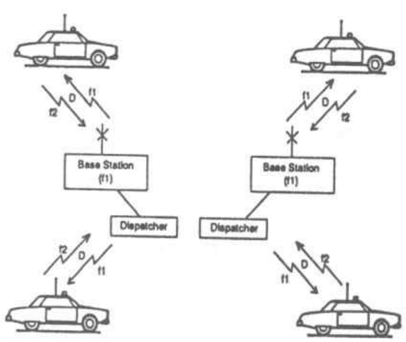
Dispersed Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
Multi-Channel Network
Duplex

Fig. VII-2 Network No. 1



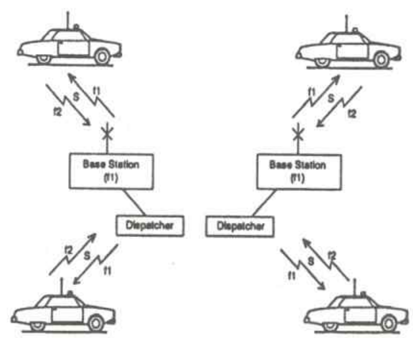
Dispersed Dispatching Personnel
Dispersed Radio Equipment
Multi-Frequency Channel
Multi-Channel Network
Simplex

Fig. VII-3 Network No. 2



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

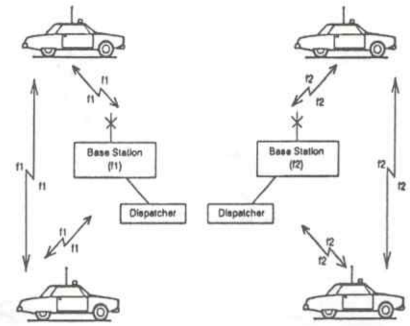
Fig. VII-4 Network No. 3



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

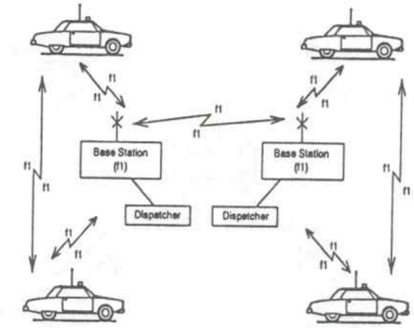
Fig. VII-5 Network No. 4

NETWORKS OF PUBLIC SAFETY RADIO SYSTEMS



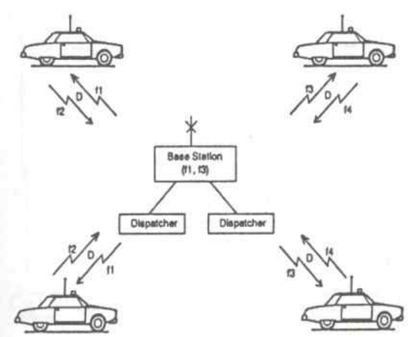
Dispersed Dispatching Personnel
Dispersed Radio Equipment
One-Frequency Channel
Multi-Channel Network
Simplex

Fig. VII-6 Network No. 5



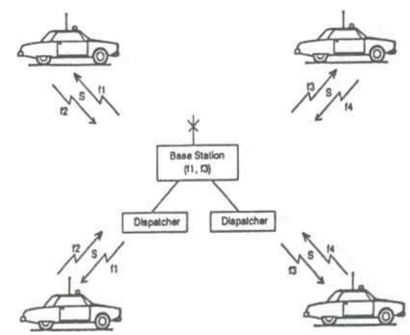
Dispersed Dispatching Personnel
Dispersed Radio Equipment
One-Frequency Channel
One-Channel Network
Simplex

Fig. VII-7 Network No. 6



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

Fig. VII-8 Network No. 7



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

Fig. VII-9 Network No. 8

NETWORKS OF PUBLIC SAFETY RADIO SYSTEMS

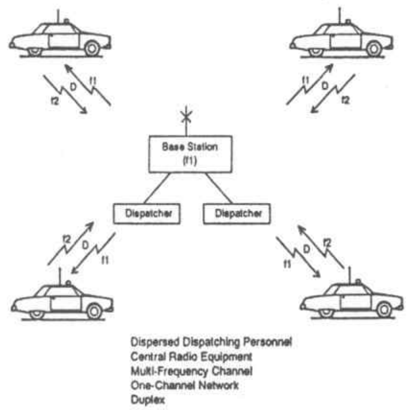


Fig. VII-10 Network No. 9

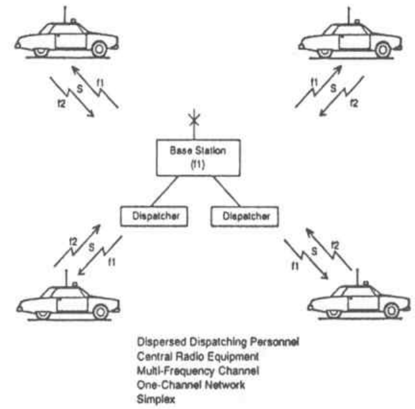


Fig. VII-11 Network No. 10

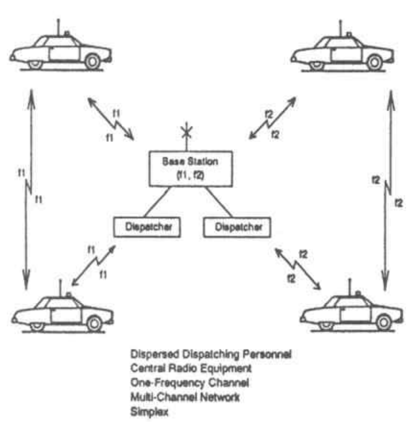


Fig. VII-12 Network No. 11

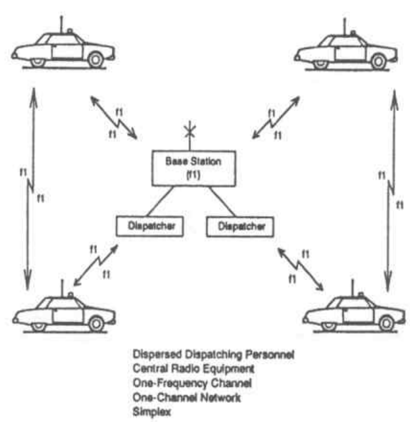


Fig. VII-13 Network No. 12

NETWORKS OF PUBLIC SAFETY RADIO SYSTEMS

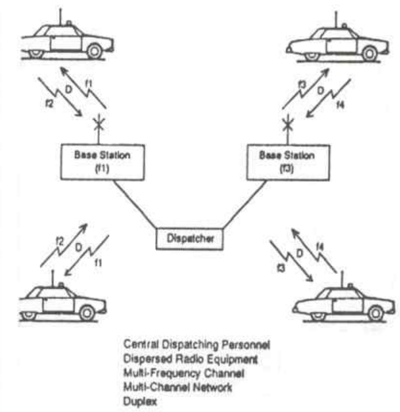


Fig. VII-15 Network No. 13

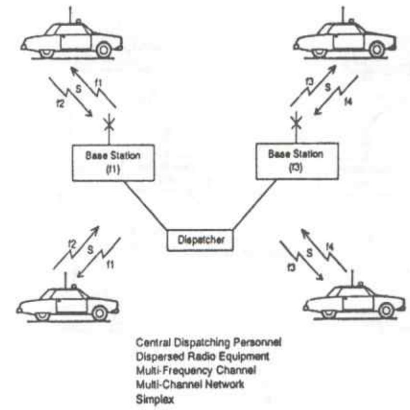


Fig. VII-15 Network No. 14

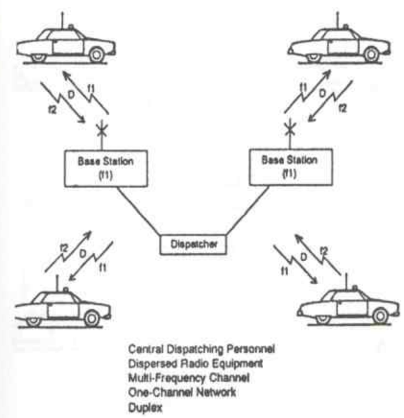


Fig. VII-16 Network No. 15

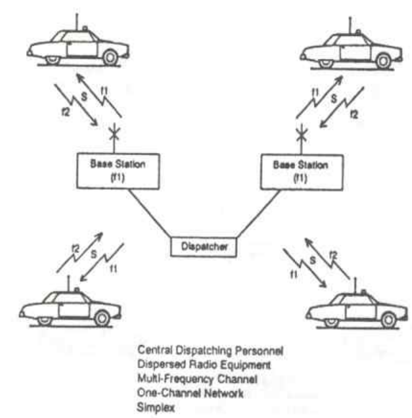
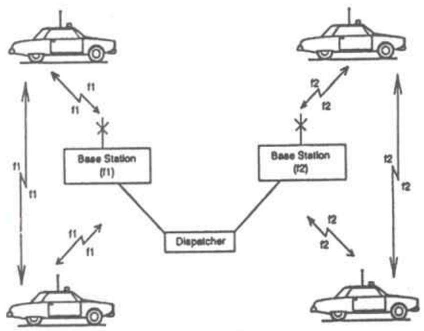


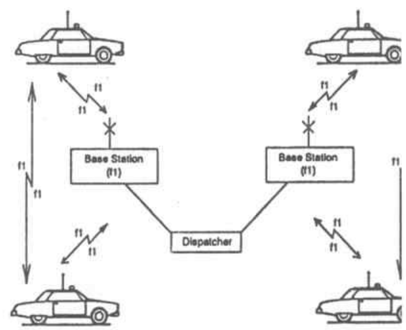
Fig. VII-17 Network No. 16

NETWORKS OF PUBLIC SAFETY RADIO SYSTEMS



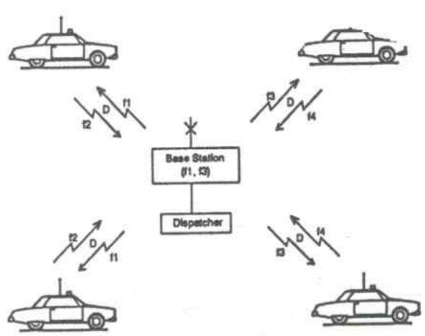
Central Dispatching Personnel
Dispersed Radio Equipment
One-Frequency Channel
Multi-Channel Network
Simplex

Fig. VII-18 Network No. 17



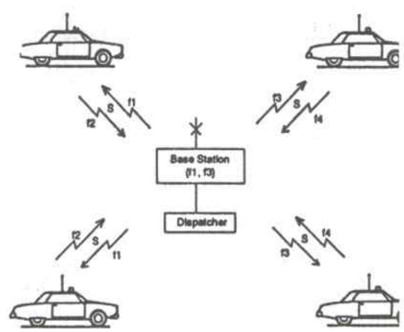
Central Dispatching Personnel
Dispersed Radio Equipment
One-Frequency Channel
One-Channel Network
Simplex

Fig. VII-19 Network No. 18



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

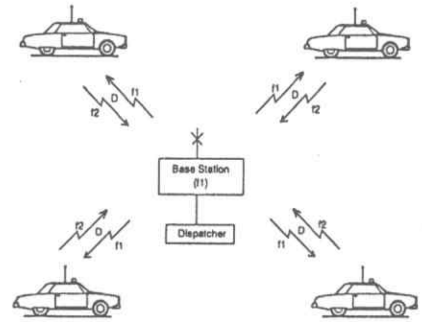
Fig. VII-20 Network No. 19



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

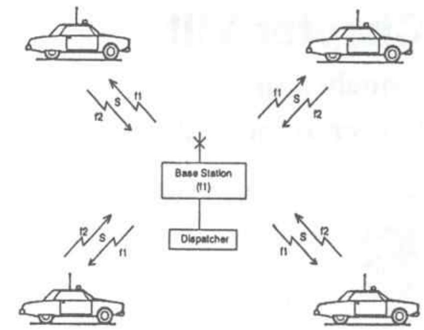
Fig. VII-21 Network No. 20

NETWORKS OF PUBLIC SAFETY RADIO SYSTEMS



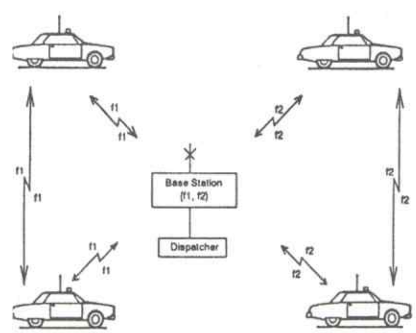
Central Dispatching Personnel
Central Radio Equipment
Multi-Frequency Channel
One-Channel Network
Duplex

Fig. VII-22 Network No. 21



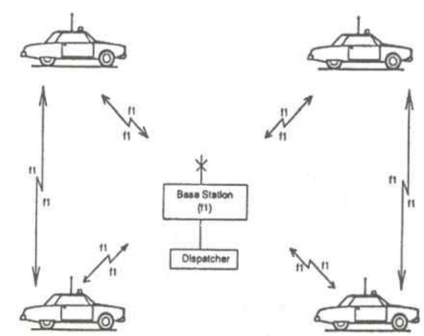
Central Dispatching Personnel
Central Radio Equipment
Multi-Frequency Channel
One-Channel Network
Simplex

Fig. VII-23 Network No. 22



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

Fig. VII-24 Network No. 23



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

Fig. VII-25 Network No. 24

Chapter VIII

Conclusion
Congratulations!

VIII.1 Well, Well, Well

Someone once said a conclusion is where you stop thinking. Not you. You're going on. You have every reason to be proud. Even though this book was written in the easiest and least formidable manner possible, it does present a challenge of some magnitude. We can only hope it has been, and will continue to be, of significant help to you in your chosen endeavors.

VIII.2 There's More

There is still more for you to learn. The degree of that learning depends upon where you are right now. If you are looking around for a career, and are new to the field, you have come to the right place. As stated in Chapter III, we were going to attempt to stay away from training and procedures. We think we did a fair job in that respect. Our objective, indeed, was to describe public safety telecommunications systems. We wanted to concentrate on "what" a system is, and "why", rather than on "how" it is operated.

We fell by the wayside in several places. It is difficult to differentiate between what a thing is and how it works, especially in technical areas. This is because a complicated picture being portrayed can be incomplete if the viewer has no idea of what it's about. We really fell off the wagon in Chapter IV with regard to effectiveness, reliability and evaluation.

We minimally included these topics because of the difference between public safety and other systems. Unless these subjects become everyday concerns that are not only preached but practiced, the public is being cheated. You would be a cheat and work for, say, a police telecommunications system? You should be arrested, yet!

If, instead, you're already a member of the public safety telecommunications system corp., you may find this book helpful as a reference and as a means of introducing new personnel to the job who are slated to work with you.

VIII.3 Be Aware

One other thing. In Chapter III.4, we stated it was typical that standards, or better said, requirements, on systems could too often be unknown, understood or not met. This seems true, to some degree, even at the higher levels of systems. But, we're stressing a different point here. If you do indeed go into, or are already in, public safety telecommunications systems, please know that you can't perform your work well unless you have an awareness of why it's there in the first place. Even if you're in a job making widgets, you can make them better and faster if you know why they're being made, where they fit in the whole assembly and what the assembly does.

Chapter IX

Appendix
Concerning History, Contributors and Resources!

IX.1 The Historical Viewpoint

Here are some things we think you should know about APCO. Why? Because in the public safety radio services field, there's no way you will not come across its name or works. If you're going to work in public safety telecommunications, you ought to know who started it.

Bob Batts of the Detroit Police Department built the first land mobile radio ever employed for scheduled public safety operation. His first radio equipped police car went into service in 1921, and the Detroit PD Radio Broadcasting System was put into full operation in 1928. Mobile radio pioneers immediately saw the need for a representative organization. As the result, a voluntary membership group called the Associated Police Communications Officers was founded on January 24, 1935 in St Louis, Mo., by 23 men from 13 states.

This marked a new venture, which had to start from scratch. From this point on in this historical review, the pronoun "we," rather than the more officious term APCO, is going to be used often. The reason is, in the beginning, "we" were just a bunch of good-old-boys tackling one of the biggest and most important jobs ever known in the annals of radio. We think you'll appreciate our struggles more on this informal basis.

We had to build our own equipment. Then we had to interest the manufacturing community in our market. There were no experienced consultants. We designed and implemented our own systems. We originated our own procedures and practices. We founded the world famous "Ten Signals" in 1929. Fred Link of Link Radio, and Dan Noble, later of Motorola, built and installed the first statewide FM multi-base police radio system for the Connecticut State Police, during 1939-40. The Federal Communications Commission didn't know us from Adam. No spectrum was set aside for our use. These were the first areas where we did battle, and won.

No sooner did the FCC recognize us as a separate radio service than it held a general reallocation proceeding after WW II. During this time, we had to protect what little spectrum we had, we were also required to prove we needed more frequencies. We had to do this despite powerful opposition from the old broadcasters and the new giant on the block; TV.

Police radio operations grew fast. Gradually, the police telecommunicators became involved in all municipal communications, such as fire and general city operations. In recognition of this, the name APCO was changed in 1961 from Police Communications Officers to Association of Public-Safety Communications Officials. The dash was put in the Public-Safety Communications portion of the title to preserve the meritorious historic value of the APCO seal.

We were the leader in founding the Public Safety Communications Council (PSCC). This organization was formed on April 6, 1962. The PSCC is an organization of all public-safety frequency coordinators. We were also among the founders of the Land Mobile Communications Council (LMCC). The LMCC was formed on November 30, 1967, by representatives of all users in the land mobile radio services. Members of these national organizations are listed in Chapter VI.

During this entire time, membership in the association was possible only by means of a recommendation from a voting member. A voting member was one who was intimately involved in the design, planning and implementation of radio systems. No operator membership classification existed. A significant event occurred in 1971 when membership was opened to the operators and dispatchers of public safety systems. This marked the beginning of a major period of transition. Concern about what was in the "black box," and where it was located, began to equate with how it was operated.

Also, up until this time, even though we were a national organization, we had no central fixed seat of operations. Each time elections were held, the APCO "business office" moved to wherever the new APCO secretary lived. The increase in activity at the national levels caused APCO to take stock of this situation. As a result, the APCO national office was founded in New Smyrna Beach, FL in 1971, with J. Rhett McMillian Jr., in the new office of executive secretary.

After this important step, APCO began to grow in size and importance. It received funding from industry and governmental agencies for its project series efforts. It fought for, and received, FCC authorization for a National Emergency Radio Channel. It worked with congressional subcommittees and was successful in having the Communications Act of 1934 amended to give greater recognition to the importance of the public safety radio services.

APCO became an international organization in 1988, with Canada becoming its first foreign associate. In late 1986, APCO, by FCC directive, became a frequency coordinating point, the largest, in the public safety radio services. Last, but not least, APCO now holds the world's largest public safety trade shows in conjunction with its annual conferences. The conferences, themselves, are the largest of their kind. In addition to its regular business sessions, APCO holds panel discussions with regulatory and industrial leaders. Seminars dealing with training and education at all levels are standard features.

IX.2 The Current Viewpoint

APCO now has 5 major operational centers: general administration, membership/

marketing and publications, APCO Institute, conferences and exposition and automated frequency coordination. The association is recognized by industry and regulatory bodies as the leader in the public safety radio Services. Membership has grown steadily. Educational efforts, which include publications such as this, training manuals and seminars held around the country, have increased tremendously. Coordination efforts are well known. APCO national and regional conferences are the largest in the field.

This very short review was written to inform readers a dedicated group of telecommunicators is working hard to better its members professionally and provide a higher level of service to communities. The operation of public safety telecommunication systems is fast maturing as a profession in the truest of terms.

APCO is available to you.

IX.3 Resources : More about APCO and the APCO Institute

The Association of Public-Safety Communications Officials, Inc. (APCO) is the nation's oldest and largest professional membership organization dedicated to the needs of public safety communications. Founded in 1935, APCO is a not-for-profit corporation with 13,700 members and 48 chapters in the United States, its territories, and Canada. APCO members include government communications personnel from law enforcement, fire and rescue, emergency medical services, 9-1-1, forestry and conservation, highway maintenance, local government, with commercial members who serve the communications market, and others who support the enhancement of public safety communications.

Among its many functions, APCO is certified by the Federal Communications Commission as the frequency coordinator for all radio spectrum allocated to law enforcement and local government, and for all 800 MHz (and other) spectrum in the public safety pool. APCO also publishes a monthly "trade" journal, the Public Safety Communications/APCO Bulletin, which provides up-to-date information on developments, both operational and technical, in public safety communications.

In addition, APCO plays an aggressive role in public safety communications training. Education also has been among the association's main functions throughout its history. In 1988 APCO established the APCO Institute as a not-for-profit subsidiary dedicated to more fully addressing the educational and training needs of public safety communications.

APCO also hosts the nation's largest annual conference and trade show, bringing together public safety professionals throughout the world for five days of networking, educational seminars for operational, supervisory and technical personnel, and an opportunity to view the latest in public safety communications technology, equipment, systems and services. APCO and its chapters also host four annual regional conferences and hundreds of chapter level conferences and meetings each year.

Information on APCO membership or any of its activities can be obtained by calling 1-888-APCO 9-1-1, or visiting our Web site www.apco911.org.

Chapter X
Glossary

The definitions of many of the following terms were obtained from FCC Rules and Regulations, and from two dictionaries of electronic terms:

Markus, John, "Electronics and Nucleonics Dictionary," 3rd Edition, McGraw-Hill Book Co., New York, 1966

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. 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 or 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 multiconductor 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 communication between two definite fixed stations.

Channel, radio: As 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 piezoelectric crystal.

Crystal-controlled transmitter: A radio transmitter or receiver in which the or receivercarrier 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 PR in decibels as defined as 10 10910 (P/PR)

Directivity: The value of the directive gain of an antenna in the direction of its maximum value. The higher the directivity value, the narrower the beam in which the radiated energy is concentrated.

Distortion: Unfaithful reproduction of audio or visual signals due to changes occuring 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 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 variation 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 specific 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: 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.

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 powre 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 portion 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 at 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 that 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 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 that are jointly administered or that communicate with each other by sharing the same radio channel or channels.
Radio receiver: An instrument that 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 that 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 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 frequency (for comparison see "simplex channel, single-frequency").
Simplex channel, two-frequency: A simplex radio system utilizing two distinct assigned 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 that 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 or 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 funtions 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 that terminates at a switchboard rather than a telephone.
Two-way radio: A radio that is able to transmit and receive.
Width, channel: The difference of the upper and lower frequency limits of a channel, expressed in Hertz.

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