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ABSTRACT

The Federal Communications Commission's opening of the 900 MHz spectrum for use by the land mobile radio community was a landmark event in the history of mobile radio in the United States, as this action almost doubled the amount of spectrum available. This report describes the current regulatory environment, analyzes the applicability of 900 MHz to law enforcement communications, and presents the conclusions and recommendations that result, as well as recommending a program for demonstration of a working system. A historical, regulatory, and litagory background of Docket No. 18262 is presented. Also detailed are those factors peculiar to the 900 MHz spectrum and the regulatory environment created by affecting the applicability of this spectrum to the satisfaction of law enforcement needs, and the operation of a law enforcement communications system. This discussion provides a basis for understanding how these new technical and regulatory concepts relate to law enforcement systems needs. A description of a five-phase demonstration and technology transfer program including cost estimates and schedules is also included. (JEG)

THE APPLICATION OF THE 900 MHz BAND TO LAW ENFORCEMENT COMMUNICATIONS

AN ANALYSIS OF TECHNICAL AND REGULATORY FACTORS AFFECTING THE APPLICABILITY OF THE 900 MHz PORTION OF THE RADIO SPECTRUM TO LAW ENFORCEMENT COMMUNICATION SYSTEM PROBLEMS

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PREPARED UNDER GRANT NO. 77 SS 99 6009

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UNITED STATES DEPARTMENT OF JUSTICE

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EXECUTIVE SUMMARY

The Second Report and Order in the proceedings relating to Docket No. 18262 published by the Federal Communications Commission (FCC) in 1974 promised relief of the long-standing frequency congestion problems of the law enforcement communications community. Concurrently, fundamental revisions to the procedures and policies by which law enforcement agencies obtain access to the 900 MHz portion of the spectrum were made.

These proceedings allocated 30 MHz for all elements of the land mobile communications community, including law enforcement. Of the 600 channels possible in this portion of the spectrum, 100 were allocated for conventional systems, 200 for "trunked"1/ systems, and the remaining 300 held in reserve. New ground rules were established for the assignment of these frequencies. Block assignments reserving specified frequencies for designated classes of users such as law enforcement agencies were not authorized in this band. No provisions were made for local frequency coordination. The procedures at 900 MHz call for the FCC staff to use a first come, first served assignment technique based upon Commission-established standards of channel loading. The Commission also mandated that all systems requiring more than five channels be "trunked".

These and related concepts were developed by the Commission in recognition of the rapidly expanding spectrum requirements of the land mobile communications community. Its stated intention was to apply modern technology to the problem of the growing demand for a finite amount of spectrum. But the impact of these policies, together with the engineering questions pertaining to the technical suitability of this newly available spectrum have, heretofore, not been considered in light of the specialized communications needs of law enforcement agencies.

In February 1977 the Law Enforcement Assistance Administration (LEAA) recognized that many technical, economic and managerial questions about this newly available spectrum and related frequency assignment philosophies must be answered before the potential benefits inherent in Docket No. 18262 could be fully available to the law enforcement community. Under LEAA Grant No. 77 SS 99 6009 the Associated Public-Safety Communications Officers, Inc. (APCO) was requested to analyze these problems, make appropriate recommendations for future actions, and describe a program to demonstrate the potential capabilities of these new concepts.

In this study (called Project 16), APCO has determined that these frequencies do, in fact, present the opportunity for significantly improved spectrum availability and communications system performance for law enforcement agencies. Conventional type 900 MHz equipment is now available. It is relatively cost effective and functionally suitable for installation, maintenance and operation by many law enforcement agencies. The 900 MHz spectrum offers a major opportunity to alleviate much of the spectrum congestion that has long afflicted the public safety communications community.

On the other hand, the present regulatory environment for 900 MHz as established in Docket No. 18262 poses certain difficulties that may impede the effective utilization of this vital portion of the spectrum. The absence of block allocations, coupled with the elimination of the requirement for local area coordination, can seriously jeopardize the implementation of integrated and cooperative systems. The first come, first served frequency assignment pol[illegible] threatens potential access to these frequencies by the tax-supported members of the la[illegible] mobile community. The rate at which the business and other economically flexible elements of the land mobile community are moving to these frequencies raises serious questions regarding the eventual availability of frequencies for law enforcement agencies that are faced with the time-consuming financial processes that must be complied with by tax-supported entities.

The question of trunked system implementation by public safety agencies has proven to be highly complex. The potential for improved spectrum utilization that might result from trunked system technology in the law enforcement sector has not been demonstrated in light of the specialized law enforcement operational needs; nor is the responsibility of the taxpayer to support these potentially more costly systems, even if perhaps they are more spectrum-efficient, been established.

1/ See Chapter I for definitions.

While improved spectrum efficiency may result from such systems, the degree of improvement attainable seems largely dependent upon the number of units involved in the system. Trunking systems with fewer than 300 mobiles offers little improvement in spectrum utilization. Trunking larger systems, under present standards of loading, offers only marginal improvements in possible channel availability.

Little spectrum-related benefit derives from trunking heavily loaded channels. Improved spectrum utilization is not likely to result from trunking the existing number of channels of a major metropolitan system that is currently loaded with 100 or 150 mobile units per channel. Overall increased spectrum utilization, while maintaining a present or an improved level of service in such systems, is more likely to occur in large municipalities if multi-agency systems can be developed. Systems in which the communications needs of several (or all) agencies of a given unit of government could be united, such that lightly loaded channels can be combined with the heavily loaded law enforcement channels (incorporating the time phase difference of periods of peak loading), could provide opportunities for improved spectrum utilization by using trunked techniques. Similarly, the combination of several agencies of different but contiguous units of government also offers the possibility of providing the system size and channel availability needed to make possible improved spectrum utilization through trunking. Both of these options present significant management, political and economic problems.

A most important result of this study has been the identification of significantly improved operational possibilities that are inherent in the trunked system concept. Such systems, employing digital address and control channel techniques, make possible system configurations that offer greatly increased flexibility, multiple address system organization, automatic priority designators, multiple system control points, channel redundancy, flexible system expansion capabilities, and other advantages yet to be identified. These techniques can greatly enhance the functional capabilities of law enforcement communications systems. The trunked system concept currently mandated by the FCC offers the possibility of satisfying law enforcement communications needs for the next several decades.

Project 16 recognized that the technologies required to implement these trunked systems exists today. The principal impediment to their immediate application is the need to identify those necessary functions that this technology can provide and to configure a system that demonstrates the improved operational capabilities that are possible. Project 16 concludes that the federal government should provide the initiative needed to develop a demonstration system that will make potential users aware of its capabilities and resolve those engineering questions inherent in the implementation of new technologies.

The study recommends that the federal government initiate a program to develop a model trunked system demonstrating those operational features having particular application to law enforcement communications needs. It also recommends that the federal government absorb the costs associated with system development, test, and technology transfer, and that the selected model community bear those costs associated with hardware manufacture and installation.

Project 16 has answered many of the questions relating to the opening of the 900 MHz spectrum to law enforcement communications needs. It has pointed out certain regulatory areas that need modification if these frequencies are to be most effectively used. It has shown that the equipment needed for conventional, traditional type 900 MHz systems is available today. But perhaps of most importance, it has pointed out the potential of trunked, 900 MHz systems to exploit existing technologies in a way that will provide new systems configurations that will accommodate the operational needs of law enforcement agencies during the coming decades.

ACKNOWLEDGMENTS

The Report on Project 16, APCO's study on the Application of the 900 MHz Spectrum to the Needs of Law Enforcement Communications Systems, is the product of many dedicated individuals and organizations. Of primary importance are those members of the Systems Development Division of the Law Enforcement Assistance Administration (LEAA) who recognized the need for such a study if the benefits of this new technology were to be fully exploited, contributing to the solution of some of the criminal justice problems in this country. The appreciation of the regulatory and technical complexities of this emerging technology, and the foresight that recognized the potential role that such technology might play in improved law enforcement agency effectiveness, offer a clear example of the contributions that that agency is making toward the improved performance of law enforcement agencies throughout the country.

The accomplishment of this Project was made possible by the voluntary membership of APCO. Many of these individual members gave freely of their time and experience by participating in seminars, offering suggestions and providing insights into complex managerial and operational questions. Of no less importance are the members of the vendor community who responded to surveys and who gave so willingly of their time to participate in conferences and provide in-depth engineering and economic information.

Particular appreciation is expressed for the many days of study, evaluation, discussion and writing voluntarily contributed by the members of APCO's Project 16 Task Groups I and II. These individuals, taking valuable time from their own work, participated in review sessions, analyzed draft documents, wrote suggested additions and revisions, and provided both policy and technical guidance. It is these Task Group members, representing the membership of APCO, who made possible the accomplishment of this Project.

Special recognition must be accorded J. Rhett McMillian, Jr., the Past Executive Director of APCO. His wisdom, coupled with the experience of a long career in the field of Public Safety Communications, was instrumental in establishing the form of the Project and providing the guidance needed to assure the orderly completion of each step of the program.

The entire land mobile radio community is indebted to Mr. Joseph M. Kittner and Ms. Virginia S. Carson for the summary of the regulatory history of Docket No. 18292 and the description of the ramifications of this proceeding contained in Chapter I. Their extensive knowledge of these proceedings, long association with matters pertaining to public safety communications, together with their widely recognized professional expertize, made possible the concise and clear presentation of the complex spectrum-related issues presented in this Report.

The gratitude of all the Project participants is offered to Mrs. Peggy Webster, the Project secretary. Her professional skill, willing accomplishment of revision after revision, and cheerful performance of those many tasks necessary to assure the reproduction and distribution of the numerous drafts to various participants, made the timely accomplishment of this Project possible.

Those many members of APCO who contributed so much to the success of this Project deserve the gratitude of the entire law enforcement community. Their willing contributions, professional skills, and enthusiastic participation have made a major contribution to the continued development of public safety communications capabilities.

Donal D. Kavanagh, Project Director

New Smyrna Beach, Florida

February, 1978

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INTRODUCTION

The opening of the 900 MHz spectrum for use by the land mobile radio community by the Federal Communications Commission in its proceedings in Docket No. 18262 was a landmark event in the history of mobile radio in the United States. By this action the FCC almost doubled the amount of spectrum available to the land mobile radio services, offering a long-awaited hope of relief from constraints on system design caused by the limited number of available frequencies.

In this proceeding the Commission laid a foundation for the future of mobile radio. It authorized the development of "cellular systems" which may some day make possible the establishment of a mobile radio system able to serve the general public much as the public telephone network does today. It set aside 40 MHz for the development of these cellular systems.

The Commission provided for the growth of private land mobile radio systems by establishing two 15 MHz bands (806 MHz to 821 MHz for base only, and 851 MHz to 866 MHz for mobile only)1/ for use by the land mobile radio services. This 30 MHz provides sufficient spectrum for the eventual assignment of 600 two-way voice channels in the land mobile radio service.

In this action the FCC did much more than authorize much needed spectrum for land mobile use. It radically altered many of its long-standing concepts of how this spectrum would be managed and how these frequencies would be assigned. The Commission did away with block allocations at 900 MHz. That concept, long in use in the lower bands, reserved specific frequencies or groups of frequencies for use by specific services, to the exclusion of other users. In lieu of this block allocation concept, the Commission established a "first come, first served" frequency assignment procedure whereby all authorized users, regardless of service, would be assigned frequencies by the Commission staff in the order of the sequence of their license applications, based upon channel loading standards established by the Commission.

The Commission also mandated that the larger systems (those with loading requirements justifying the assignment of more than five channels) must employ trunked 2/ system technologies. These trunked systems would be based upon automated computer controlled switching technologies that could instantaneously select an unused channel from among any of those assigned to the system, rather than rely upon discrete assignments of channels to individual mobile units or groups of units.

The Commission explained in the Second Report and Order resulting from Docket No. 18262 that it was pursuing these policies in the interest of increased "spectrum efficiency" and improved spectrum management. It made clear in public statements made in connection with Docket No. 18262 that it foresaw a great growth in the demand for mobile radio systems, and that in view of the finite limits of the available spectrum, the Commission was determined to exploit the resources of technology and management policy to best use the available spectrum.

The Commission recognized that the trunked technologies it had mandated are likely to be expensive and, in some cases, might only be justified by some form

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1/ This newly available spectrum has been referred to by several appellations during the development of Docket No. 18262. Technically, it is a portion of the UHF band and currently it is frequently referred to as the "800 MHz" band or the "860 MHz" band. During much of the period in which Docket No. 18262 was active, the entire portion of the spectrum under consideration in that Docket was widely referred to as the "900 MHz" band. In deference to this historical precedent, this Report will continue to use that term to designate that portion of the spectrum available for land mobile radio service use between 806 MHz and 870 MHz.

2/ For definitions of this and similar terms used extensively in this Docket, see Chapter I:

of cooperative or common user management organization. To this end it authorized the establishment of Special Mobile Radio Systems, or SMRSs. These SMRSs would not be licensed as common carriers regulated by State Public Utilities Commissions. They would be authorized to provide base station services to only those users who are individually licensable in their own right.

The complexity of the Docket No. 18262 proceedings posed significant questions concerning the Commission's policies affecting spectrum management. While these innovative policies had long been discussed in the near decade of argument preceding the publication of the Second Report and Order resulting from Docket No. 18262, the impact of these new policies upon the special needs of the public safety sector, including the specialized needs of law enforcement communications, was not clear. What are the effects of the elimination of block frequency allocations? Of first come, first served frequency assignments? Does the Commission have the resources to support the frequency assignment program? Will frequencies be available when tax-supported agencies have finally obtained funds for system implementation?

As with any innovative technology, engineering questions need answers before new systems can be installed. What are the propagation characteristics of these frequencies? Is equipment available and what will it cost? Can it be maintained using available skill levels and test equipment? Is it safe to operate? Reliable?

The mandating of trunked systems technology raises additional problems for those considering designing large systems. What are the potentials for improved spectrum utilization? How many trunked channels will be adequate to replace a given number of conventional channels? What is the availability of the equipment? How will such systems work, and what will they cost? What will it cost to develop and demonstrate the technology and who should pay for it? What role will the SMRSs play and how can they be applied to public safety needs?

A related family of questions of special interest to law enforcement and other public safety agencies springs from the operational potentialities of trunked systems. Given the development of this concept of mobile communications system design, what are the possibilities of new approaches to equipment design and system configuration to improve the operational capabilities of the using agencies? Considering the developmental "break point" inherent in the introduction of trunked systems, are there other technological or conceptual innovations that might be introduced concurrently?

The Law Enforcement Assistance Administration (LEAA) recognized that these and related questions must be resolved before the newly allocated 900 MHz frequencies can be fully applied to the introduction of modern law enforcement communications systems that are responsive to the growing demands being imposed upon them. LEAA also recognized that the adaption of the technological potential to the command control needs of the law enforcement community would likely call for a comprehensive, formal development program that included schedules, budgetary estimates, and identified management, fiscal and technological responsibilities.

In February 1977 the LEAA provided Grant No. 77 SS 99 6009 to the Associated Public Safety Communications Officers, Inc. (APCO) to develop answers to these and related questions. APCO was also called upon to outline the objectives, schedules and costs associated with a program to demonstrate the operational and technological capabilities inherent in the trunked system concept.

APCO, as the oldest and largest association of public safety communications supervisors, operators and technicians, possesses special capabilities in this area. With its voluntary membership that includes system user responsibilities operational experience, and technical expertise, it is in a unique position to provide policy level insights and technical judgments, unbiased by economic self-interest, moderated by the awareness that its members will be those most affected by the conclusions reached.

To accomplish this task, APCO established a task group comprised of the Board of Officers assisted by the Association's Executive Director and the Project Director, to provide overall project supervision and policy-level representation of the Association's membership. A second task group, made up of members selected for their engineering skills and operational experience, was organized to provide technical guidance. Seminars were conducted during the regularly scheduled Regional Conferences of the Association during which the memberhip participated in discussions with Project personnel to provide insight into the issues presented. A mail survey of the vendor community was made to determine the status of equipment development and likely projected costs. Project personnel participated in conferences with representatives of the engineering and management staffs of several major vendors to determine the status, costs, potential problems, and opportunities that they believed might be associated with trunked system implementation. APCO's retained legal firm of McKinnon, Wilkinson and Kittner provided a summary of the regulatory background considerations and an overview of the final Report to assure conformance with regulatory concepts. A Project Director was assigned to the National Office of APCO, working under the general supervision of APCO's Executive Director.

The Report is presented in five Chapters that describe the current regulatory environment, analyze the applicability of 900 MHz to law enforcement communications, present the conclusions and recommendations that result, and recommends a program for demonstration of a working system. The first Chapter presents the historical, regulatory and litigatory background of Docket No. 18262. The second presents those factors, peculiar to the 900 MHz spectrum and the regulatory environment created by Docket No. 18262, affecting the applicability of this spectrum to the satisfaction of law enforcement needs. Chapter III describes the operation of a law enforcement communications system and how trunked communication systems work. This discussion provides a basis for understanding how these new technical and regulatory concepts relate to law enforcement systems needs. Chapter IV lists conclusions developed by APCO regarding these issues, and the recommendations associated with these conclusions. For the reader's convenience, the recommendations are summarized at the end of the Chapter. The fifth Chapter establishes the objectives to be attained by a demonstration system, and describes a five-phase demonstration and technology transfer program, including cost estimates and schedules.

The scope and complexity of the material presented in this document makes complete assimilation at one time difficult. Each Chapter has therefore been prepared such that it may be read alone. While this approach results in some redundancy, it is hoped that it will improve its usefulness as a source of reference material.

Since the initiation of this Project, the Commission has seen fit to recognize a number of the regulatory and spectrum management issues that now affect the land mobile community. In its Docket No. 21229, published in June 1977, it asked a number of questions regarding spectrum management proceedings, frequency coordination, and similar issues. APCO's response to this Docket, included as Appendix I to this Report, presents a comprehensive overview of its position on these subjects.

The following document provides APCO's response to the issues and opportunities presented by the proceedings of FCC Docket No. 18262 as viewed from the perspective of the public safety community in general and the law enforcement community in particular. It is directed toward the management level communications system executive. While it is written in non-technical language, it assumes familiarity with fundamental mobile communications concepts. A Bibliography is included to provide source material for those interested in pursuing the technical analysis upon which the report is based.

CHAPTER I

THE 900 MHz REGULATORY BACKGROUND AND ENVIRONMENT

1. INTRODUCTION

1.1 GENERAL

In a proceeding titled "An Inquiry Relative to the Future Use of the Frequency Band 806-960 MHz", the Federal Communications Commission took steps to open a major segment of the radio spectrum for public safety communication systems and other members of the land mobile radio community. 1/ Within the new spectrum allocation, the Commission determined to require innovative engineering techniques and methods of frequency assignments among radio systems as well as to continue some features of established technology and spectrum management systems. The stated purpose of these FCC actions was to devise and implement radio systems and technologies that would use the newly available spectrum with hitherto unachieved efficiency while offering a wide range of choices to eligible spectrum users.

To this end, the FCC did not limit the availability of 900 MHz frequencies to the conventional individual and cooperative type of systems now prevalent in other mobile bands - although such use is permitted at 900 MHz. Rather, the Commission encouraged the use of "trunked" or computer-switched technology in private dispatch systems, in which many users can share a number of frequencies by use of computer controlled channel switching. Since these trunked systems might be more complex (and therefore more expensive) than single radio users might need or desire, groups of eligible users and new, profit-making "Specialized Mobile Radio Systems" (SMRS) were encouraged to design and operate multi-user systems. For public mobile telephone service 2/, the FCC mandated the provision of public mobile telephone service in the "900 MHz" band by sophisticated "cellular" systems that featured simultaneous use of frequencies by small cells distributed throughout an urban area.

The Commission's past practice has been to allocate blocks of the radio spectrum to radio services and then rely upon private radio service coordinating committees for the actual frequency selection. In the case

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1/ The land mobile radio community includes all users of mobile radio or portable radio units which communicate with base stations at fixed locations or with other mobile units. In addition to public safety radio users, major members of the land mobile community include business and industrial users, taxicabs, railroads and transportation companies, petroleum and energy companies, all of whom use radio for their internal needs. Telephone companies and radio common carriers also offer mobile radio service and one-way radio paging service to the public.

2/ The distinction between public mobile telephone service and private dispatch service is a constant refrain in the 900 MHz area. Public mobile telephone service offers two-way communications between a mobile unit and any landline telephone or other mobile unit; generally, public mobile telephone service is used for personal or business conversations of 3-4 minutes or more. Public service is offered by common carriers who are regulated under Title II of the Communications Act and Part 21 of the FCC Rules. Private dispatch service, on the other hand, is a valuable tool in the internal management of a business or government organization, and it is used only for communication among officers and employees of the organization.

Typically in dispatch service, a controller at a dispatch center communicates with a fleet of vehicles or employees in very brief (roughly 5-8 seconds) transmissions related to the business at hand. Private radio systems may be operated by any eligible organization, as specified in Parts 89 (Public Safety), 91 (Industrial), and 93 (Business and Land Transportation) of the FCC Rules, provided a license is obtained from the FCC under the applicable probisions of the Rules.

of 900 MHz applications, the Commission determined to have its staff make all the frequency assignments from one common pool of frequencies, including those channels to be shared by licensees, where such sharing might be necessary to achieve the level of channel usage, in terms of the number of mobile units, it has set as feasible and desirable.1/

The Commission's decisions for the 900 MHz band were the result of a concerted effort by the regulatory officials, with substantial support from the land mobile industry, to go beyond the patterns of the past in the hope of achieving a more effective and efficient use of the 900 MHz band. In particular, the authorization of the profit-making private entrepreneurs (SMRS) to provide multi-user service and the selection of all frequencies in Washington were decisions by the FCC designed to shape the technical and organizational future of land mobile radio use.2/

Because of the broad scope of the 900 MHz proceeding, however, the FCC did not explore or determine the precise applicability of its decisions to any particular radio service such as the public safety radio field. In this study the Associated Public-Safety Communications Officers, Inc. (APCO) proposes to evaluate the effect of the policies established by the FCC for the 900 MHz band, including the applicability of the new system and technology contemplated by the FCC for use in that band, on tax-supported public safety radio users. It will evaluate the utility of "trunked" technologies for multi-channel systems and the potential of non-profit and profit-making suppliers that might be set up to provide these trunked systems. In addition, it will evaluate the practical effect of the decision to abandon block or pool frequency assignments to particular radio services and to remove frequency assignment and coordination from the private radio committees which have been an integral part of public safety radio planning and use.3/ As part of this latter point, attention will be given to the staff method of selecting frequencies by "vertical stacking" of systems on each channel in turn and the resulting "first come, first served" licensing apparently without detailed consideration of the systems to be placed on each channel.4/

1/ The basic plan for the 806-960 band was announced in the Second Report and Order, Docket No. 18262, 46 FCC 2d 752 (1974) and affirmed in a Memorandum Opinion and Order on Reconsideration, 51 FCC 2d 945 (1975). The United States Court of Appeals for the District of Columbia Circuit upheld the FCC in National Ass'n of Regulatory Util. Comm'rs v. FCC, 525 F 2d 630 (D.C. Cir. 1976). The Supreme Court refused to review the Court of Appeals decision, leaving it the final word from judicial authorities on the FCC decisions in Docket No. 18262. Cert. denied, 425 U.S. 922 (1976).

2/ Subsequently, however, the Commission has apparently reversed its decision to delete the rule of the local frequency coordinator in its entirety. Practices and Procedures for Spectrum Management in the Land Mobile Services are governed by Parts 89, 91, and 93 of the Commission's Rules and are the subject of Docket No. 21229, Notice of Inquiry, released May 17, 1977. For APCO's Comments on this Docket, see Appendix I.

3/ APCO performs the frequency coordination work for many public safety and local government radio systems applying for channels in the 150 MHz, 450 MHz, and 470 MHz bands. In Docket No. 21229, however, the FCC has begun a broad inquiry into frequency assignments in all land mobile radio bands and into the role of frequency coordination efforts. Notice of Inquiry, FCC 77-287, released May 17, 1977.

4/ See, Chicago Spectrum Force 'Will Be Disbanded', Donal D. Kavanagh, The APCO BULLETIN, August, 1976.

Chart 1.1 shows the principal frequency allocations authorized in the 800 MHz to 1,000 MHz portions of the spectrum.

1.2 DEFINITIONS OF TERMS

Through this publication, several terms appear which describe parts of the FCC plan for radio systems in the 900 MHz band. The following definitions are provided for the convenience of the reader.

Community repeater: a radio base (repeater) station and antenna system 1/ built and operated by an equipment vendor or other party who is not licensed by the FCC. The base station and antenna facilities are leased to organizations eligible for licenses under the FCC rules, and these eligibles obtain a license for the base station and antenna, as well as mobile units and a control point from which the eligible's radio system will be operated. Since the community repeater equipment may be licensed to more than one eligible organization, the arrangement is also called "multiple licensing" of facilities for private radio systems.

Radio common carrier (RCC): an entrepreneur who obtains a license for base station, antenna, mobiles and control points from the FCC and then offers mobile telephone service and one-way paging service to the public. In concept, the RCC is required to offer service to anyone who orders it, and this public offering distinguishes an RCC operation from the private land mobile systems operated for the internal, business communications of the licensee. As a general matter, RCCs and telephone companies who offer public mobile telephone service and paging service are regulated by state utility commissions as to their rates and terms of service and by the FCC (under Part 21 of the Rules) for technical aspects of service.

Specialized mobile radio system (SMRS): according to the Reconsideration decision:

> Under this category we will license base station facilities and make their use available (under certain restrictions and limitations) to persons eligible in the Public Safety, Industrial and Land Transportation Radio Services. The SMR system licensee may, in turn, make these facilities available to either an eligible individual or to a number of eligible individuals in one or more of the service groupings set out at Sections 89.801 and 89.802 of the Rules.

SMRSs are expected to provide trunked systems for 6 to 20 channels; mobile units and control points used with SMRS are to be licensed separately to eligible organizations. The differences between SMRS and community repeaters are the requirement for trunked operations with SMRS and the direct licensing of the SMRS to operate the base station and antenna facilities as opposed to licensing the community repeater customer for the shared base station and antenna facilities. The primary difference between SMRS and RCCs is the requirement that SMRS serve only eligibles in Parts 89, 91, and 93 and not the general public, a characteristic of SMRS operation that removes it from state and federal common carrier regulation.

Conventional system: a conventional system in the Commission's definition is:

1/ The base/repeater station is called a mobile relay station in the FCC Rules.

A method of operation in which one or more radio frequency channels are assigned to mobile and base stations but are not employed as a trunked group. An "urban-conventional system" is one whose transmitter site is located within 15 miles of the geographic center of any of the first 50 urbanized areas (ranked by population) of the United States. A "suburban-conventional system" is one whose transmitter site is located more than 15 miles from the geographic center of the first 50 urbanized areas.

Section 89.602 of the FCC Rules.

A conventional system must be operated by an eligible organization or a group of eligibles under Parts 89, 91, and 93 of the FCC Rules (the private land mobile radio services), but some equipment may be supplied and operated by an equipment vendor as a community repeater facility. If more than one channel is involved, a conventional system operates by discrete assignment of channels for specific periods of time by manual means. A conventional system at 900 MHz is limited to five or fewer channels under current FCC Rules; larger systems must use "trunked" or computerized-channel switching equipment.

Trunked system: The Reconsideration opinion gives this definition:

> In simplest terms, a "trunked" radio system is a radio communication facility employing between five and twenty channel pairs. Channel access by any user at any time is controlled by a computer which assigns that user the first available channel or places the "call" in a waiting line until a circuit becomes available.

Trunked technology can be used with any system of two or more channels. The FCC has required all systems at 900 MHz with more than 5 channels to use trunked technology, based on the view that the switching technology is faster and more efficient than other systems.

Cellular system: a high capacity system in which a geographical area is divided into a number of smaller areas called cells. Radio channels are assigned to each cell, and non-adjacent cells share channels in order to limit the total number of channels needed by the system. When a mobile unit using the system travels from one cell to another, its frequency is automatically switched by the base stations to accord with the frequencies assigned to each cell. Under FCC Rules, cellular technology must be proposed for any public radiotelephone system planned for 900 MHz frequencies. Developmental applications and simplified call or pre-cellular applications will be accepted in the early stages of the 900 MHz program.

Planned system: A planned system refers to a telecommunication network configured to integrate the policies, procedures, equipment, and personell required to fulfill the communication requirements of tax-supported public safety entities. Such systems normally involve extensive time for requirements definition, design and funding approvals, procurement, implementation, test and cut-over. They are usually designed to satisfy the total communications requirements of one or more tax-supported agencies. They frequently involve coordination of responsibilities of several agencies or levels of government and require the commitment of financial and spectrum resources for protracted periods of time.

800 – 1000 MHz SPECTRUM

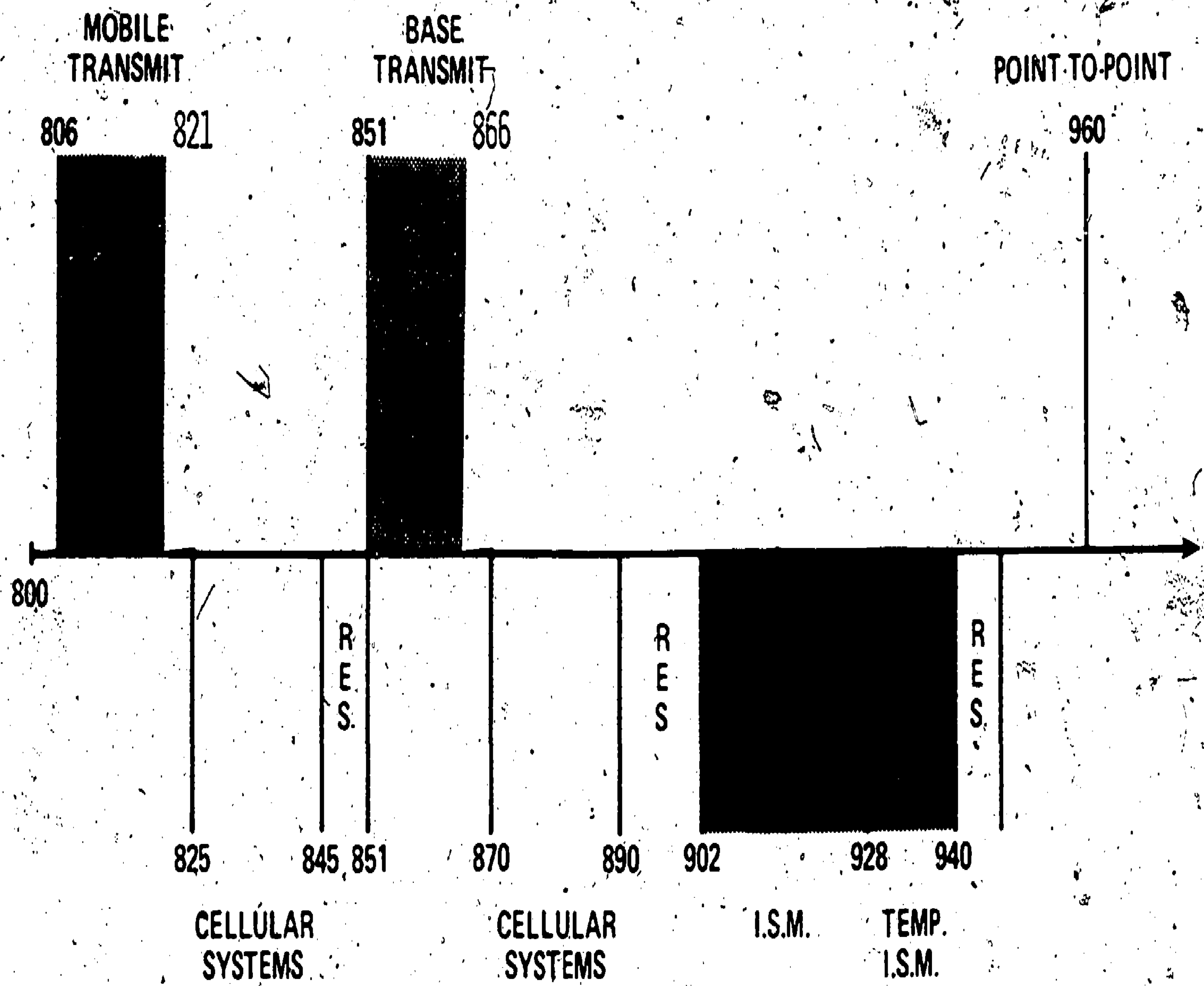

CHART 1.1

2. THE DEVELOPMENT OF DOCKET NO. 18262 CONCEPTS

2.1 THE INQUIRY PERIOD - 1968-1974

The frequency band 806-960 MHz was originally assigned for use by UHF-TV, certain industrial equipment, and government experiments.1/ By the mid-1960's, however, investigations began into the use of the UHF-TV frequency band and the government frequencies for the relief of crowded land mobile radio services. The land mobile community had outgrown original allocations in the 25-50 MHz and 150-160 MHz bands, even though the initial channels were split several times to achieve 1631 channels in the same spectrum space.2/ Channels in the 450-470 MHz band were allocated in 1949, split in 1966, and still crowded by 1968.3/ The need for additional spectrum for long-term relief was voiced in Congressional hearings, to the Executive Branch and to the FCC.4/

The search for new radio space to accommodate land mobile needs quickly centered on the broad allocation given to UHF-TV, then a small and unsuccessful service struggling with the preeminence of VHF-TV stations.5/ After considerable promoting from land mobile users and its internal Advisory Committee, the FCC announced two inquiries, one proposing shared use of the lower portion of the UHF-TV band next to the 450 MHz land mobile channels and one proposing to reallocate the range of 806-890 MHz in the upper UHF-TV band for long-term land mobile spectrum relief.

In the first inquiry, Docket No. 18261, the Commission proposed to allow land mobile users access to one or two of the lower UHF channels (channels 14-20 or 470-512 MHz) in the ten largest urban centers.6/ The

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1/ The UHF-TV assignment of 470-890 MHz was made in 1951. The band 915 MHz + 25 MHz (890-940 MHz) was allocated for use of certain industrial, scientific and medical (ISM) equipment in 1947. The government also used portions of the 890-942 MHz band beginning in 1958. At this time, land mobile users shared bands. See generally, Frequency Allocations 25-890 M/cs, 39 FCC 567 (1964); Notice of Inquiry and Notice of Proposed Rulemaking, Docket No. 18262, 14 FCC 2d 312 (1968).

2/ Docket 18261, Second Report and Order, 19 RR 2d 1585, 1591-92 (1971); U.S. Dept. of Commerce, Electromagnetic Spectrum Utilization - The Silent Crisis at 12-13 (1966). The expedient of making two channels from one was possible because of technical improvements to radio equipment that made it less likely to transmit and/or receive signals removed from the assignment channel.

3/ See, Channel-Splitting in the 450-470 Mc/s Band, 11 FCC 2d 648 (1968). In this time period land mobile users grew from 12,000 licensees (1949) to 290,000 licensees operating three million transmitters. Docket No. 18262, Reconsideration, 51 FCC 2d at 963.

4/ The Silent Crisis, supra; FCC, Report of the Advisory Committee for the Land Mobile Radio Services (1967); Hearings on the Allocation of Radio Frequency and its Effect on Small Business, before Sub-committee 5 of the Select Committee on Small Business, 90th Congress, 2d Session (1968); Report of the President's Commission on Law Enforcement and Administration of Justice (1968.

5/ In 1951, the FCC allocated 420 MHz to UHF-TV, set up as Channels 14-83 to augment the VHF Channels 2-13. By 1964, however, only some 200 of the 1550 available UHF channels had been applied for. Frequency Allocations 25-890 Mc/s, supra, 39 FCC at 595.

6/ Docket No. 18261, Notice of Proposed Rulemaking, 14 FCC 2d 297, 299 (1968). The lower channels, 470-512 MHz, were chosen for limited, immediate relief because of their proximity to land mobile channels in the 450 MHz band and the ready availability of land mobile equipment for that band. With the remaining 69 UHF channels, moreover, the loss of one or two channels to land mobile use was not considered fatal to UHF-TV movement.

Commission stressed, however, that the 470 MHz channels would provide only limited spectrum relief. To insure efficient use of the shared channels, the Commission insisted upon frequency allocations to pools of kindred services rather than discrete allocations to each radio service.1/ In addition, the Commission pledged a larger role for the FCC staff in selecting channels from the pools and enforcing certain optimal levels of mobile units for each channel (channel loading standards).2/ Notwithstanding these efficiency measures, the FCC and land mobile parties recognized the need for extensive long-term relief through broader allocations and more efficient radio technology. These objectives were set as the goal of the Second Inquiry, Docket No. 18262, reallocation of the 900 MHz band.

In the First Report and Second Notice of Inquiry in Docket No. 18262, the Commission rejected a determined defense of the upper channels by broadcasting interests.3/ A tentative allocation gave 75 MHz of spectrum to the wireline common carriers, primarily AT&T, for the development of "cellular" mobile telephone systems that could serve entire metropolitan areas.4/ An additional 40 MHz of spectrum was tentatively allocated to the private land mobile systems of Parts 89, 91, and 93 for long-term spectrum relief and the implementation of innovative systems.5/ In making its initial allocations, however, the Commission stressed the intended use of the new spectrum for new and more efficient technological systems, despite the cost and effort required in developing the new equipment:

1/ Docket No. 18261, Second Report and Order, 22 RR 2d 1691, 1693-95 (1971). The system of discrete assignments of a number of channels to each radio service (police, fire, local government, etc.) was known as the "block-grant" method. Its virtues were the assurance of channels for immediate use and for long-term planning by eligible organizations. Since some services grew more quickly than others, however, the block grant system produced a checkered pattern of relative feast and famine until all channels were filled. The service pool concept was meant to insure more flexible use of frequency assignments by the sharing of spectrum among related services. In May, 1977 the remaining unassigned channels in the service pools were aggregated into a General Access Pool open to all private radio services. Report and Order, Docket No. 20909, FCC 77-226, released March 31, 1977.

2/ Id. at 1698-1705. Notwithstanding this greater staff role, the radio service frequency coordination efforts which facilitated channel assignments in the 150 and 450 MHz bands were specifically endorsed for continued service with 470 MHz channels. Id. at 1704-05.

3/ 19 RR 2d 1663, 1664-68 (1970). The broadcasters, represented chiefly by the Association of Maximum Service Telecasters (AMST), argued that land mobile service was not growing as rapidly as expected, that its growth could be accommodated by more efficient spectrum use and that the upper channels would eventually be used for broadcasting auxiliary stations. The AMST studies were rebutted by The Silent Crisis and other studies cited, supra, and the Commission rejected the AMST position.

4/ Id. at 1665-67, 1673. As early as 1950, AT&T had begun arguing for a large allocation in the UHF band for a broad-band, multi-channel, high-capacity system. UHF Allocations, supra; Frequency Allocation 25-890 Mc/s, supra. The cellular concept for high-capacity public mobile service was discussed in The Silent Crisis and the FCC's Advisory Committee Report.

5/ 19 RR 3d at 1665-66.

The Commission is hopeful that AT&T, as well as others, will undertake a comprehensive study of market potentials, optimum system configurations and equipment design looking toward the development and implementation of an effective, high capacity common carrier service in the band 806-881 MHz.1/ Parties intending to undertake such studies are requested to so indicate to the Commission within 180 days of the release of this action, including therein their estimates as to when such studies will be completed.

Interested parties are encouraged also to submit proposals within 180 days, with respect to the manner in which the frequency bands 881-902 and 928-947 MHz can be most effectively used in meeting the needs of the private land mobile users. We are looking particularly for innovative techniques applicable to bands thus far uncluttered by land mobile systems.

19 RR at 1676-77 (emphasis supplied).

The period 1970-1974, between the Second Notice of Inquiry and the Second Report and Order, 46 FCC 2d 752 (1974), was one of study, debate, and development for the Commission and interested parties. AT&T pursued its plans for a cellular system that would allow city-wide mobile service by re-use of a number of frequencies.2/

A key aspect of the AT&T plan was a comprehensive system for all mobile services including dispatch services, and the carrier argued strongly for an allocation of 75 MHz for cellular systems offering public telephone, air/ground and dispatch service on a common carrier basis.3/ Non-carrier parties stressed the beneficial role of the present competitive system for both public and private service and argued as strongly that the wireline carriers should not be permitted to extend their monopolies over all mobile telephone service and dispatch service by means of the unprecedented 75 MHz allocation and the monopoly resources of the Bell System.4/

1/ The band 806-881 MHz was tentatively allocated to the public mobile service because the Commission considered its location away from the 915 MHz ISM band essential to an interference-free public service. Second Notice, 19 RR 2d at 1674-75.

2/ AT&T Comments and Technical Report, Dec. 20, 1971; AT&T Comments, July 20, 1972. The cellular approach as discussed by AT&T envisions dividing a city into many small cells, each with a portion of the radio channels assigned to the system. Each geographic cell would be assigned the number of frequencies it was most likely to use efficiently. These frequencies would not be assigned to adjacent cells. Calls would be switched from cell to cell (and frequency to frequency) by central computer switching facilities connected by wirelines to the base stations serving each cell. The base stations would operate at low power levels to prevent interference and allow re-use of frequencies by other cells. AT&T's original cellular plan envisioned the offering of public telephone, air/ground, and dispatch service, using at least 74 MHz of spectrum. Motorola, Inc. and RCA submitted studies and proposals for cellular systems on a more modest scale than AT&T's.

3/ AT&T Comments, July, 1972.

4/ Comments of General Electric Company, RCA, and Motorola, Inc., Dec. 20, 1971; Comments of GE and the Land Mobile Section of the Electronic Industries Association (EIA), July, 1972. Comments of the Justice Department and the Office of Telecommunications Policy (OTP), filed August 17, 1973, were instrumental in persuading the FCC against the 75 MHz grant to the common carriers.

Within the private land mobile community, the debate centered on the method of encouraging most efficient use of frequencies while providing the users' needs. Motorola and the Electronics Industries Association (EIA) argued for a continuation of single user systems and a specific allocation of frequencies for them on the grounds that single-user systems would bring immediate relief to the bulk of land mobile users.1/ Motorola also defended the "community repeater" type of multi-channel operation in which base stations are used by several licensees in connection with their own dispatching facilities or control points.2/

General Electric and RCA saw a role for larger single-user systems but argued that the more numerous medium and small-sized single-user systems would be served most efficiently through shared, multi-channel systems. The RCA system followed a cellular model and offered a high capacity system for a given block of frequencies.3/ General Electric's proposal involved trunked or computer-switched channels that could accommodate up to 3000 mobiles per MHz with only 10 seconds of waiting time for access.4/

Speaking as a major user of private systems, APCO argued that the trend of private systems in the public safety radio field testified to a need for significantly more radio spectrum and greater flexibility in its use. In its oral presentation to the FCC, the APCO representative summarized the statistical studies predicting heavy growth for public safety radio use and focused on the varied tasks and systems contemplated for public safety radio services: responses to the "911" emergency number; computer-assisted call dispatching; automatic vehicle location; use of personal radios for foot patrolmen; mobile teleprinters, and facsimile equipment; use of automatic alarm and signalling devices; roadside emergency call boxes and highway monitoring systems.5/ Other land mobile users echoed APCO's presentation of the need for a sufficient allocation to the private services and the premature nature of a 75 MHz grant to the common carriers.6/

2.2 SECOND REPORT AND ORDER

The Second Report and Order which set forth the permanent allocations in

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1/ Motorola Comments, Dec. 20, 1971; EIA, July, 1972. The EIA is a group of equipment manufacturers.

2/ Motorola Comments, Dec. 20, 1971, at V-4 - V-6. The community repeater base station, shared by a number of private systems, is defined in Section 1.2. See also, Multiple Licensing Safety and Special Radio Services, 24 FCC 2d 510 (1970).

3/ RCA, Dispersed Array System, Dec. 20, 1971.

4/ General Electric, Dec. 20, 1971. The General Electric system would operate like a telephone exchange where channels are assigned when a user calls in and reassigned at the termination of the call. With computer switching, GE maintained, a shared, multi-channel system can achieve great effeciencies over analogous multi-channel systems that are switched by operators manually or with automatic terminals.

5/ Argument on Behalf of APCO and International Association of Chiefs of Police (ICAP), by James R. Cooke, May 15, 1973, Tr. 774-84.

6/ Land mobile parties appearing at the Oral Argument were the National Association of Business and Educational Radio, Inc. (NABER) and Special Industrial Radio Service Association, Inc. (SIRSA). Equipment manufacturers, wireline common carriers, radio common carriers, and broadcasters also argued before the Commission.

the 900 MHz band reflected all of these views plus the considerable internal study of the FCC staff.

2.2.1 The Allocation Decisions: The Second Report and the Opinion on Reconsideration

In the Second Report and Order, 46 FCC 2d 752 (1974), the Commission adopted AT&T's proposal for cellular systems for public mobile telephone service, ruling that only cellular systems operated by wireline telephone companies would be licensed for public service at 900 MHz. The cellular systems were given 40 MHz with which to provide two-way mobile telephone service, one-way paging service to individuals, and some dispatch service to individuals, but not the "fleet dispatch" commonly employed in private systems.1/ The Commission determined that the expense, spectrum requirement, and wide coverage of a mature cellular system dictated that only one system in each urban area would be feasible. To meet the concerns of radio common carriers and others who feared the competition of comprehensive, subsidized cellular systems, the Commission limited telephone companies to one cellular system, which must be provided by a separate subsidiary of the wireline carrier.2/

For private systems, the Commission authorized 30 MHz of spectrum, two technologies, and four means of obtaining service.3/ The technologies were "trunked" (or computer-switched) systems and "conventional" systems as used in the lower bands.4/ The trunked systems were clearly encouraged, however, as the Commission allocated 25 MHz to trunked applications and only 5 MHz to conventional applications.5/ Standards were set forth for both trunked and conventional systems, governing antenna height, power, emission, and other operating parameters.6/ For purposes of separating co-channel systems and the establishment of standards for channel loading, conventional systems were further classified into urban and suburban systems depending on the location of the base station.7/ In addition, "channel loading standards" or specified

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1/ 46 FCC at 760-61. "Fleet dispatching", in which a base station contacts all mobile units simultaneously, was not allowed in cellular systems, since fleet dispatching involved radio use inimical to the one-on-one communications with which re-use of frequencies by cells is most feasible. Dispatch service of all kinds, however, had been a staple of the smaller, competitive radio common carriers and private radio systems, not the monopoly-based wireline companies, and the entry of the monopoly carriers into the dispatch market was strongly opposed by non-wireline parties.

2/ 46 FCC 2d at 760.

3/ The four methods are discussed at Section 4.1.2.

4/ Conventional systems may have more than one channel and may be shared by several users by means of an automatic terminal or a manual dispatcher. The differences between conventional and trunked systems are discussed in Section 1.2.

5/ Because the Commission viewed trunked systems as more efficient, conventional systems seem to have been considered interim systems pending the availability of economic trunked systems. 46 FCC 2d at 754-55, 771-72.

6/ The final technical rules are embodied in Subpart S of Part 89. A summary of the technical requirements are discussed below at § 2.2.2.

7/ 46 FCC 2d at 774-75. Because of the anticipated trunked technology and improved radio equipment, and because of the 45 MHz base-mobile separation, the Commission determined that adjacent channel protection would not be given to trunked systems or the "interim" conventional system. Id. at 773.

numbers of mobile units per channel were adopted as the primary mechanism for assuring efficient use of each channel. In the 900 MHz band, channels were to be selected by the FCC staff from a single pool of frequencies, and each channel in a geographic area was to be loaded with applicants up to its maximum number of mobiles before the next channel in the pool would be assigned.

2.2.2 Licensing Criteria

2.2.2.1 General

The FCC has adopted regulations guiding the allocations of channels to potential users. A summary of these rules, as they apply to the public safety users of the 900 MHz spectrum follows.

2.2.2.2 Limitations on Power and Antennae Height

The Commission has established tables of antennae heights v. effective radiated power (ERP) for base station operation. For trunked systems and urban conventional systems the ERP shall be no greater than 1000 W. and the antenna heights no greater than 1,000 feet above average terrain (AAT). For suburban conventional systems, the maximums shall be 500 W. and 500 feet AAT. Depending upon the required radius of coverage, these figures must be scaled down in accordance with the Commission's tables.

The maximum power output of the transmitter for mobile stations is 100 W.

For the definition of "urban area" see the list of the fifty major metropolitan areas in Section 89.751(h) of the Rules.

2.2.2.3 Channel Loading Criteria

In conventional type systems, channel loading criteria for public safety systems are as follows:

	Police and Fire	Other Services
Single license user	50/100	150/300
2 to 5 licensees/users	40/80	125/250
over 5 licensees/users	30/60	100/200

Numbers indicate the number of mobile units per channel/number of portable units per channel. For the purposes of channel loading, the Commission considers one mobile unit the equivalent to two portable units.

The number of mobile units required per system in a trunked system is:

	5-channel system	10-channel system	20-channel system
Police and Fire	300	750	1500
Other Services	400	800	1600

For the purposes of loading criteria, no distinction is made in trunked systems between mobile and portable stations.

The following criteria pertains to the establishment of 900 MHz systems near the borders of Canada and Mexico:

a) No base stations will be authorized within 100 miles of the Canadian/U.S. border; and between 100 and 125 miles of the Canadian border such stations will require special arrangements between the FCC and Canada. Between 125 and 145 miles 500 W. ERP and 500 feet antenna height will be the maximum allowed. Beyond 145 miles the usual rules apply. Mobile units may not operate within 90 miles of the Canadian border and within 145 miles are limited to 200 W. ERP. All stations within 250 miles of the border will be authorized only on the condition that no harmful interference to Canadian TV results.

b) Presently, base stations are authorized within 85 miles of the Mexican border in California, but not within 100 miles in Texas, New Mexico and Arizona. The attenae heights and power restriction are in effect in California between 85 and and 125 miles and between 100 and 125 miles in the other States.

2.2.3 Frequency Assignment and Coordination

To accommodate the enlarged FCC staff role in assigning and loading channels, the procedures for processing applications were modified from practices that have been followed with applications for the lower radio bands. Because of the tremendous volumes of applications under Parts 89, 91, and 93 of the Rules, the FCC staff relies on certain technical criteria and voluntary frequency coordination efforts to eliminate non-compliant or non-compatible applications. Applications for licenses in the 150 MHz, 450 MHz, and 470 MHz bands are checked against specific rules for power, emission, antenna height, numbers of mobile units and the like, and non-conforming submissions are usually returned. The remainder are granted on a fairly routine basis since competitive protests are not allowed and most technical or frequency problems are solved by the service's frequency coordinator or advisory committee.1/

The Commission proposed to adopt the same system at 900 MHz because of its familiarity, but with the important difference that the staff would make the frequency assignments, including shared assignments, from one pool of frequencies, rather than relying upon the tentative assignments from a service pool of frequencies recommended by the volunteer frequency coordinator.2/

The matters of frequency assignments, mandatory shared channels from one large pool, and the "first in/first out" processing system, were, in fact, larger changes in the licensing procedure than the Second Report appeared to have recognized. At the lower bands, frequency selection and sharing of channels are worked out largely by coordinating committees of users in the various radio services, working with pools of available frequencies. While these committees have an advisory role, in practice their frequency selections are made after considerable work with the applicant and are normally accepted by the FCC staff who then

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1/ In the lower bands, most services have an association of licensees who perform frequency selection advisory services for new applicants. The Commission has recognized the value of private frequency coordinating organizations such as APCO and has relied on them for help in resolving interference problems. Docket No. 18261, Second Report and Order, 22 RR 2d 1691, 1704-05.

2/ 46 FCC 2d at 769-70. Recently the FCC has undertaken a review of frequency coordination procedures for the 900 MHz band to consider, among other things, whether the user-provided frequency coordinator should not be accorded a greater role than was originally contemplated. See also, Notice of Inquiry, Docket No. 21229, FCC 77-287, May 17, 1977. See Appendix I.

make the formal assignments.1/ With the staff assuming responsibility for all frequency selections at 900 MHz and assigning the frequencies from one large pool rather than from service pools or blocks, applicants may find themselves without the detailed planning and support services rendered by the frequency coordinator. The "first in/first out" processing system and the possibility of mandatory sharing of channels by compatible systems may result in a mixed pattern of radio systems and services on the same and adjacent channels.2/ Unlike the system long in use in the lower bands, users will have little assurance as to which frequency will be operated in their geographic or spectrum vicinity and therefore what possibilities for future growth are available.

Finally, this procedural system is to be applied to the four means of providing service authorized by the Second Report.

2.2.4 Methods of Service

As in the lower bands, individual organizations eligible for licenses under Parts 89, 91, and 93 of the Rules can apply for one or more discrete channels for a single-user private system.3/ Eligible organizations can also apply for channels as a group proposing shared use of the facility and its management by one of the sharers or a non-profit radio service entity.4/

As a third alternative, eligibles can procure service from an entrepreneur called a Specialized Mobile Radio System (SMRS), who is licensed to offer base station service on a profit-making basis.5/ SMRS entrepreneurs are to stand in the shoes of their eligible customers regarding compliance with technical rules and use of the facilities. However, no regulations will be made regarding rates charged to SMRS customers, and SMRS will not be considered radio common carriers. According to the Commission, the authorization of a profit-making SMRS would attract capital needed for trunked systems and the radio expertise needed but un-

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1/ These coordinating committees, including APCO, are normally established within geographic regions so that local users work together to achieve the best use of the frequencies allocated to their services in the area.

2/ The only modification from the "first in/first out" assignment plan seems to be in the case of community repeater systems, as discussed below.

3/ The reader should recall that the trunked or conventional technologies apply to the number of channels in the radio system, regardless of the means of providing the system. Under the current Rules, Section 89.805, any radio system needing more than 5 channels must use trunked technology.

4/ 46 FCC 2d at 762-63.

5/ An SMRS is an equipment supplier or other entity which designs and builds base station facilities to be used by one or more private radio stations. The differences between SMRS, community repeaters and radio common carriers are discussed in Section 1.2.

available to many smaller eligibles.1/ However, the Commission required the SMRS applicants to show that the control points and mobile units used with SMRS would be owned and operated by eligible individuals or organizations.2/

The fourth alternative is service from a traditional community repeater operator who supplies base station facilities that are licensed to a number of eligible organizations.3/

2.3 THE RECONSIDERATION DECISION

Virtually every aspect of the Second Report was contested in petitions for its reconsideration. The decision to license only wireline carriers to operate cellular systems was attacked by non-wireline carriers 4/ while AT&T objected to the reduced allocation for cellular systems and the requirement of a separate corporation to offer the mobile service, designed to protect competing carriers from a subsidized cellular system.5/ The decision to license SMRS to offer service for profit but not to regulate them as common carriers was also controversial, with a number of parties arguing that the Commission had no authority to abstain from common carrier-type regulation of any entity offering communications service to others.

Other parties urged the error of federal preemption of state regulatory actions in the 900 MHz area,6/ the ambiguity of the "ancillary" dispatch services allowed by cellular systems, the restrictions on the number of trunked systems operated by equipment companies,7/ the failure to provide for non-voice communications and limited fixed operations and the mechanisms to facilitate the movement of users from lower bands to 900 MHz in phases.8/ The problem of reallocating UHF-TV channels for land mobile in the U.S. while TV systems operated on the same channels in Canada and Mexico was also brought out.

1/ 46 FCC 2d at 764-67, 781.

2/ 46 FCC 2d at 769, 789. An SMRS offering service to the public at large rather than to only a few eligible organizations would be in competition with the radio common carriers whose rates are regulated by the state regulatory commission. Limitations on the number and type of customers served by SMRS are therefore key to their unregulated status.

3/ Community repeaters are discussed extensively below. See Section 4.1.2.5.

4/ Petitions for Reconsideration of Airsignal International, Inc., NARS, AT&T. Motorola advocated restricting cellular systems to an initial 12.5 MHz grant until the developmental phase proved the viability of the concept and sufficient demand for the service developed.

5/ Petition for Reconsideration of AT&T.

6/ The Commission determined that orderly and efficient development of the 900 MHz spectrum required a nationwide plan. Accordingly, its federal powers were asserted to prevent any contrary state action such as regulation of SMRS as radio common carriers. 46 FCC 2d at 766-67. The National Association of Regulatory Utility Commissioners (NARUC), an organization of state regulatory officers, challenged this point in particular.

7/ Petitions for Reconsideration of Motorola and Land Mobile Communications Council, an organization representing mobile radio users.

8/ Petition of Land Mobile Communications Council.

The decision on reconsideration answered most of these competing contentions and set the initial working rules for 900 MHz applications. The cellular system approach was modified so that applications would be accepted from any group that could meet rigorous technical and financial criteria for building a developmental system. The separate corporation requirement was affirmed for wireline carriers building cellular systems but developmental systems were exempted from its strictures.

For private systems, the Reconsideration decision also affirmed the option of taking service from a profit-oriented SMRS. In the Commission's view, it possessed sufficient authority to adjure common carrier rate regulation of SMRS where technical regulation would suffice and competitive forces would control prices.1/ The decision pointed out that the direct licensing of mobile units and control stations to SMRS customers rather than to the SMRS base station, the technical rules as to channel loading and use of the system, and the users' options of applying for individual and non-profit shared systems would keep the SMRS in check.2/

On technical points relating to private systems, the Commission made an accommodation in its co-channel spacing and coverage rules for the Los Angeles area and pledged a degree of flexibility in applying its technical rules where other unique situations required consideration.3/ Non-voice communications were allowed in single-user systems and in trunked systems if used for establishing and maintaining communications within the trunked system, and other minor technical revisions were made.4/ On other policy issues, the Commission stuck by its decision to encourage trunked systems over conventional systems 5/ and to require efficient use of all assigned channels through the mandatory loading of channels with mobile units shortly after licensing.6/ The decision to have the FCC staff assign all channels from one pool of frequencies, on

1/ 51 FCC 2d at 959. Appendix B to the decision gave a further legal defense of the SMRS option.

2/ 51 FCC 2d at 961. In this passage the Commission affirmed the intent to license SMRS without regard to the need for the service or economic protection to other entities. The benefits to be derived from the open-entry SMRS policy were set out at 962-72.

3/ Id. at 979-80. The geography of the Los Angeles area was said to frustrate the urban-suburban spacing scheme for conventional systems, and the rules were modified to allow "wide area coverage: by stations exceeding the normal technical limits, one kilowatt of power and an antenna placement over 1000 feet above average terrain.

4/ Id. at 980-82. Non-voice or digital communications are used in certain vehicle location systems, and tone-only paging systems. It is expected that public safety systems will incorporate additional digital communication features.

5/ Conventional systems are limited to five channels; larger systems must use trunking technology. Id. at 983-85.

6/ Id. at 983. The decision requires a private system to be loaded with 70% of the mobile units specified on the application within 8 months from licensing. If channels are not 70% loaded within the time limit, other applicants can be assigned to the same channel until its loading maximum is reached. Additional channels may be assigned to a system when 90% of the mobile units specified as the channel maximum have been placed on the channel.

a "first in/first out" basis, was also affirmed although limited modifications were made.1/ The Commission acknowledged the problem of incompatible land mobile and UHF TV systems operating along the Canadian border, and its Rules provided that U.S. land mobile systems should operate on a secondary basis to any Canadian or Mexican TV stations.2/ At the same time assurances were given of further effort at coordination at some time in the future.3/

2.4 THE COURT APPEALS

In court appeals of the Second Report and Reconsideration, parties challenged the allocation of 40 MHz rather than 64 MHz to cellular systems, the authorization of SMRS on a non-common carrier basis and federal preemption of state actions in the 900 MHz area.4/ The United States Court of Appeals for the District of Columbia circuit affirmed the FCC on all points, although reluctantly in the case of several aspects of the 900 MHz plan. For example, the cellular system approach and its 40 MHz allocation were challenged as granting the Bell System an effective monopoly over the urban radio-telephone market including dispatch services.5/ The Court found the Commission's 40 MHz allocation decision to be "precisely the sort that Congress intended to leave to the broad discretion of the Commission, by imposing a broad public convenience, interest or necessity standard."6/

The SMRS decision also drew a lengthy analysis from the Court, addressing the nature of common carriers and the application of common carrier principles and regulation. The Court held that the single most distinguishing characteristic of a common carrier is an undertaking or "holding out" to serve all members of the public without discrimination.7/

1/ For example, the Commission limited amendments to applications which proposed a substantial change in ownership of systems, so that applicants could not sell a place in the processing line.

2/ Id. at 949; Section 89.751(g) of the Rules.

3/ The border problem was also discussed in Docket No. 18261, 22 RR 2d 1691, 1710; and it remains unsolved. The FCC is currently engaged in preparation for the 1979 World Administrative Radio Conference (WARC) at which the international and Western Hemisphere allocations in the 900 MHz band will be discussed. See, Fifth Notice of Inquiry, Docket No. 20271, FCC 77-349, May 23, 1977.

4/ NARUC v. FCC, 525 F. 2d 630 (D.C. Cir. 1976). The Court initially stayed the effectiveness of the Commission's decisions to license SMRS pending review by the Court. The stay was lifted when the Commission was affirmed, and the Supreme Court refused to stay the FCC action further.

5/ Id. at 636-39; see also, Brief for Petitioners NRS and Illinois Association of Radiotelephone Systems.

6/ 525 F. 2d at 636. At the same time the Court acknowledged the pro-monopoly aspects of cellular systems and held open the prospect of future antitrust challenges to the systems if their anti-competitive potential came to fruition. Id. at 647.

7/ Id. at 641-42. The act of "holding out" or offering service to the public indiscriminately distinguished common carriers from private carriers, in the Court's analysis, although both may serve specialized portions of the public and large clienteles. The common carrier's holding out to the public gave rise to the common law doctrine of a duty to serve all comers up to the capacity of the system, in contrast to private carriers who may choose their customers. 525 F. 2d at 642.

Since the SMRS, as projected, would solicit and serve only a few customers on a long-term contract basis, the Court approved their classification as non-common carriers.1/ However, the Court added, "our holding is subject to future challenge should SMRS in practice behave as common carriers."2/ The Supreme Court refused to review the Court of Appeals decision, leaving it the law of the land regarding the deliberations of Docket No. 18262.3/

3. REMAINING ISSUES

3.1 LINGERING LITIGATION

Following the Court of Appeals decision, the focus of litigation shifted to the FCC. Illinois Bell Telephone Co. (IBT), an AT&T affiliate, proposed to build a developmental cellular system in the Chicago area. The IBT plan involved 21 MHz of spectrum and $23.5 million for a system to cover an area over 48 miles.4/ The IBT proposal was attacked by a group of Chicago radio common carriers as beyond the guidelines set out by the Commission for developmental systems and prohibitively expensive and expansive for an initial model system.5/ The Commission agreed with the criticism of the IBT plan and suggested its revision.6/ Ultimately, a compromise was reached between the FCC and AT&T, and the revised IBT proposal was approved as a two-phase plan for equipment and service tests and then commercial operation.7/

1/ Id. at 643, the Court said:

> The nature of the dispatch services which SMRS will primarily offer appear necessarily to involve the establishment of medium-to-long-term contractual relations, whereby the SMRS supply the needs of users for dispatch facilities for a period of time. In such a situation, it is not unreasonable to expect that the clientele might remain relatively stable, with terminations and new clients the exception rather than the rule. It might even be that the turnover will be sufficiently minor that, except for the commercial mode of operation, SMRS will be much like non-profit community repeaters.

2/ Id. at 647.

3/ NARUC v. FCC, 425 U.S. 992 (1976).

4/ Application of Illinois Bell Telephone Co. for Authority to Construct a Developmental Cellular System at Ten Sites at Various Locations in the State of Illinois, filed July 21, 1975, File No. 20115-CD-P-76.

5/ The criticisms were directed to the size of the cells (8-mile radius), the height of antennas and the minimal frequency re-use proposed. Petitions to Deny or objections were filed by Rogers Radio Communications Service, Inc., NARS, Radio Relay Corp.-Illinois, Motorola and the Illinois Association of Radiotelephone Systems, Inc.

6/ Letter of July 15, 1976, from Vincent J. Mullins, Secretary, FCC to Illinois Bell Telephone. The FCC required the use of only 12.5 MHz in two blocks of 6.25 MHz each and suggested a two phase approach of tests and then full-scale operation. The Bell System and other parties petitioned for reconsideration of this latter decision.

7/ Order, FCC 77-166, (March 10, 1977). Appeal pending, NARS v. FCC, 77-1357, (D.C. Cir. filed April 11, 1977). The Commission accepted a plan for independent tests of equipment if the Chicago system were scaled down to 10 cells and 135 mobile units during the Phase I tests of equipment and service. Illinois Bell was further required to obtain authority for commercial operation of its system following the test phase and to file detailed financial reports.

for private systems, more serious litigation centered on the role of community repeaters in the 900 MHz plan. NARS and General Electric petitioned for clarification of the Reconsideration opinion on this point, arguing that the similarity of unlicensed community repeaters to the licensed SMRS caused great confusion in the industry and in the Court appeal challenging SMRS.1/ General Electric maintained that few entrepreneurs would develop and offer the efficient, trunked SMRS systems, under FCC licensing, if unlicensed community repeaters could offer shared services to single-user and conventional systems free of all restrictions.2/ In a brief Memorandum Opinion and Order, 55 FCC 2d 771 (1975), the Commission replied that the community repeater option would be available at 900 MHz since it seemed to meet the needs of many users.3/ However, the Commission noted the method of "first in/first out" frequency assignments by the staff, plus the mandatory sharing of channels until maximum numbers of mobile units are reached, as probable limitations on the utility of community repeaters:

> (W)e acknowledge that the practice may have limited application at 900 MHz. There we plan to assign frequencies on a 'first in-first out' basis and there will also be "verticle" loading (mandatory sharing). These features will for practical reasons restrict 'multiple licensing' of 'community repeaters.'
>
> 52 FCC 2d 773.

The question of accommodating community repeater operations with the staff frequency selection rules illustrated the conflicts between the new rules and those radio systems having unique requirements as to who they serve and how service is rendered, such as public safety systems.4/ That is, frequency assignments by the FCC staff on the "first in/first out" basis could result in shared frequencies between repeater and non-repeater customers, preventing economic loading of the repeater base station. For multi-channel community repeater operations, the problem of mechanistic frequency assignments by the FCC would remove assurance of enough customers to pay for the facilities. With these practical difficulties, the Commission seemed to suggest that the spectre of unlicensed community repeaters undercutting expensive but efficient SMRS

1/ NARS, Petition to Refrain from Granting Licenses Pursuant to Applications Filed for Authorizations in the 900 MHz Band Involving Entrepreneurial Community Repeater Operations, June 19, 1975; General Electric Co., Petition for Clarification Or, Alternatively, for a Declaratory Ruling, May 23, 1975, and related pleadings.

2/ General Electric Petition at 6-8, 11-14; Supplement to Petition at 1. A key assumption of the parties was the expense anticipated for computer-switching base stations. A full computerized system was assumed to be economical for eligible users only if it was large enough to accommodate several thousand mobile units on at least five channels. The few single-user systems large enough for trunked operations were considered sophisticated enough to operate their own systems, and the entrepreneurs pegged their hopes on shared systems for many smaller eligibles.

3/ The Commission acknowledged some problems with community repeaters which were at issue in Docket No. 18921. 55 FCC 2d at 773.

4/ As discussed in detail below, public safety radio systems have unique requirements for long-term planning and growth and for designation and use of channels by function (special squads or patrol areas, for example) rather than by numbers of mobile units. Neither the long-term planning need nor functional designation of channels is consistent with a rigid application of "first in/ first out" frequency assignments or by maximum loading of channels by arbitrary numbers of motile units.

would recede.1/

3.2 THE "CLARIFICATION"

In November, 1976 the Safety and Special Radio Bureau released a lengthy "Clarification of New Policies and Practices Governing the Assignment and Licensing of Conventional Systems of Communication at 900 MHz,"2/ which discussed the practical steps in assigning frequencies to community repeaters, customers, and other radio applicants. The Clarification explained the processing system for conventional systems, the urban-suburban distinction, eligibility, restrictions on use, channel loading requirements and frequency assignments. Of particular interest was the announcement that a degree of flexibility would be used in assigning frequencies, including accommodation of community repeater operations by assigning five channels for the use of repeater customers in a given area.3/ This accommodation of formerly rigid standards to the unique needs of individual systems may be of significance to public safety systems planned for the 900 MHz band. The Clarification emphasizes that "in every case each proposal will be examined to determine the requirements of the applicant" and that "consideration will be given to the mode of operation planned and the purpose for which it is to be used, and . . . other factors, includ(ing) the technical features of system design. (I)t is provided that applicants in one service group will not be required to share with applicants in other service groups." The Clarification also affirmed that the "Commission may take into consideration any other factor which might enable the persons licensed to use a given channel in more efficient and effective ways."4/

In a Petition for Relief of December 27, 1976, however, the National Association of Radiotelephone Systems (NARS) asked the Commission to nullify the Clarification as a substantive modification of the Commission's Orders and beyond the authority of the Safety and Special Bureau Chief. NARS argued that the "back door" assignment of five channels to community repeaters would firmly establish that practice at 900 MHz with all the problems of its unlicensed operation, and discourage any licensed SMRS from the more expensive trunked system.5/ Motorola opposed the NARS Petition, arguing the utility of community repeater operations for single-user systems and the propriety of a statement from the staff explaining actual processing matters.6/ The NARS petition is still pending before the Commission, but processing of 900 MHz applications is proceeding in the meantime.

1/ Community repeater defenders point out its efficiencies and shared nature as consistent with the 900 MHz plan. ~~Without direct control over the base station,~~ however, it is not clear that the Commission can force channel loading to maximum levels by community repeaters or remove a possible incentive to monopolize desirable antenna locations and available frequencies.

2/ FCC Public Notice 73035, Nov. 24, 1976, (hereinafter cited as "Clarification").

3/ Clarification at 8.

4/ Id. at 9, quoting Sec. 89.803(c).

5/ NARS Petition at 15. It was assumed that the 900 MHz community repeaters would operate conventional systems, possibly with some switching, but that the Commission would have no means of forcing larger community repeaters to use trunked technology when the five-channel maximum for conventional systems was reached.

6/ Motorola Opposition, Feb. 4, 1977. A major user group, the National Association of Business and Educational Radio, Inc. (NABER) also opposed the NARS Petition. Opposition, Feb. 4, 1977.

4. PRESENT STATUS

As a result of the Clarification and other policy initiatives, significant leeway has apparently been introduced into the "first in/first out" channel assignment process. For example, SMRS are given two years in which to build and load their systems, and no non-SMRS applicants will be assigned to the SMRS block of channels during the two-year period.1/ In addition, competing SMRSs will be licensed in the same area, and no SMRS will be required to serve any unaffiliated applicant even though the applicant may be compatible with the existing SMRS customer. A similar flexible attitude has evolved regarding trunked systems; while the FCC will require trunked technology for any single system of more than five channels, there is apparently no bar to an application for a second or third conventional system by the same licensee.2/

4.1 SUMMARY OF SYSTEMS CURRENTLY AUTHORIZED AT 900 MHz

The result of nearly ten years of litigation in the 900 MHz area is the authorization of three technologies for radio systems and five types of servides for the systems. Each system and service is briefly summarized below.

4.1.1 Technologies

4.1.1.1 Cellular Systems

Cellular systems featuring city-wide services, re-use of frequencies among many cells, computer-switching and very high capacities are required for public mobile telephone systems. Public systems may offer two-way, paging and ancillary dispatch service. There appears to be no reason why the Commission would not also consider cellular technology for private systems, if the appropriate technical criteria can be met, although the Commission's decisions do not discuss this use.3/

4.1.1.2 Trunked Systems

Trunked technology authorized for private systems also involves computer switching among five or more channels. In contrast to cellular systems,

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1/ Non-SMRS applicants are required to build and load their systems with 70% of the mobile units specified in the application within 8 months. Section 89.802.

2/ The rules are not explicit on this point, but appear to be consistent with such an interpretation. At least the Commission has not indicated a different view although obviously policy considerations could be raised. In fact, the channel assignment system may encourage a licensee to apply for a second conventional system rather than a larger trunked system, because the frequencies given trunked systems are far removed from those for conventional systems. If a conventional system has grown and needs more channels, it faces the choice of receiving five or more channels for a trunked system and relinquishing its initial channels because they are incompatible with the trunked channels or because the applicant cannot justify both the conventional and the trunked channels, or of designing a second conventional system in order to receive channels near its initial assignment.

3/ The RCA Dispersed Array System, for example, proposed a dispatch operation using cellular technology. RCA Comments, Dec. 20, 1971.

trunked systems function by frequency re-use on an instantaneous time basis rather than the geographic re-use inherent in the cellular system concept. Trunked technology is required for private systems using more than five channels up to a limit of twenty channels per system. FCC Rules prescribe antenna heights, power, emission, short-term and long-term channel loading standards in numbers of mobile units 1/ and eligible users for trunked systems.

4.1.1.3 Conventional Systems

Conventional systems at 900 MHz will be authorized to eligible users to operate as single channel or manually switched multi-channel systems analogous to systems in the lower frequency bands. According to the Clarification, conventional systems may use automatic terminals and trunking techniques if desired, but trunking will not be required. Efficient use of conventional systems will be encouraged by short-term and long-term channel loading requirements and shared frequency assignments, made by the FCC staff, where necessary to load a channel in a particular location.

4.1.2 Services

4.1.2.1 Common Carriers

Common carriers will be authorized to provide cellular mobile service to the public. If the carrier is a wireline telephone company, its commercial (not developmental) system must be provided by a separate subsidiary corporation whose costs and revenues are distinct from the monoply base of the parent carrier. Non-wireline carriers may operate cellular systems without a separate corporation, and joint applications from groups of carriers will be accepted.

4.1.2.2 Private Systems

For private systems, eligible organizations under Parts 89, 91, and 93 of the Commission's Rules may apply for single-user systems. If more than five channels are needed in one system, trunked technology must be proposed.

4.1.2.3 Shared Systems

Eligible users may also apply for a shared system to be managed by one of the sharers or by a non-profit coordinating committee or organization. In the case of shared systems, the channel loading criteria will follow the highest level of mobile units of the services involved, and trunked technology will be required if more than five channels are

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1/ The phrase "short-term and long-term" channel loading requirements refers to the requirement that applicants be prepared to load channels with 70% of the mobile units applied for within eight months of grant of the application. The long-term channel loading standards require an applicant to show that the channel handles 90% of the mobiles specified in the Commission's Rules as the maximum for the use made of the channel before additional channels are assigned. Channel loading criteria differ from trunked and conventional systems and by radio services -- public safety, business and industrial, taxicab, land transportation, etc. See Section 89.801-803 of the Commission's Rules.

needed by a single system. A shared system managed by a non-profit entity will stand in the shoes of its members in terms of use of the system, technical criteria and the like.

4.1.2.4 SMRS

Eligible users may take service from a (possibly) profit-making manager called a Specialized Mobile Radio System entrepreneur or SMRS. The SMRS will be licensed only for base station facilities; its customers must submit applications for control points and mobile units specifying an agreement to use the SMRS service. Further, the SMRS base station licensee is bound to offer trunked technology if more than five channels are needed, and to follow the Rules for technical criteria and use of the system prescribed for single-user and non-profit shared systems.

4.1.2.5 Community Repeater

A final type of supplier is the traditional community repeater vendor who provides base station facilities that are licensed in the name of the customers. A community repeater customer normally applies as a single-user for base station, mobiles and control points under the single-user, conventional system procedures. To accommodate community repeater service, the FCC staff may set aside a five channel group of frequencies for assignment to community repeater customer-applicants.1/ Short-term channel loading standards will be applied to the applicants, but the requirement of trunked technology for systems of more than five channels is uncertain. The Clarification seems to indicate that additional five-channel groups will be assigned to users of community repeater systems, without regard to trunked technology, if the first five channels are 90% filled.

5. THE REMAINING REGULATORY ISSUES

5.1 For public safety radio users, a number of questions remain regarding the legal framework set up for 900 MHz systems. For example, <u>will the requirement for trunked technology with SMRS systems or any operations of more than five channels be suitable for public safety systems?</u>2/ For example, fleet dispatching requires a call to all mobiles, interrupting other conversations if necessary. <u>Will trunked systems have the ability to handle fleet calls as well as individual calls to the base station and other mobiles?</u>

5.2 <u>A second major question is to what extent would an SMRS type of operation be usable by public safety entities?</u> Does the fact that an SMRS operator might be an "outside" business entity make a difference to the public safety entity? Or, to what extent would an SMRS-type facility, operated by a governmental entity for its varied communication needs, be desirable? Is the SMRS option, as created by the FCC, advantageous from

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1/ As noted earlier, this procedure is not subject to objection in a petition filed by MARS, pending before the FCC.

2/ Indeed, APCO has expressed grave doubts whether trunked systems will ever reach their efficiency potential with the unique and varied requirements of public safety radio systems. *See* APCO Reply Comments, Docket No. 20271, March 4, 1977, p.3.

a public safety viewpoint?

5.3 What will be the role of cellular systems or technology in serving public safety radio systems? Can cellular technology be adapted to all or some of the communications needs of an urban public safety system? Will the 20-channel limit on private systems or other technical requirements for private systems frustrate the development of private systems? Could the common carrier cellular system offer a cost-efficient means of serving some or all of public safety radio requirements?

5.4 How does the 900 MHz regulatory scheme accommodate the long-term planning requirements and other unique aspects of public safety systems? The "first in/first out" frequency assignment method determined for 900 MHz applications removes the assurance of a related block of frequencies for the growth of radio systems. At the same time, public safety radio systems have seen steady growth in the size, complexity and sophistication of communications systems. The prospects for the future indicate even larger systems -- many operated in conjunction with other local government entities. These comprehensive systems call for detailed planning, budgeting, approval by appropriate local authorities, and possibly phased cut-over from older radio systems. In short, they require extensive and intricate planning by state and local agencies as well as implementation over a long period of time as compared to small private systems. If the "first in/first out" assignment system, the short-term channel loading criteria, and the mandatory channel sharing option are applied rigorously by the FCC staff, will such comprehensive system planning and implementation be possible?

The need for channel assignments by function rather than by strict numbers of mobile units is also unique to public safety systems. The use of a particular channel by one part of the police force or another functional group may be vitally important to effective use of radio in the tasks of a public safety agency. In former block or pool allocation schemes, the designation of one or more channels to a particular function could be accommodated, but the channel assignment and loading plan at 900 MHz seems to preclude functional designations.

The Clarification promised a rule of reason and a degree of flexibility in frequency assignments, but the potential for mechanistic rules and mandatory loading requirements is troublesome to radio system planners. In order to assure the implementation of long-term planning, should there be some form of "block" allocation in the 900 MHz band to ensure the future availability of needed spectrum? How should the FCC take into account state or local plans for coordinated radio use? How should the need for functional designations of channels in public safety systems be accommodated.1/

5.5 The role of APCO and other service frequency coordinators in planning and assisting 900 MHz applications is also open to question. For applicants seeking frequencies in the radio bands, frequency coordination committees are recognized by the FCC as the primary mechanism for selecting frequencies and working with applicants to design interference free systems.2/ Often this frequency coordination work entails considerable time advising applicants, mediating between possibly con-

1/ For detailed discussion of conclusions regarding these and related questions, see APCO's Comments on Docket No. 21229 in Appendix I.

2/ Docket No. 18261, Second Report and Order, 22 RR 2d 1691, 1704-06.

flicting proposals, and encouraging the redesign of systems where unforeseen interference creates problems.

The FCC staff's role in frequency assignments to 900 MHz systems and the contemplated method for staff assignment of frequencies may well suffer from the absence of the counseling, designing, and mediating functions performed by the volunteer coordinators. Even if APCO and the other service coordinators were to continue in advisory roles, the lack of information as to frequency assignments made by the FCC staff could effectively frustrate their efforts. It is difficult to believe that the FCC has the resources available on a nationwide basis, needed to perform the counseling and mediation often required by smaller, local applicants. In sum, the 900 MHz decisions leave a large hole in the application process formerly filled by the service frequency coordination committees and the lack of full frequency coordination work may disadvantage many applicants and burden the FCC staff. It is for reasons such as these that the FCC is taking a further look at its policies governing frequency coordination in the 900 MHz band.1/

5.6 Finally, an issue that pervades the whole future of 900 MHz systems is the ability of the FCC staff to carry out the processing and enforcement role assigned to it. The enforcement of technical rules, channel loading standards and license cancellations by defunct systems at the lower bands has been haphazard at best. With the help of frequency coordination committees, the FCC has barely kept abreast of the flood of applications it receives. For 900 MHz systems, the FCC staff proposes to make all frequency assignments, presumably to enforce the eight-month deadline for channel loading and the 90% loading prerequisite for assigning additional channels, etc. Although the growth of 900 MHz system may be slow in the beginning years, even an optimistic observer must have concerns as to the availability of the FCC staff to take on these varied tasks.2/

1/ The topic of staff resources and efforts in spectrum management is now under consideration in a broad inquiry, Docket No. 21229. Notice of Inquiry, FCC 77-287, May 17, 1977. Frequency coordination methods are also considered in some measure.

2/ See Docket No. 21229. Notice of Inquiry, FCC 77-287, May 17, 1977.

CHAPTER II

FACTORS AFFECTING 900 MHz SYSTEM PERFORMANCE
ELEMENTS OF THE 900 MHz CONCEPT

2.1 INTRODUCTION

Chapter I describes the regulatory history of Docket No. 18262 and the background that led to the opening of the 900 MHz spectrum for use by the land mobile radio services. It also describes the present regulatory environment and presents some of the unresolved issues that affect the application of this spectrum to the needs of public safety communications systems.

This Chapter describes those engineering, economic, and management-related factors, peculiar to the 900 MHz environment, that also affect the application of this newly available spectrum to public safety, and in particular law enforcement, communications systems. This presentation is not intended to be an exhaustive discussion of all the elements of law enforcement communications system design, nor is it meant to be a rigorous, engineering analysis. It is intended to present those considerations of law enforcement communications system design and operation that are, or may be, peculiar to the 900 MHz portion of the spectrum under the conditions by which it has been made available to the public safety community. It will describe those system-related factors that affect system planning, operation, and implementation decisions.

A discussion of 900 MHz propagation considerations is presented to yield insight into the probability of coverage throughout a given area. Concepts employed in the presently envisioned trunked system designs are discussed to provide a basis for the discussion in Chapter III regarding the roles such systems might play in the public safety environment. Design considerations for 900 MHz equipment are presented to provide an appreciation of the system-related factors of cost, availability, maintenance, and training that may affect 900 MHz system implementation decisions.

This discussion is designed to assist the executive level public safety communications system managers' decision-making process. The technical aspects of propagation phenomena, noise levels, information handling, trunking theories, and similar related topics are presented in a summary, non-rigorous form. It is intended to be a managerial level summary of the work done by authors listed in the Bibliography, the technical inputs of the APCO project staff and the APCO Task Groups I and II. For more rigorous, academic treatment, the reader is referred to the Bibliography.

2.2 900 MHz COVERAGE CONSIDERATIONS

The history of land mobile communications during the last 25 years has been marked by the opening of higher and higher portions of the RF spectrum. Each of these moves to higher frequencies was accompanied by uncertainties. How will the new frequencies work? What coverage can be expected? What equipment problems will develop? Will different base station locations, more repeater installations, different network designs, be required? Will authorized antennae heights and power outputs permit the coverage of the required geographic areas with the needed degree of certainty?

The opening of the 900 MHz spectrum is no different in this regard. Prior to the Report and Order resulting from Docket No. 18262, little operational experience had been gained using these frequencies in a civilian, land mobile, law enforcement type of environment. Even as questions relating to trunked system concepts, equipment costs and availability, and system management problems must be considered, the basic question of whether or not these frequencies will permit the required reliability of communications throughout specified environments, using practical systems configurations, must be answered.

The following section of this report discusses those inherent properties of the 900 MHz portion of the spectrum that affect its usefulness for law enforcement communications system design.

2.2.1 900 MHz Antenna Performance

The area of coverage provided by a 900 MHz system is determined by those same parameters that determine coverage of lower frequency systems. As in any radio communications system relying on line of sight transmission paths, transmitter power, transmitter and receiver antennae heights and relative gains, system noise, generated either internal or external to the system, receiver sensitivity and band with characteristics and the nature and length of the path between the transmitter and the receiver, are among the more obvious factors that determine whether the system will pass an intelligible signal between two points. For rigorous treatment of these considerations and for additional discussion of the more subtle considerations affecting radio frequency system design, the reader is referred to the Bibliography.

Of special interest to those considering 900 MHz applications are those particular factors that result from the characteristics of the shorter wavelengths that are characteristic of these frequencies.1/

A basic, physical consideration, and one that has long inhibited the application of the 900 MHz portion of the spectrum to mobile/portable applications, is the reduction of the effective capture area of 900 MHz systems' antennae, as a result of the use of these higher frequencies. As frequency increases, the wavelength of the radiated energy decreases proportionally and, therefore, the physical length of a resonant antenna decreases. As the physical length of the antenna gets less, the area throughout which it captures energy from an electromagnetic wave gets smaller. Therefore, the receiving antenna picks up a smaller share of the energy radiated by the transmitting antenna.

For example, a quarter wavelength antenna designed for a 900 MHz system would absorb only one fourth the amount of energy from a 1000 watt 900 MHz transmitted signal that a quarter wavelength antenna designed to work in a 450 MHz system would absorb from that radiated by a similar powered transmitter -- other factors being constant. In many types of systems, such frequency-dependent losses can be compensated for by increasing the gains 2/ of the smaller antennae, i.e., since higher frequency means smaller antenna element length, antenna can have increased numbers of elements or increased electrical length for a given physical size with a resulting increased gain. This gain can be used to compensate for the frequency-dependent reduction of capture area.

1/ Wavelength in meters = $\frac{300}{f}$ where f is expressed in megahertz. Practical consideration of system design usually requires that antenna length (either transmitting or receiving) be an integral function of 1/4 of a wavelength. Therefore, as operating frequencies become higher, the physical length of an antenna becomes less. At 806 MHz a typical 1/4 wavelength antenna is approximately 3½" long.

2/ "Gain" in this context loosely means the amount of energy a given antenna captures (or radiates) in a desired direction in comparison to some standard radiator, usually a half wavelength dipole.

But mobile/portable system operation places limits on the amount of gain that can be tolerated. Antenna gain can only be provided by concentration of available energy, i.e., increasing directivity. Mobile and portable units must normally be nearly omnidirectional in a horizontal plane and can only use limited directivity in the vertical plane if antenna pointing is not to become an operational problem.

Base station antennae can normally employ larger figures of vertical directivity, with resulting increased gain. In some instances where the needed coverage is not uniformly distributed around the antenna, directivity, with resulting increase in gain, can be tolerated in the horizontal plane.

Normal engineering practice calls for system designs that employ the maximum directivity, and associated gain, that the system geometry will allow. Therefore, in moving from a lower frequency to the 900 MHz band, system designers may not be able to rely on increased antenna gain, over that used in lower frequencies systems in the same location, to compensate for the reduced energy capture that results from shorter wavelengths, i.e., the lower frequencies system is already using as much gain (directivity) as the systems' geometry will permit.

This fundamental system-related problem has, to a large extent, been overcome in recent years by advances in receiver design technology. A characteristic of the 900 MHz portion of the spectrum is the significantly reduced level of noise that normally exists in the environment in which the desired signal must be received. Without delving too deeply into what constitutes noise generated by sources external to a radio system, it is sufficient to point out that those noise sources (when added to noise generated within the system) establish the minimum amplitude of a usable signal, i.e., if a signal is any weaker than the noise, it will not be intelligible. As a result, even a very weak signal at 900 MHz, one whose amplitude is such that it would be no stronger than the noise arriving at the receiver in a lower frequency system, can be copied by a receiver having adequate, and currently available, technical characteristics.

The technological advances of the past several years that now make 900 MHz a viable approach to mobile communications system design is the development of receivers having usable sensitivities at these frequencies in the order of .25 to .5 microvolts and that are capable of being mass-produced at costs comparable with existing equipment.

The above discussion has been presented with two objectives in mind: first, to show the importance of technology in making the 900 MHz portion of the spectrum available for use; the second is to illustrate the need to maintain a noise-free environment for 900 MHz systems. Should poorly selected frequencies result in significant intermodulation (IM) products, should spectrally "dirty" transmitters be permitted, even at frequencies well removed from systems under construction, or should other ill-conceived or uncoordinated operations be permitted, exploitation of the system sensitivities made possible by modern 900 MHz technology will be impossible, and the usefulness of the 900 MHz spectrum for law enforcement and other public safety needs seriously compromised.

2.2.2 Shadow Effects

Electromagnetic radiation is normally envisioned as traveling in straight lines, much like light rays. As a result of this linear path, shadows often exist behind objects that either reflect or absorb the incident rays. Close observation of the edges of these shadow areas will show that these boundaries are not perfectly defined. There is a region of transition between full illumination and shadow at the border (called the Fresnel zone). As the wavelengths become shorter, the region of transition between illumination and shadow becomes more sharply defined. The width of this transition region is a function of (among other things) the wavelength and is inversely proportional to the frequency.

It is this transition region that permits much of our line of sight radio communications; however, as noted above, as frequencies increase, the borders between usable signals and unusable signals become more distinct. Above the UHF region shadows can exist in which the movement of a receiving antenna by only a few feet can result in severe signal degradation. Tests 1/ at 900 MHz have shown that individual variations from the mean transmission loss at these frequencies can be as high as 30 db. These tests have also shown that the amplitude of the variations from the mean path loss is, to some degree, a function of the absolute field strength and that the variations become larger as the mean value of the path loss increases. This observation suggests that higher energy densities, i.e., more effective radiated power (ERP) than is normally indicated necessary by theoretical calculations, may be required in some environments to minimize the operational problems that may be caused by these large path loss variations.

2.2.3 Scattering effects

Another phenomenon affecting the usefulness of the 900 MHz band for urban, mobile/portable communication systems is the increased reflectivity of these frequencies. The short wavelengths involved make energy at these frequencies more easily reflected by the typical concrete/steel structures encountered in an urban environment. This reflection, or scattering effect, caused by the multitude of buildings and other structures normally existing in a typical city, can result in a distribution of energy throughout what normally would be expected to be shadow areas. Experimental data 2/ supports the theoretical conclusion that this scattering effect throughout an urban community can greatly increase the percentage of coverage in the zone of interest by "filling in" holes normally caused by the shadow effects described in Section 2.2.2.

These scattering effects are of great interest to the designer of urban law enforcement communication networks. Tests in a typical urban environment show that this scattering phenomena can have a significant beneficial effect on overall system performance by providing increased coverage within buildings, tunnels and throughout the highly complicated propagation paths existing in a typical urban community.

This scattering, however, is not a completely unmixed blessing. As cited above, there can be variations as much as 30 db from the mean propagation loss throughout the area of coverage. However, these studies have concluded that coverage will be generally adequate for land mobile communications, and in some cases superior to that available on lower frequencies. However, "holes" can and will exist.

2.2.4 Building Penetration

The attenuation of electromagnetic energy passing through natural or man-made structures is a major problem in portable law enforcement

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1/ UHF Radio Wave Propagation in Dallas, Texas Base to Mobile Stations for Vertical Polarization, by N. H. Shepherd, GE Mobile Radio Products Dept., March, 1975.

2/ Ibid. pp. 2.7.

system design. The literature indicates that 900 MHz frequencies penetrate average structures with propagation losses in the order of 10 db to 20 db per 100 feet. As a result, massive structures can cause shading that prevents usable transmission or reception inside of buildings or similar structures. Though somewhat frequency-dependent, this phenomenon exists at all frequencies. However, evidence exists that the scattering effects of 900 MHz systems described above significantly improve the coverage inside buildings and tunnels.

2.2.5 Foliage Loss

The short wave lengths at 900 MHz are susceptible to serious attenuation from foliage. This problem is particularly difficult to treat analytically due to the many variables encountered. The losses can be much greater in summer when trees are in leaf than in winter when they are barren. Moisture after a rain increases losses noticeably. Different kinds of vegetation have different amounts of attenuation. A number often used is 1.5 db loss per meter of vegetation for "average" attenuation. Of more significance, perhaps, is the estimate that foliage losses at 900 MHz are probably about 25% greater than those experienced at 450 MHz.

2.2.6 Site Selection Considerations

The generation and transmission of radio frequency power at 900 MHz is more expensive than at the lower bands. Transmission line loss is of somewhat greater system significance at 900 MHz. Conventional RG8/11U transmission line has a loss of 2.8 db per 100 feet at 150 MHz. Its loss at 900 MHz is 6.8 db per 100 feet. 7/8" copper foam flex has a loss of 1.7 db per 100 feet, and air dialectic coaxial cables (with their attendant expensive pressurization systems) cause loss in the order of 0.5 db per 100 feet at 900 MHz. This implies that if the transmission loss between the transmitter and the antenna is not to be exhorbitant, transmission line runs must be kept reasonably short.

These loss characteristics indicate that fixed sites must be selected with some degree of care. As a rule of thumb, the radius of the area of coverage is directly proportional to the square root of the antenna height. Antenna height v. ERP is a basic trade-off consideration in systems design. Practical considerations prevent the radius of coverage from being increased to a great degree by increasing the height of the mobile or portable receiving antenna. Therefore, base station heights usually must be the maximum possible, consistent with terrain and area of coverage requirements. In the typical system, the need for maintenance accessibility and structural cost considerations prevent the location of RF generating and receiving equipment at the antenna near the top of a tower. Therefore, at 900 MHz sites must be selected at which the transmitting and receiving equipment can be located reasonably close to the radiating elements of the antenna, such as the roof of a tall building or a strategically located mountain top.

It is perhaps unfortunate that a "strategically located mountain top" for a 900 MHz system is very often also one for other systems. This can result in a number of antennae, serving many different systems, operated by many different users, being located in close proximity to each other. The potential for intermodulation (IM) products seriously degrading system performance under such conditions is great. This degradation can be minimized by careful system design. Frequency selection must be based upon careful evaluation of system performance needs and the frequencies, modes of operation, power output, and user service of other collocated or proximate system installations carefully evaluated.

As noted in Par. 2.2.1, the inherently greater path loss experienced at 900 MHz can be overcome by the lower ambient noise existing at these frequencies, permitting full exploitation of modern receiver usable sensitivity. This factor must be kept in mind in selecting sites, and then protecting these sites from electromagnetic pollution. In addition to the IM considerations described above, site selection should include surveys for possible sources of noise, such as high power TV stations on nearby channels, high powered control stations directed toward the site, and major industrial or medical installations nearby that radiate with significant levels of spectral impurity.

2.2.7 Physiological Considerations

The portion of the RF spectrum in the vicinity of the 900 MHz band has been used for various industrial and governmental purposes since World War II. These frequencies are only slightly above the UHF television channels and are below government radar and telemetry frequencies. Many of those systems have long used radiated power levels in excess of hundreds of thousands of watts.

Despite this experience, there is an ever-present concern about the possible physiological effects that these frequencies may have on equipment users. Such concerns are particularly appropriate when considering the employment of portable equipment. Although such equipment is normally very low power, i.e., 1 to 5 watts RF output, normal usage often places the antenna only inches away from the head and eyes of the user when talking into a microphone mounted on the portable unit.

Despite periodic studies by the Department of Defense during the past quarter century and more recently by governmental consumer protection agencies, little specific information exists pertaining to the potential physiological effects of 900 MHz radiation in the type of environment that might be encountered in the law enforcement field. The Chief Engineer of the FCC has stated that 1/ the FCC is now studying these problems and intends to provide a definitive report in the future. He further stated that the potential extent of the problem is not known but recommended that, pending publication of the results of the Commission's findings, personnel working in the proximity of such systems exercise reasonable care.

Since the maximum power level authorized for base stations, 1000 watts, is considerably lower than that long in use by television stations at similar frequencies, it is not likely that base station personnel will be subjected to a measurable level of risk due to electromagnetic radiation. By the time portable equipment becomes available, it can be expected that the results of the FCC's investigation will be public knowledge. As recommended by the FCC's Chief Engineer, 900 MHz system designers and managers should keep abreast of published information relating to this consideration.

2.2.8 Summary

The phenomena described above are similar to those experienced at lower bands, varying only in degree. Certain characteristics of 900 MHz propagation seem advantageous while others offer problems. None have proved to be unacceptably detrimental to communications system performance. Most are simply the inherent considerations encountered in the design of communications systems. Engineers compensate for their effects by other coverage calculations or empirical judgment and thereby

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1/ Presentation to the 43rd APCO National Conference, August 24, 1977, Chicago, Illinois.

determine the number of "fill in" repeaters, antennae heights, or the ERP required. The degree to which special measures may be required in the 900 MHz band is a function of the operational impact that the anomalies predicted may create. Full appreciation of the impacts that 900 MHz coverage phenomena will have on operational systems design can only be determined by experience. Analysis shows that there are no insurmountable difficulties inherent in 900 MHz system implementation. Empirical data, acquired by observations of practical systems, will provide the guidance needed for future system designers to configure their designs in ways that best overcome the problems and exploit the advantages offered by 900 MHz propagation phenomena.

2.3 THE TRUNKED SYSTEM CONCEPT

2.3.1 General

The Second Report and Order resulting from Docket No. 18262 has made mandatory the use of trunked system techniques in those systems at 900 MHz that require more than five channels. While a form of trunking has been in use by the mobile telephone service for some time, all users of the 900 MHz band with requirements in the excess of five channels are now required to employ trunked techniques.

The Commission based this policy on its determination to assure the most efficient use possible of the 900 MHz portion of the spectrum. While public safety agencies with their specialized operational requirements (see Section 3.2) are required to consider many factors in the configuration of their systems, they also consider spectrum usage efficiency as being one of the more important.

This Section will describe the basic principles of how trunked systems operate. This description is necessarily generalized, as it represents a synthesis of several approaches now under development by the vendor community. While significant differences of engineering specifics may exist, these systems have many basic characteristics in common. The differences do not dilute the usefulness of a generalized description of system operations to help understand how trunked systems can be applied to public safety communication needs.

Trunking is not a new concept. The national public switched telephone service is based upon this technology. As stated, the mobile radio telephone service has long used a trunked type of system. But this system, the Improved Mobile Telephone System (IMTS), uses an automatic, sequential frequency stepping approach. It is slow; as much as 20 seconds can be taken to obtain access to a channel. Such a system would be of little use to law enforcement networks wherein the typical transmission may average less than 3 or 4 seconds. Therefore, the following discussion is limited to those high speed, flexible systems whose development has been made possible by the introduction of high speed switching equipment and rapid, remotely controlled frequency change capabilities in modern mobile radio equipments.

2.3.2 Trunked System "Spectrum Efficiency"

The presumptive objective of the introduction of trunked concepts is to increase spectrum usage efficiency. For the purpose of this study, "spectrum efficiency" (a widely used misnomer) has been defined as the ratio of the actual number of users assigned in a defined portion of the spectrum to some (not specified) theoretical maximum number of users that could be assigned to that portion of the spectrum, holding the level or quality of service constant, within a defined area. Since the theoretical maximum number of users that could be assigned in a given area, and a quantifiable measure of "level or quality of service" is not available, the term "spectrum efficiency" is not very precisely defined. However, it does have useful meaning in a relative, non-quantifiable way. Intuitively, we feel that techniques that permit more users to fit into a fixed amount of spectrum or conversely, that permit a fixed number of users to be accommodated in a smaller portion of the spectrum, without impeding their communications effectiveness, improve "spectrum efficiency".

From this concept springs the corollary that unused air time is an indication of spectrum usage inefficiency. This idea is based upon the regulatory principle that anyone meeting minimum established requirements has a right to exercise his privilege to utilize air time ("use" being defined as an authorized transmission).

This concept might have validity if all users of the spectrum have the same requirements and made equal contributions to the public's interest, convenience or necessity. If that is not the case, then the idea of unused spectrum and therefore the term "spectrum efficiency" may have little meaning. The possibility exists that the worth of unused spectrum, by simply being available, may be greater than the worth of spectrum fully occupied by less essential services.

As an example, the worth of the "hot line" between the White House and the Kremlin is not measured by the number of messages transmitted. Its worth lies in its guaranteed, instant availability when needed for the good of the community at large.

Keeping in mind the above cautions regarding the general applicability of the term "spectrum efficiency", several analyses of the possible contributions of trunking techniques to "spectrum efficiency" are available. These studies, deriving from telephone experience, show that trunking techniques can be expected to significantly reduce the probability of delay in a system of a fixed number of trunked channels.

Chart No. 2.3.1 shows the probability of delays that have been calculated for various numbers of trunked channels under various conditions of loading. A single channel system is included (see dashed line) to illustrate a boundary condition. For example, a 4-channel system, each channel loaded 40%, would present an overall probability of delay of 40% to any user if the system were operated in a conventional mode. (See dashed line. Each channel has the same probability of delay as a single channel system.) The chart shows that this delay probability would be reduced to 9% if those same four channels, each 40% loaded, were connected in a trunked system. A 16-channel system, with all channels loaded 40%, would provide any user with a .1% probability of delay if operated in a trunked mode. Similar calculations are possible showing the theoretical reductions in waiting times, rather than probability of delay, that can result from trunking available channels. (See Chart 2.3.2.)

The application of these generalized conclusions to a specific mobile radio service presents certain difficulties. The calculations from which the above charts are derived assume a telephone type environment, wherein a large number of randomly selected callers are attempting to communicate with a large number of receivers over a limited number of channels. A similar situation may or may not exist in the various services that constitute the land mobile communication community.

Subsequent descriptions of law enforcement systems operational needs (Section 3.2) shows that this analysis does not exactly represent law

PROBABILITY OF DELAY IN

MULTICHANNEL TRUNKED SYSTEMS

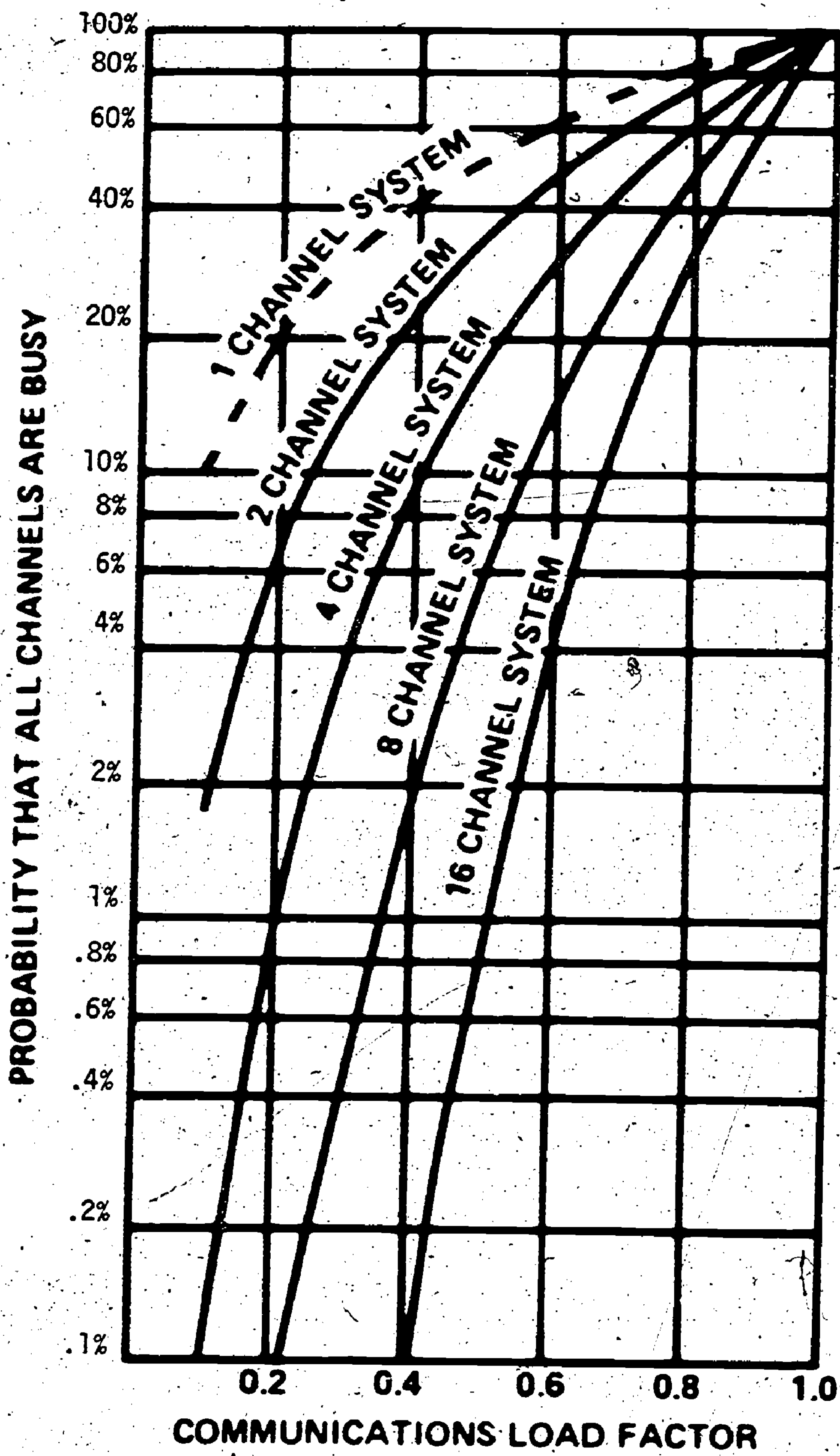

CHART 2.3.1

EXPECTED WAITING TIMES

IN MULTICHANNEL TRUNKED SYSTEMS

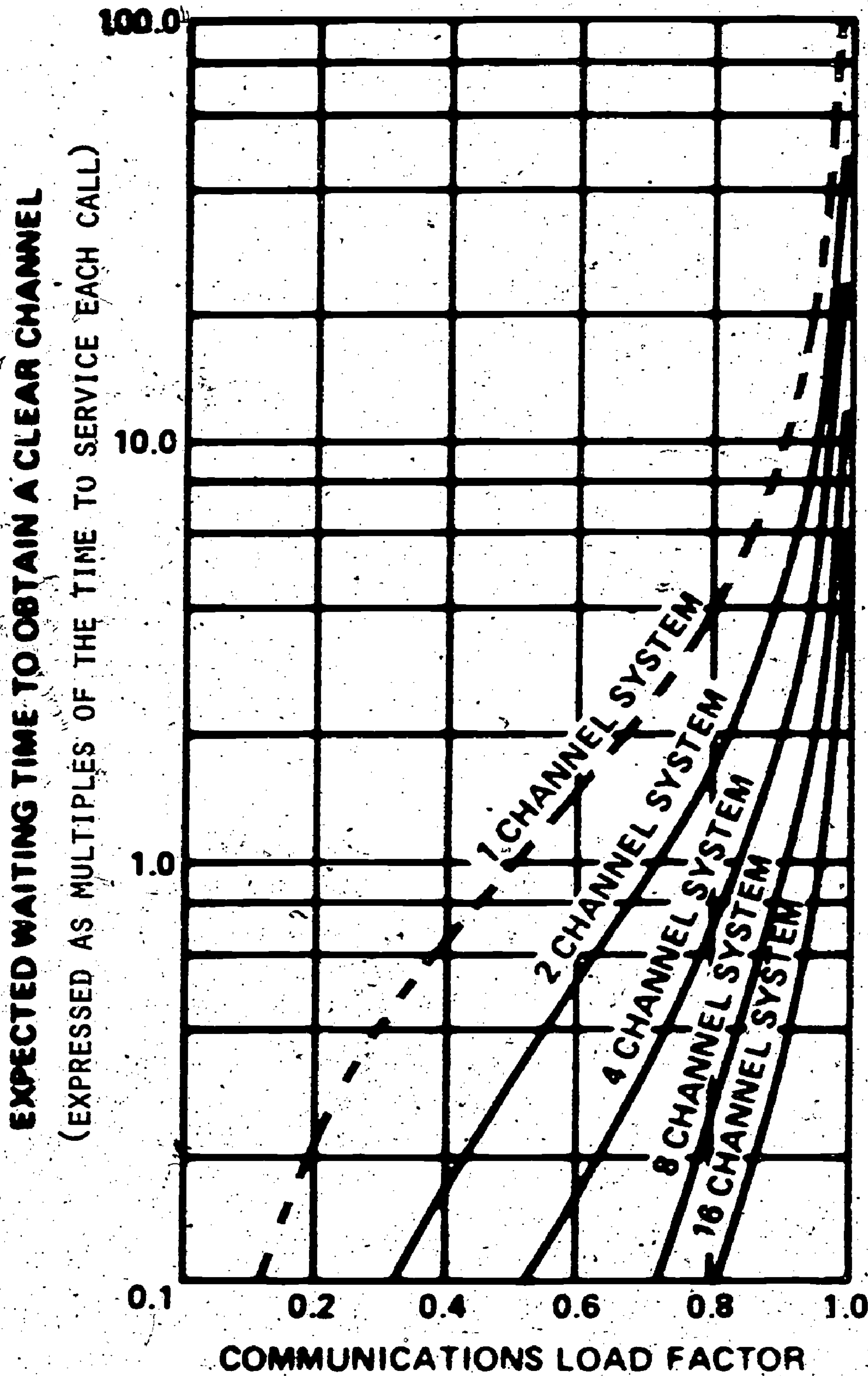

CHART 2.3.2

enforcement operations. In those types of systems, generally a single caller (the dispatcher) must communicate with a large number of simultaneous recipients (the patrol units) or one (or more) of the patrol units must communicate with a dispatcher.

Since the number of system users at one part of the system (the dispatchers) is relatively small compared to the number of users at the other part (the patrol units), the basic mathematical formulations used to develop Charts Nos. 2.3.1 and 2.3.2 should not be applied too literally to the public safety service. For example, the nature of the law enforcement operational procedures may cause the probability of delay to be not only a function of the number of radio channels, but also a function of average message length, time required to service a message, the number of units per channel, and other similar factors.

These observations are not intended to negate the possibility of spectrum-related benefits that might be derived from trunking. They are offered to show that the present popular calculations of potential benefits are based upon assumptions that do not precisely pertain to the public safety service. They are not likely to provide a highly exact basis for determining the increase in "spectrum efficiency" that might derive from trunking public safety radio systems, nor calculating the number of trunked channels that will provide a required level of service.

If one is to assume some relatively large sized system, for example, one having 10 patrol areas with 10 dispatchers, it is possible that the number of channels needed can be reduced from the 10 channels required in a conventional mode to some smaller number if the system is operated in a trunked mode. Just how much of a reduction may be possible cannot be determined from these figures. Law enforcement communication systems designers must provide near absolute assurance that the systems will support the level of service required to satisfy the law enforcement mission under peak load conditions. Therefore, the possible reduction of channel needs that might result from the use of trunked systems in law enforcement can be determined, with the credibility necessary for future system design, only from practical experience.

2.3.3 Trunked System Operational Concepts

2.3.3.1 General

A trunked communication system is one in which users at either terminal of a multiple link path have access to all the circuits between the two terminals. In the classic telephone case, a small number of lines may connect two exchanges. A caller from one exchange can reach the other exchange via any one line. The next caller to use the same circuit is given the next unused line, and so on, until all the lines are occupied. In this way no one caller experiences a busy signal until all the lines are in use.

The antithesis of this approach is the "conventional" system, wherein one or more of the customers at each end are assigned one specific circuit. In this case, as soon as a circuit is placed in use, the rest of the customers assigned to that circuit must wait until the call is completed, even though the remaining circuits between the two exchanges might not be busy.

Traditional frequency assignment concepts in the land mobile radio service have constrained operations to this latter type of conventional service. Users assigned to a given frequency must await the availability of that frequency to initiate their communications. Even though nearby frequencies assigned to others may not be in use, they are not available to non-assigned users.

Current concepts of trunked system operation overcome this difficulty by assigning several frequencies (5 to 20 two-frequency channels are now considered by the FCC to be a practical number in a single system) to a larger number of users. Users are given specific frequencies by automatic switching techniques so that no one user experiences a "busy" condition unless all the frequencies assigned to the system are in use at the same time.

The nature of a trunked system is such that it derives its spectrum efficiency benefits by combining the RF channels into a common pool for use by all users of the system on either a first come, first served basis or in accordance with some prearranged scheme of priorities.

2.3.3.2 Components of Trunked Systems

The techniques for accomplishing this automatic switching involve a number of system elements described below.

a) The base site transmitters and receivers. The base station installation includes a number of transmitters and receivers equal to the number of channels assigned to the system, each operating on a designated frequency. These transmitters and receivers are individually conventional in operation and are connected to primary power sources and antennae just as if they were elements of a standard, conventional system. These units can be switched on and off by a collocated (usually) electronic control unit.

b) The portable mobile transmitter/receiver unit. This unit operates similar to a conventional mobile or portable unit. In addition, however, it incorporates a frequency change capability that can be controlled by a data command signal. A data controlled frequency synthesizer is a possibility; however, a multi-channel crystal exciter might serve the function also. Incorporated in the portable/mobile unit is an address logic capability, i.e., the logic ability to recognize its assigned unit designator or address, and to comply with frequency assignment commands.

c) The control channel. This is the heart of a trunked system's operation. It includes a separate transmitter and receiver at the fixed site, operating continuously on a fixed frequency, sending various items of control information to all portable/mobile units or system control points. Portable/mobile units monitor or reply on this channel whenever not transmitting or receiving on an assigned channel in response to a command.

d) The system's language. Here is included the many system features that dictate how the system operates. It includes the data system concepts that establish what the system does and how the system functions. It is made up of a digital data stream transmitted on the control channel that addresses each portable/mobile unit to provide information regarding RF channel assignments for each addressed portable /mobile group or unit. The composition of this language and the constituent elements of the instructions contained therein directly determine system functional performance.

e) System control points. One or more transmit/receive units, usually fixed but can be mobile or portable, in the system having the ability to direct the control channel. By so doing, these points can initiate calls to designated units or groups of units or in other ways exercise control over the system. Such a unit would normally be assigned to a dispatch center. There can be more than one control point in a single trunked system, each serving different users and generally unaffected by each other's operation.

2.3.3.3 Trunked System Configuration

Each mobile and control unit of a trunked system is assigned an address. This address includes a group designator in addition to the discrete unit address, similar in concept to a seven digit telephone number. The base station control channel constantly transmits coded instructions that include address information and frequency assignment information. All mobile units assigned to the system monitor this channel whenever they are in a stand-by mode.

When a dispatcher initiates a call to units in a patrol area, the control channel carries instructions to the units in that patrol area (by addressing them all via their group designator) and directs them to move from the control channel to a frequency that the central control unit has determined to be unoccupied at that time. All units in the designated group hear the fixed site (and a rebroadcast of the mobile transmission if the system is so configured). All units of other groups remain on the command channel or on a working channel if they are occupied.

When mobile units have moved to a working frequency, a "hand shake" takes place by transmitting 'check' signals that assure that the mobile units are on the same working channel as the fixed station. This all takes place in small fractions of a second. Depending upon system organization, a working channel may be held for the duration of a message or of just a single transmission. Upon completion of the traffic exchange, the units revert automatically to the command channel.

Should a member of a group wish to initiate a call, he automatically queries the central controller via the command channel by simply depressing the microphone switch. The automatic controller selects an available frequency and directs the mobile unit to move to the channel selected. This command information can also be received by other members of that group and their units automatically moved to the channel selected so that they would monitor the communications.

Should mobiles be required to communicate with other mobiles or units other than the dispatcher, both units would switch to a designated new address. For example, if a unit from Group 123 was required to communicate with a unit from Group 321, each could be directed to switch to a common group address 456. The control unit would recognize this as just another group call.

The command channel is a data link, suitable to a standard 3 KHz voice channel band width. Data can be transmitted at a rate that permits complete command information transfer in small fractions of a second. As a result, all of the automatic channel switching takes place in the time it takes the operator to depress the mike button.

There are two important benefits to be derived from these techniques. The first is the reduction of probability of delay resulting from the availability of all RF channels to all users at all times. (See Section 2.3.2.) The second may be of even greater importance. The system's operational configuration is no longer limited by channel availability. Special functions can be accommodated by setting up special group addresses rather than through the use of discrete channels. The potential value of this latter tool ~~in~~ configuring systems to provide complex, user-oriented functions is difficult to fully appreciate at this time.

Present trunked system concepts allow the command language to provide more items of information than merely address and frequency instruction. Priority instructions can be incorporated. Status information can be transmitted with the address group permitting direct interface with computer aided dispatch systems. Only careful analysis of user functional needs will determine which of the many possibilities inherent in this concept should be incorporated in a given system design.

Because of the random frequency selection problems, it is impractical to use remote repeater configurations having fixed frequency offsets to extend coverage throughout areas beyond the coverage of a single transmitter location. Trunked systems can be used in repeater type systems where repeat transmissions are on the same frequency as the primary transmission. This technique, called "simulcasting", has been used on occasion at the lower bands. Very close tolerances of RF carrier frequency and audio envelop phase shift are required to prevent interference in the zone where signals from both transmitters can be received. Such frequency control has not been demonstrated in practical systems at 900 MHz at this time.

This limitation does not apply to satellite receiver sites. Should remote receiver capabilities be required, as in the case of portable systems, each satellite installation would have equipment required to monitor all frequencies available to the system, each connected to the central control unit through appropriate voting systems by the usual land line or microwave system.

The above description of trunked systems is sparce. It does not describe various specific system functions considered proprietary by those vendors now developing such systems. It does show the critical elements of such systems and how they function. It is intended only to provide familiarity with the basic system operation so that judgments can be made regarding the potential applicability of these techniques to specific user requirements.

2.4 CELLULAR SYSTEMS FUNCTIONING

2.4.1 General

The concept of cellular systems contained in Docket No. 18262 poses one of the most far reaching innovations in the history of radio communications. The ultimate objective of this concept is to make mobile telephone service available to the general public in much the same way that the public switched telephone service, using fixed wireline connections, is used today.

The problem that has prevented the development of such service in the past is the lack of the huge number of frequencies that would be required to serve the large number of general public customers, if present day techniques were to be employed. In a given service area, using a normal coverage pattern (perhaps 25 to 50 miles in radius), thousands of separate channels would be required to service the hundreds of thousands of mobile customers that might reasonably be found in the area of coverage.

Modern computer technology, coupled with the capture effect phenomena inherent in a frequency modulated radio system, offers the potential for overcoming these difficulties. The possibility now exists that such service can be provided using a reasonable, and now available at 900 MHz, number of RF channels. Several techniques have been proposed to provide these services. Development programs are under way in Chicago, Illinois and Newark, New Jersey. License applications have been filed for additional developmental cellular systems in Baltimore, Maryland. These systems vary in techniques and geometry, all having a common objective, i.e., wide-based service to the general public using computer-aided switching and repeated use of frequencies within a defined area of coverage. The following description of the technical concepts is not intended to be an in-depth description of any one system. It is intended only to present the general principles upon which such systems operate.

2.4.2 Cellular System Organization

The basic principal of operation of cellular system operation is the division of the overall area of desired coverage (for the purposes of this discussion it will be assumed that the desired area of coverage is a single city, though this limitation is by no means necessary) into a number of smaller geographic areas, or cells. Radio coverage of each cell is provided by low power (relatively) transmitters and fixed receivers. Typical sizes of such cells may be only a few miles across. (The optimum size of each cell is a subject of controversy and one of the differences between the various competing developmental systems.) While each cell has its own transmitters and receivers, operating on assigned frequencies, adjacent cells will have different frequencies, but frequency conservation occurs by repeating frequencies in cells separated by other cells. As mobile vehicles move from cell to cell the capture effect, i.e., an FM receiver's capability of responding to the strongest signal on frequency and ignoring others, and the relatively low power of the fixed transmitters, prevents interference.

As the mobile unit moves from cell to cell, its received frequency of operation can be automatically switched as needed by techniques inherent in the system concept. Central computer switching provides continuous connection of the cell in use by the mobile to the system interface, usually but not necessarily the wireline telephone system.

By such a system, the number of simultaneous conversations possible within a cell is limited by the number of frequencies assigned in each cell. Mobile units receive continuous service as they pass from cell to cell through centralized switching of the cells in contact with the mobile unit. A reasonable number of frequencies can be used to support a large number of customers through multiple repetition of frequency usage.

The objective of such systems is to provide telephone type, customer-to-customer service, throughout a designated service area. There is significant technological development and economic investment needed before such systems become widespread. It is clear that it will be many years before such systems will have demonstrated their capability and reliability to the degree necessary to make them a viable consideration in serving public safety communications needs.

2.5 900 MHz EQUIPMENT AVAILABILITY

2.5.1 General

At the time this study was initiated, none of the vendors in the land mobile community listed base station or mobile equipment suitable for 900 MHz use in the public safety service as standard catalog items. Since that time several major vendors have advertised complete lines of base and mobile equipment. Other vendors have equipments in development and promise full availability in the near future. By the beginning of 1978 a full line of base and mobile equipment should be available from most of the vendors in the public safety field.

Costs closely track with those at 450 MHz. Vendors claim that 900 MHz equipment will cost initially between 10% and 20% more to manufacture than similar units designed for the 450 MHz bands.

At the time of writing, there is no 900 MHz portable equipment on the market, although most vendors observe that this is due to the lack of an immediate market rather than because of technological difficulties. No equipment specifically designed for use in public safety trunked systems is available. The following Section provides a description of these equipments and relates them to past experiences on lower bands.

2.5.2 Description of 900 MHz Equipment

2.5.2.1 Conventional Base and Mobile 900 MHz Equipment

The most apparent difference between present day 450 MHz equipment and the available 900 MHz hardware is the need for an additional stage of multiplication in the transmitter exciter and receiver local oscillator chains. Designs now being offered by major vendors incorporate existing chassis, IF strips, audio boards, and exciter chains. An additional doubler stage is added, and a new final power amplifier for transmitters and new receiver front end are needed. Solid state RF devices, able to provide required levels of power output, are readily available at a cost only slightly higher than for those at 450 MHz. Oscillator stability must be improved to meet FCC standards but this has proved feasible.

Stripline circuit layout techniques, long used in the lower bands, find similar application at 900 MHz, the principal difference being the changed size of the circuit and the resulting need for greater precision in fabrication and handling.

A noteworthy characteristic of the 900 MHz equipment now available is that full coverage of both the transmit and receive bands is possible without retuning. The bandwidth of the front end circuits is such that full coverage of the authorized band is possible by only changing the oscillator frequency.

2.5.2.2 Portable Equipment

No conventional portable equipment has been announced or promised for use at 900 MHz. Vendors are in general agreement that this is due to lack of a present market to justify the research and development investment. There are some inherent difficulties in the design of a conventional 900 MHz portable transceiver, but none that appear to be beyond state of the art resolution.

The main difference between existing 450 MHz and 900 MHz equipment is the need for an additional stage of doubling, both for the transmitter exciter and for the receiver local oscillator chain. This requires additional space, and also adds to the battery drain. If units are to meet the 5-5-90 duty cycle for an 8-hour shift, then portable power output must be kept as low as practical, keeping operational needs in mind. Estimates are that a 2 watt 900 MHz portable might have a size and power drain similar to that of a 4 to 5 watt 450 MHz unit.

2.5.2.3 Ancillary Equipment

Antennae, coaxial cables, duplexers, connectors, and similar equipment are now available for 900 MHz land mobile systems. A variety of antennae configurations have been developed so that systems designers have flexibility of choice. Low loss coaxial cable, while relatively expensive, is available.

The main distinction of 900 MHz ancillary equipment is the degree of care with which it must be handled. A poorly installed coaxial connector that would cause loss of several db at lower frequencies can render a 900 MHz system completely inoperative.

2.5.3 Trunked System Equipment

There are no trunked systems currently in operation, nor do any of the known vendors offer such systems as standard items. Several of the vendors describe breadboarding such systems. Such breadboard models are being used to develop and evaluate system concepts. Many of the system elements have long been in existence or have been developed for use in other types of systems. Remote control or switching of transmitters and receivers represents nothing new to the land mobile field. High speed switching of oscillators is well developed. Frequency synthesis techniques are well along. While there are many pitfalls possible between the availability of a technology and its implementation in a practical system, trunked systems do not require the resolution of yet unsolved theoretical problems.

As of this time no definitive requirement, specifying the functional needs of a law enforcement trunked system, has been prepared. It is only to meet such a specific set of needs that a specific system can be designed. It is estimated that the design and implementation of such a system would require 18 to 24 months after the specific needs were established.

Portable operation poses more difficult engineering problems in a trunked system. The trunked, portable unit has the same basic design requirements as the conventional portable described above. This means increased doubler circuitry and resulting battery drain. To the trunked portable must be added a multichannel exciter, either crystal controlled or frequency synthesized, plus the logic circuitry needed to decode address and frequency instructions on the command channels. No vendor has published any indication of the early development of units with these capabilities that meet normal operational requirements for size, weight and battery life.

This implies that near term trunked system development would involve mobile only systems or some form of hybrid system using trunked mobiles with conventional portable units. Depending upon the operational needs of the agency involved, such systems could be configured by having the portable work conventionally through a trunked mobile unit in a repeater or relay type mode, having a separate conventional network for portables that interfaces with a trunked mobile system, or other suitable configuration.

2.6 MANAGEMENT INNOVATIONS

2.6.1 General

The regulatory environment established by the FCC for operation of land mobile systems in the 900 MHz band includes a new concept of systems management not heretofore permitted. Community repeaters and radio common carriers have long been in use by the business community at the lower bands and are also authorized at 900 MHz. In addition, the Commission has authorized the establishment of Special Mobile Radio Systems (SMRSs) whose organizational concepts were recognized as necessary to fully exploit the advantages of the trunked system technology. (For definition of these terms and detailed discussion of their regulatory roles, see Chapter I.)

As described in Section 2.3 of this Chapter, the spectrum efficiency advantages believed to result from the trunked system concept spring from a conceptual scheme involving a multitude of callers, randomly seeking access to a multitude of call recipients. Statistical analysis shows that the degree of improved spectrum efficiency resulting from such a system configuration is dependent upon the number of channels in the "grab bag" of channels that is randomly available. The theoretical advantage of such a system is therefore largely dependent upon the number of users that can be combined into a single system. In a major metropolitan area this need could be satisfied by the requirements of a single agency due to its size. However, in those communities having no one agency large enough to fully exploit the inherent capabilities of the trunked concept, it might prove spectrally advantageous, and economically necessary, to combine the communications requirements of a number of agencies into one municipal system. In this case, the SMRS concept provides a system management structure suitable to support the needs of all users.

2.6.2 The SMRS Concept

It seems heuristically evident that the typical community could improve spectrum efficiency and enjoy the operational benefits of a sophisticated trunked system if several different community agencies, each now requiring an individual communication network, could pool their available channel needs in such a manner that the individual channels would "lose" their identification with the individual agencies and become available for the use of the entire community.

The objective of establishing SMRS was to make such a system more attractive from an economic and managerial point of view. An SMRS, as conceived by the Commission, is an economic entity established by an entrepreneur, on a profit-making basis (this profit-making element is authorized but it is not an inherent requirement under the Rules), to provide services to those mobile communications users WHO WOULD NORMALLY BE LICENSABLE IN THEIR OWN RIGHTS. An SMRS has two uniquely distinguishing characteristics. These are: (a) the SMRS is authorized to provide fixed radio services (under current rules the users of these services must own the control points and mobile units themselves) to land mobile users who are in themselves licensable under the existing regulations of the Commission; (b) the SMRS is not authorized to provide services to the public in general and therefore is excluded from regulation as a common carrier by the individual states. All regulatory authority over the SMRS resides in the FCC.

This new concept was the cornerstone of much of the controversy regarding the promulgation of the present 900 MHz regulations under Docket No. 18262. Chapter I discusses the legal ramifications of this concept and presents some of the questions still to be answered. Chapter III discusses the possible applicability of this concept to the law enforcement communications community showing some of the problems and the opportunities presented.

The existence of such an entrepreneurial function provides the community leaders with the possibility of contracting the fixed portion of their community's tax-supported communication network, in whole or in part, through competitively selected contractural arrangements. Superficially, it might seem that such arrangements would reduce the tax-supported manpower requirements of the community government, provide for increased efficiency through the consolidation of resources, and permit greater managerial efficiency through the competitive contractural selection process. However, the possible pitfalls of such a simplistic view should not be overlooked.

Such entrepreneurial functions should not be confused with "telephone type" service. As pointed out above, one of the distinguishing characteristics of an SMRS is, unlike the public telephone network, its exemption from state regulation. Such organizations are prohibited from providing services to the public as a whole. It seems, therefore, that many of the economics of scale now enjoyed by the telephone services might not be available to an SMRS.

Because existing restrictions on SMRSs preclude them from owning the control points and mobile installations, the procurement and maintenance problems encountered by a tax-supported agency would not be significantly reduced. Finally, the degree of "competitive procurement" that might actually take place seems questionable. It is unlikely that, within a typical community, sufficient capital would exist to provide a significant number of bids competitive with an established SMRS once its equipment has been installed and amortized.

On the other hand, there is nothing in the existing regulations that precludes the establishment of SMRS by governmental agencies. Should a community decide that its mobile communication service could best be provided through a single fixed station management entity, it now has available under the Rules the mechanism to establish such an entity. Whether this service would be required to operate in a conventional mode or as a trunked system would be a function of channel loading and the Commission's regulations.

The previous Sections of this Chapter describe trunking concepts, the status of equipment therefor, and the functional implications of this technique. These discussions have significant bearing upon any decisions regarding the desirability and costs of establishing SMRS. The reader's attention is invited to discussions in Chapter III which deal with the operational considerations and the functional requirements of communication systems in support of the law enforcement mission. These basic mission-oriented needs must be the dominent considerations in the selection of any communication system management technique.

CHAPTER III

OPERATIONAL SUITABILITY OF THE 900 MHz SPECTRUM

3.1 INTRODUCTION

Chapters I and II of this report have described the background of the opening of the 900 MHz band for land mobile communications. They have presented the regulatory, managerial, technological and economic factors that affect the way in which this new portion of the spectrum can be made available for law enforcement communications. This Chapter presents a generalized description of the operation of law enforcement communications systems and the system needs that derive therefrom. This description provides a basis for the analysis of how the 900 MHz spectrum, as now made available, may or may not contribute to meeting these needs.

The growing demands for public safety services by the general public and the increasing requirement for the application of sophisticated technologies in support of law enforcement objectives, have imposed increasing demands upon the capabilities of law enforcement communication systems. These demands are, in turn, imposing new and stringent requirements upon law enforcement communication systems performance. They are placing even greater requirements upon the electromagnetic spectrum.

The advance of technology has recently presented new opportunities to alleviate these problems. It is now feasible to produce equipment that can operate at 900 MHz in a practical, day-to-day environment. This technological development, recognized by the FCC in its Docket No. 18262 proceedings, has nearly doubled the amount of spectrum available to the land mobile community.

Trunking techniques, as defined in Chapter I and described in Chapter II, offer the possibility of significant improvement in spectrum efficiency and a hope for increased spectrum availability. These techniques also offer opportunities for new approaches to systems management that may yield significant improvements in the way public safety communication systems can respond to the needs of their users. The purpose of this Chapter is to analyze the extent to which these technologies can contribute to the solution of law enforcement's present and future communication problems. To do this, it will identify those special requirements of a law enforcement communication system and thereby point out the major functional capabilities that systems configured under Docket No. 18262 requirements must provide.

The experience of the last several decades indicates the naivete of stating that such-and-such a requirement cannot be satisfied because of technological limitations. A technical solution can eventually be provided to almost any technological problem. But these solutions may be long in coming, and they are inevitably expensive. The present problems faced by community, municipality and state governments demand near term solutions. It is insufficient merely to assert that such-and-such a capability "can be done" simply because it is technologically feasible. Whether or not it is realistically feasible, whether or not it is cost effective, whether or not the risks of development can be borne by the taxpayer, are all questions that demand clear-cut answers. Therefore, a study such as this must deal with the real world of that which is practical now, as well as in the future.

However, in the urgency of today's problems and the pressing needs for their solutions, we should recognize that 900 MHz represents the threshold of a new era in communication management. While principles and policies established in the coming months and years will be the precedents for decades to come, today's decisions must accommodate the near term needs of the public safety communications community as well as its long term goals.

As described in Chapter II, trunked systems represent a significant advance in technology. As of this writing a trunked system fully satisfying the needs of the public safety community has not been demonstrated. The FCC has, in Docket No. 18262, promulgated a policy intended to lead to the eventual use of trunked systems throughout the major portion of the 900 MHz spectrum. The law enforcement community, long awaiting the spectrum relief offered by the 900 MHz band, is now looking toward the development and demonstration of trunked systems that meet both the Commission's goal of increased spectrum efficiency and the community's needs for cost effective, increased operational capabilities.

Those responsible for the expenditure of local tax funds have specific responsibilities. Research and development, and the risks attendant thereon, are not normally parts of this responsibility. While the federal government can, and probably should, take such risks to advance the state of the art on a national basis, it is clearly not the role of the taxpayer of a local community to engage in the high risk and high cost research and development programs needed to develop theoretically possible but still unproven technical concepts. A local community, to solve its problems, must rely upon proven techniques and established concepts. The local community must look to the vendor to assume technological responsibility. The local community must define its requirements in terms of the technology that the vendor is willing to produce and guarantee.

Therefore, this study will evaluate the technologies and concepts of the 900 MHz band in light of those equipments currently offered by the vendor community, or those technologies that the vendor community asserts will be available in the near future.

3.2 FUNCTIONAL DESCRIPTION OF LAW ENFORCEMENT COMMUNICATION SYSTEMS

3.2.1 General

Public safety, and particularly law enforcement, communication systems have a common characteristic that distinguishes them from other services in the land mobile communication community. This characteristic is simply that they deal directly with the safety of the public. The agencies these systems support are directly responsible for the protection of the life and property of the citizen. In the performance of this responsibility the individual members of many of these agencies have as routine an element of risk to their personal safety seldom known to the rest of the land mobile communication community.

These systems, therefore, must have performance characteristics tailored with this consideration in mind. The safety and the protection of life and property bears with it a responsibility far beyond that of public convenience, entertainment, profit or mere economic efficiency. Since the risk element of, and the dangers to, members of the agency are unpredictable factors never precisely foreseeable far in advance, the system must be tailored to satisfy both normal and peak requirements on an instantaneous, 24-hour a day basis.

These considerations are not theoretical in nature. They have very practical aspects in the development of public safety communication systems design. While these systems must obtain maximum utilization of the limited spectrum, they must also maintain the required degree of performance at the least cost to the taxpayer. Above all, they must guarantee to those responsible for the agency's performance that the system will work as needed to fulfill that agency's responsibilities under all reasonably foreseeable conditions.

These systems must be cost efficient to operate in the routine mode, but they must also have the capability to handle peak loads in a highly effective, operationally efficient manner. They must satisfy local needs while also supporting regional and national systems requirements. They must be capable of expanding to meet growing community requirements while also able to operate at reduced levels under conditions of man-made or natural disasters.

The safety considerations and the operational procedures established by law enforcement agencies must be the basic criteria for design and planning decisions in the development of public safety communication networks. Channelization plans cannot be drawn solely on the basis of regulatory channel loading standards. Channel utilization, measured in terms of percentage of occupancy, is not the only criterion of the effectiveness of design.

While it is valid to consider loading standards as a measurement consideration when designing a routine dispatch network, the public safety system planner must always keep in mind the fact that life and property can be jeopardized by inadequate communication facilities. The efficiency of the public safety system is measured not by how many mobiles can be placed on a given number of channels, but rather how effectively the system supports the performance and safety of their personnel as they fulfill their responsibilities for the protection of the public.

The managers of law enforcement communication systems are responsible to the elected officials of the community. This responsibility cannot be delegated to a regulatory body. Nor should it be diluted by regulations or guidelines perpetrated for administrative convenience.

The following description of the general operational characteristics of typical municipal law enforcement agencies is provided to assist the reader in understanding the role that must be performed by a 900 MHz law enforcement communication system. For more detailed explanation, the reader is referred to the Bibliography.1/

3.2.2 Law Enforcement Agency Operational Philosophy

Any analysis of the suitability of a particular communication technique for a particular law enforcement function must be based upon an understanding of the role that the communication system must fulfill. The first step, therefore, in determining the operational suitability and the technical adequacy of the new 900 MHz band is to understand the way that law enforcement communication systems support law enforcement agencies' operational needs.

While a great portion of a law enforcement communication system's air time is spent in what appears to be "dispatch" type operations, it should be recognized that there are profound differences between law enforcement communication functions and those of other users of the land mobile spectrum.

1/ Police Telecommunication Systems, 1971. Product of Project Three, Phase Three of the Project Series Foundation of the Associated Public-Safety Communications Officers, Inc. prepared by ITT Research Institute under Grant No. NI 70-091 from the U.S. Department of Justice, LEAA-NILECJ.

The first and most obvious difference is the fact that protection of life and property of the public and of the individual police officer are dependent upon the speed and accuracy of the communication network. While these priority considerations might be difficult to relate to spectrum allocation concepts, they must nonetheless be kept in mind when evaluating the degree of compromise with which public safety communication users can view trade-offs between system performance and spectrum conservation.

The term "dispatcher" as applied to a law enforcement communication network may be an unfortunate misnomer. It may lead those not familiar with law enforcement operations to confuse the functioning of a law enforcement system with the more widely used and perhaps better understood "dispatch" systems found in other portions of the land mobile communication community. In a law enforcement radio system, the dispatcher is an extension of the command authority needed to supervise and coordinate the activities of the deployed forces on duty. As such, the dispatcher does far more than merely direct mobile units to specific locations.

There is an iterative communication process between the dispatcher and the patrol units. It is through the total provision of all available information to the patrol unit, in even the most routine case, that the patrol officer is able to properly plan his actions upon arrival at the scene of an incident. This prior preparation and employment of optimum techniques suitable to the situation are vital to the safety of the officer and the fulfillment of his responsibilities to the citizen.

A further requirement of this law enforcement network, imposed by the need for command/control type operation, is the capability for instantaneous substitution of the routine dispatch function by that of a supervisory level officer. As incidents increase in level of severity, the communication network ceases to resemble a dispatch type function and assumes a command/control nature. The communication network must make possible reliable, multiple communications between commanders and selected units in the field. The duty supervisor must have the ability to receive information deployed from units and to issue instructions to those selected.

Inherent in the functioning of a law enforcement patrol force is the concept of mutual support. Each officer keeps abreast of developments within his area of patrol responsibility by monitoring the dispatch channel. This is the primary means by which he learns of developing situations and can be prepared to render assistance to other officers in a minimum amount of time.

The patrol element is the cornerstone of most law enforcement agencies' functional procedures in the fulfillment of their responsibilities for the safety and welfare of the public. A patrol element is usually a one-man (sometimes two) vehicle assigned for a given period of time to patrol throughout a designated geographical section of the community. This geographical area may vary during different times of the day or different days of the week. The number of vehicles assigned to a given area may also be a variable, adjusted in accordance with operational and managerial decisions of supervisory officials.

The lifeline of this patrol officer is his communication link with the dispatcher. In the case of routine complaints, the dispatcher is advised of the need for service via a telephone call received by the telephone answering desk, or in some cases by the dispatcher himself. Information obtained during this telephone conversation (frequently from a disturbed or highly emotional citizen) is then relayed to the patrol vehicle most appropriate to respond to the complaint. Based upon the nature or the severity of the incident, more than one vehicle may be assigned to service the complaint.

In many of the larger systems much of the complexity of the dispatch function is assisted by computer storage and information processing. These systems not only improve resource allocation through optimum use of manpower; they also provide additional information to the officer, thereby contributing to his ability to effectively discharge his responsibilities.

In a routine case, the patrol officer receiving notification of the need for service makes judgments based upon the information received regarding the most appropriate manner for him to respond to the situation. The decision made at this time can greatly affect the safety of the citizen and the officer involved. Should an officer arrive at the scene of a disturbance unprepared to handle an armed criminal, his life may well be in jeopardy. On the other hand, over-reaction to a routine family disturbance can waste a community's resources and cause undue embarrassment to a normally law-abiding citizen.

Normal resource management requires a flow of information between the dispatcher and units in his patrol area. Status reports and updating, including such items as in or out of service, report on scene, assignment complete, etc. from each unit as appropriate, provide a continuing picture of the activities and resource situation throughout the patrol area needed to make necessary management decisions.

As a situation develops, instances occur that require an iterative series of transmissions between the dispatcher and the patrol vehicle in order to exchange necessary information. If the officer requires the assistance of additional vehicles to properly contain an incident, this information and any needed guidance regarding their disposition is relayed to the dispatcher. If an incident grows in scope, the communication link can then be switched to a watch officer, a senior supervisor on duty who is capable of providing incident management and higher level supervision.

Depending upon the procedures of the agency involved, communications between patrol units may be required to coordinate their responses to an event. Such flexibility of communication can be vital in providing rapid, coordinated support to units involved in critical situations.

While one major incident may be in progress and consuming significant portions of air time, the other routine agency activities throughout the rest of the community must continue to be supported. The routine dispatch channels in support of other requests for assistance must be unimpeded by the focus of attention on any one significant event.

Larger law enforcement agencies also have special squads providing ongoing services in support of special investigations and other law enforcement activities. Special squads for particular surveillance activities may be established.

Major public activities, i.e., parades or other gatherings, may require the organization, coordination and command/control of a specialized group of officers for limited periods of time. Mass demonstrations or public disturbances such as riots may occur requiring large concentrations of law enforcement activities, coordinated and managed from a single control unit. At times of a large public disturbance or wide area disaster, extensive coordination may be required among law enforcement agencies and between them and other public safety agencies. Experience has often shown the need for a separate command channel, open to the overall emergency activity supervisor and those subordinate unit commanders directly responsible to him. Availability of such a channel reduces confusion by insuring communications flow that follows the chain of command, thereby insuring the orderly dissemination of instructions.

The introduction of modern digital and computer techniques into the criminal justice system has provided a new and valuable tool for the routine processing of law enforcement complaints. Mobile and portable digital terminals in the hands of the individual patrol officer are now giving him the capability for direct access to state and national criminal history files. These wide-area information systems are rapidly becoming an inherent part of the operation of modern law enforcement agencies. The ability to check license plates and drivers' licenses against state files has become a major contribution to increased apprehension rates. Routine checks for stolen articles and vehicles in national files have contributed significantly to the recovery rates and apprehension of wanted criminals.

The above generalized description of law enforcement communication systems operation applies broadly to the majority of municipal law enforcement agencies. While the basic principles illustrated apply to all systems, there are many local variations in techniques. For example, some agencies may have incoming calls received by one complaint taker who, in turn, makes the initial dispatch of a patrol car to the incident and then relays control of the incident to a separate dispatcher to monitor activities in the patrol area. Other agencies may have individual dispatchers receiving calls for assistance and then dispatching the needed assistance. In larger systems, complaint calls are received by one individual (or one of a group of individuals designated to receive complaint calls) and appropriate information passed to a dispatcher who maintains radio contact with units in his assigned patrol area. But in any event, there must be one centralized point where knowledge of the activities within a designated patrol area is centered.

Law enforcement systems can have many additional operational requirements that affect the organization of the communication network. Depending upon geographic and political requirements of the agency, many factors affect the design of the system. Some agencies require mutual aid channels, area coordination channels, interagency coordinaation channels and various intra-organization links. These coordination links can often be provided by relays through a central communication center. This technique is prevalent in the larger municipal areas. Also, a number of agencies have a need for interagency communications between the mobile units of many separate activities. In suburban and county type agencies, each car needs not only to communicate with its central dispatch and control points but frequently must also have facilities for car-to-car communications with such agencies as highway patrol, fire, and other public safety activities.

This functional description is intentionally sparce. Its purpose is to give the reader a basic understanding of the nature of law enforcement communication networks. It is intended to show some of the special characteristics of these networks and how their functional characteristics differ from a typical business or industrial land mobile communication system. Public safety systems are not purely dispatch systems wherein a central office broadcasts general information of interest to any one or to all recipients. They are complex command/control systems, providing for the inter-relationship of diverse emergency-oriented activities throughout the community. The efficiencies of these systems are not measured only in terms of dollars or by some standard of channel loading. The efficiencies of these systems are measured in the lives saved and the number of criminals apprehended.

3.2.3 Minimum Functional Needs

Law enforcement systems have certain minimum functional requirements in common. They are:

a) Certainty of communication.

This concept includes requirements for total coverage of the designated area of responsibility, reliability of equipment, intelligibility, and immediacy. The role of the law enforcement communication system in the preservation of life and property and the apprehension of criminals places high emphasis on these characteristics of the system.

b) Multiple user monitoring capabilities.

The operational procedures of most agencies require that all designated units in a given area monitor designated communications within that area at all times. This is necessary to assure informed, flexible, mutual support when needed.

c) Discrete, sub-unit channels.

Various designated groups and/or activities require communications independent of the basic dispatch channel. Special squads, such as detective, narcotics, etc., or special events such as riots or crowd control, require individualized communications, controllable from a field and/or central point, simultaneous to but not interfering with the routine dispatch systems.

d) Interagency coordination capabilities.

Mutual aid requirements between adjacent agencies, and coordination and cooperation needs among different law enforcement networks and between related public safety agencies, demand often complex and flexibile interagency communications interfaces.

This summary is not intended to be a comprehensive list of system requirements. Ideas such as cost effectiveness, reliability, maintainability and operability certainly are important. Many different agencies with different spans of responsibility will have other vital needs. It does represent, however, the fundamentsl, irreducible minimum requirements that any regulatory scheme or technological capability must accommodate.

3.3 TECHNOLOGICAL APPLICABILITY

3.3.1 General

This Section discusses the technical capabilities of the 900 MHz spectrum as they relate to public safety communication systems needs. It deals with inherent 900 MHz phenomena as applied to public safety needs. For the sake of clarity, the analyses of this Section are limited to conventional type systems. For those considerations peculiar to trunked technologies, see Section 3.4 below.

3.3.2 Relationship of Propagation Phenomena to Law Enforcement Requirements

The propagation phenomena associated with the 900 MHz spectrum described in Chapter II indicates several characteristics of significant importance to the public safety law enforcement community. The most obvious of these are path loss calculations, scattering phenomena, and noise characteristics.

3.3.2.1 Path Loss Considerations

Propagation calculations show that a "normal" 900 MHz system design, involving usual or readily obtainable mobile and base station powers, antennae heights and gains (and FCC limitations), in an environment where electromagnetic pollution has not been permitted to develop, results in an urban coverage radius of 15 to 25 miles. These figures indicate that the 900 MHz band might be quite suitable for typically urban and, in many cases, suburban systems.

On the other hand, "normal" VHF high band systems using similar standard or readily available components can be expected to provide coverages with radii in the order of 50 miles. Therefore, the VHF high band can usually be expected (other considerations not dominant) to provide more economic systems for rural or wide area coverage, such as statewide or countywide systems. It must be emphasized, however, that this is not a hard and fast rule but rather a broad generality. There are many other variables that can affect specific systems designs. Spectrum availability, interagency coordination concepts, topographical factors, are just a few of the considerations that must be evaluated to determine the optimum frequency band to be used in a specific application.

A variable, of yet incompletely defined operational effect, is the susceptibility of the 900 MHz frequencies to foliage attenuation. Various studies have discussed this phenomenon but no known analysis has yielded definitive data regarding its impact on urban operational systems. In regions with heavy foliage, coverage has been found to vary with seasons as trees shed or grow their leaves. In the typical urban environment this phenomenon can be expected to have little impact. However, foliated areas such as parks, located near the extremities of the area of coverage, may well require more than the usual levels of signal strength to assure reliable communication at all times.

3.3.2.2 Scattering Effects

One of the most important phenomena associated with 900 MHz that affects its applicability to public safety systems is the scattering effect demonstrated by these shorter wavelengths. Theoretical considerations and experience to date have shown that the short wavelengths of 900 MHz radiation are randomly reflected by man-made structures normally found in a typical urban environment. This scattering has the beneficial effect of filling in "holes" or dead spots that often exist in large metropolitan areas when using lower frequency systems. These holes can cause serious coverage problems at the lower bands.

The end product of this phenomenon is an as yet imperfectly defined propagation characteristic. No formal propagation model fully accounting for these effects is known. Experience to date indicates that coverage throughout a given area can be significantly better than the theoretical projections using classical propagation analysis. While the coverage radius of a 900 MHz system may be somewhat less for a fixed amount of power than that of the lower bands, the probability of coverage throughout the total area of interest may, in fact, be greater.

A corollary of this phenomenon is that 900 MHz signals also appear to give improved penetration within man-made structures. Evidence to date and results described in Chapter II indicate that communications within and through buildings, tunnels, etc., may, in fact, be better than that possible with the lower bands. These two phenomena suggest that 900 MHz radiation may have characteristics particularly suitable for the public safety communications in more densely populated urban areas.

3.3.2.3 Noise Immunity

Theoretical calculations and observed physical measurements indicate that the level of ambient noise existent in the 900 MHz portion of the spectrum is normally negligible. Noise caused by thunderstorms, solar temperatures, and other natural phenomena does not affect system performance at these high frequencies. Man-made noise such as ignition, neon signs, electrical motors, etc., has also less noticeable effect at 900 MHz. As a result, in densely populated urban areas in which the ambient noise level constitutes a major consideration of system design at lower frequencies, 900 MHz can enjoy a measurable systematic advantage in that full benefit can be taken of the sensitivity and low noise figures possible in modern receiver designs.

3.3.2.4 Foliage Effects

There are two characteristics of the 900 MHz spectrum that may cause operational difficulties. As stated, the shorter wavelengths of 900 MHz are susceptible to attenuation by foliage. Studies by the Department of Defense have shown such attenuation can be significant while at the same time difficult to predict. Credible engineering answers regarding the extent of this problem in a typical urban environment have not been developed. Systems are now being installed, and the measurement of the operational characteristics experienced can provide the basis for future systems design calculations.

3.3.2.5 Picket Fencing Effects

Another phenomenon associated with these shorter wavelengths is the characteristic called "picket fencing". The reflection of these shorter wavelengths from terrain and structures causes random reinforcement and cancellation of signals arriving at the receiving antenna. This results in areas of greater than expected signal strength followed by severe signal loss only several wavelengths away. To the system user passing through such a field of coverage in a vehicle, these rapidly fading and reinforced signals may pose difficult problems of intelligibility.

This "picket fencing" phenomenon is particularly pronounced at the outer reaches of coverage. Researchers have indicated holes in which signal strength may vary as much as 30 db from the projected mean path loss. As of this time no reports have been developed detailing the effects of this phenomenon on the day-to-day operations of a public safety communication system.

There appear to be several solutions to this problem. The first would be to define the operational area of coverage somewhere within a radius in which the phenomenon did not cause significant performance degradation. Another approach would be to significantly over-design the system power level for the radius of coverage needed and thereby "brute force" the coverage to maintain a level of signal sufficient for receiver limiting at all times. (This approach is seldom satisfactory.) A third solution might be to provide fill-in repeater systems. A fourth possibility is to incorporate significant advances in the sophistication of receiver design.

These problems do not appear to be unsolvable. They are merely engineering difficulties to be overcome in any given system design.

3.3.3 Operational Suitability

Improved building penetration and fill-in resulting from 900 MHz scatter effects suggests that these frequencies have a potential for an improved level of service in urban areas. The increase in the probability that communications will be maintained with agency personnel throughout the assigned area can contribute to the safety and effectiveness of the law enforcement officer.

As this report shows, however, there may be gaps, or holes, in coverage due to propagation anomalies. The absence of documented operational experience with these frequencies makes it difficult to fully evaluate the impact of such gaps. Experience with lower frequency UHF systems indicate that coverage problems resulting from such gaps can often be minimized by operational procedures.

Once practical experience has been obtained using operational systems, it is reasonable to expect that empirical engineering data will be acquired that will permit system design techniques that will reduce the effects of such gaps to acceptable levels.

3.3.4 Cost Unknowns

As to be expected of a developing technology, 900 MHz system costs can not be projected with a high degree of accuracy until considerable experience has been acquired by both the vendor and the user communities. However, general cost projections are now possible. At the current state of the art, and as described in Chapter II, prices for conventional 900 MHz equipment are somewhat higher (about 10% to 20%) than for lower bands.

These cost projections are based upon individual elements of hardware. They do not incorporate all the ramifications of overall system design. Until such time as more system experience has been obtained, calculations as to the numbers and locations of remote receivers and repeater equipments must be based upon estimates. Depending upon the experiences gained in evaluating "picket fencing" and foliage losses, there may be a need for a greater number of repeater and satellite receiver installations than those experienced in similar lower frequency systems. This problem may be particularly significant when personal portable system configurations are considered. (See Section 3.3.6)

3.3.5 Considerations for Site Selection

Antenna locations and heights of fixed stations are important in 900 MHz system design. The loss characteristics of transmission lines at those frequencies make it necessary to locate transmitters and receivers reasonably close to their antennae. While the cost of low loss transmission line is somewhat greater than more conventional line, it is still within the normal budgetary constraints of public safety communication systems. Site selection must be done with care and cable runs kept as short as practical. However, there are no inherent technical characteristics at these frequencies that differ greatly from those experienced in the 450 MHz band.

3.3.6 Considerations for Conventional Personal Portable System Design

The introduction of personal portable radios in law enforcement communication systems is a major trend of the future. More and more of the metropolitan agencies are using this concept to provide continuous communications with the patrol officer. This system configuration, however, requires special attention for the 900 MHz system designer.

Present personal portable system design is based upon a network of satellite receivers sited throughout the area of interest, connected to the command center by either dedicated telephone lines or microwave systems: Low power personal portable transceivers can receive messages from either a high-powered central transmitter or through remote repeater transmitters. However, the limitations on the amount of energy a portable battery can store, and the need to have the unit operable throughout an 8-hour shift, limit the portable's output power to usually between 1 and 5 w. Reliable coverage is provided by the relatively large number of satellite receivers. The portability of the unit itself demands that it be light weight and that the antenna be as small and nondirective (therefore with relatively low gain) as possible.

The present state of the art of receiver design, coupled with the low ambient noise of the 900 MHz region, indicates that overall system performance at 900 MHz will be comparable to that achieved in the 450 MHz region. The potentially greater efficiency of the small, higher frequency antenna, and the likelihood of more effective ground plane provided by the portable unit itself and the body of the user, appear to approximately compensate for any overall path loss deficiencies.

Another consideration in portable system design is the DC to RF conversion efficiency, i.e., the efficiency with which the power amplifier in the portable converts battery power to 900 MHz RF energy. At the present state of the art, the conversion efficiency of the final amplifier is only slightly less than that experienced at 450 MHz. An additional stage of multiplication is currently used to provide the higher frequency excitation to the amplifier stage. This means that it takes a greater amount of battery energy to generate the same amount of RF output power.

These considerations indicate that no significant, fundamental problems confront the designer of conventional personal portable systems at 900 MHz. The number of satellite receivers may have to be increased in some cases. If the power output is to remain the same as at lower bands, there may be a need to improve battery life or reduce battery bulk and weight through the use of more advanced battery techniques. Future portable systems might also provide for recharging facilities during the patrol shift.

The cost and system design implications of these factors cannot be determined with precision until such time as specific personal portable unit characteristics are identified by the vendor community. However, there appears to be no technical reason why conventional 900 MHz portable units that satisfy the public safety market's needs cannot be developed, once the user demand justifies their development costs.

3.4 OPERATIONAL APPLICABILITY OF TRUNKED SYSTEMS

3.4.1 General

In view of the rate of development of modern technology, it is not a very productive exercise to question whether this or that law enforcement communication system requirement can or can not be satisfied by trunked technology. There is no inherent characteristic of the trunking concept that makes it theoretically unsuitable for the law enforcement need -- given the right assumptions.

There are, however, such real world questions to be answered as: what benefits accrue to the using agency from the use of trunked technology? What benefits accrue to the community as a whole? What costs are involved? What technological and procurement risks exist? What management problems are involved?

Perhaps the most important question is: Will these unresolved questions delay solutions to the urgent, present day problems? Will a debate over trunked systems and their operational applicability, their costs and status of development, only obscure the need for immediate solutions to immediate problems? We should take all possible steps to assure that this does not happen.

The following discussion addresses these questions in light of system operational needs, current levels of technology, budgetary limitations, and existing political and managerial concepts.

3.4.2 Trunking for Spectrum Efficiency

The reason stated by the FCC for the application of trunked systems to large scale systems (over five channels) is the degree of improved spectrum utilization (efficiency) that may be expected. The spectrum, when viewed in its entirety, must be carefully managed if all the evergrowing, competing demands placed upon it are to be accommodated. Without careful management, vital services and valuable public needs may be constrained or unfulfilled because of crowded spectrum conditions on some frequencies while others remain unused.

This can be true of the entire spectrum -- not just one part. Unused TV channels for example, are as much in need of modernized spectrum management techniques as are overcrowded land mobile radio channels.

In the world of present day spectrum management, the objective of "increased spectrum efficiency" means making more spectrum available to more users, within a given geographic area, at some defined level of service. At the present time, for want of a better standard, "level of service" in the land mobile radio service translates into channel loading which is currently measured by numbers of mobiles assigned to each channel. Chapter I of this study describes present Commission standards of loading in terms of mobile and portable units per channel at 900 MHz. These standards vary from service to service. They differ depending upon whether the system is operated in the conventional or trunked mode.

Under the Commission's present rules, the decision of a public safety agency to operate in a conventional mode or in a trunked mode has only limited effect on the availability of spectrum for other users. It affects primarily the level of service experienced by that agency.

By way of illustration, assume that a municipal law enforcement agency has 300 mobile units. Under existing loading standards (in public safety, the standard is 50 mobile units per channel for a conventional system), that agency could apply for six channels (assuming the Commission would allow six conventional channels for the sake of discussion). Once these six channels are assigned, the total remaining 900 MHz land mobile allocation (including reserve) of 594 channels are available for eventual assignment to other authorized users within the same area of coverage. Should the agency be permitted to operate these channels in a conventional mode, it would enjoy one level of service. Should funds be available (and technology permit) for the agency to operate a trunked mode, a level of service attendant therewith would be attained. But since the loading standard established by the Commission for trunked systems is 60 units per channel, the number of channels required would be six: five for the mobiles plus one channel for control of the trunked system. There would still be only 594 channels available for use by the rest of the land mobile community. The decision, therefore, might affect the level of service attained, but would have little effect upon the amount of spectrum left for use by others.

We should not be misled by the fallacy of measuring public safety communication system channel requirements by some relatively arbitrary standard of "mobiles per channel". While this term may have some use in configuring a heavily populated "dispatch" channel, it takes little account of the functional needs for interagency communication channels, special forces channels, and other complex, operationally based system design needs. (See Section 3.2.)

The discussion supports two very useful observations. The first observation is that trunked techniques yield little improvement in spectrum efficiency unless they are applied to relatively large systems. As the above discussion shows, no meaningful increase in available spectrum results from trunking a 300 unit system. A similar example applied to a system supporting 1200 mobile units would yield seven channels for use by others when configured in a trunked mode rather than in a conventional mode.1/

A second conclusion is that the degree of improved spectrum efficiency to be expected from trunking is related to the number of mobile units that can be accommodated on each channel, at a given level of service, when the system is operated in a trunked rather than a conventional mode. While estimates of this figure can be made, no firm figures will be available until evaluation of an operational system has been made. (See Section 2.4.)

3.4.3 Trunking for System Capabilities

3.4.3.1 Trunked System Capabilities

The arguments pro and con regarding the potential for spectrum efficiency inherent in the trunked system concepts should not obscure the other potential benefits of this idea. It is, perhaps, easier to understand these potential benefits if the system is viewed more as a "controlled" system rather than as a "trunked" system.

The existence of a continuously operating control channel, directing specifically addressed (with such unit addresses changeable at will) units of a system to any available frequency offers opportunities for greatly enhancing a communication system's effectiveness. By carefully matching the system's organization to the needs of the user, unique opportunities for increased operational flexibility, improved reliability, and a significantly increased level of service are presented. The following is but a partial list of the kinds of functions that can be performed by a trunked system.

a) Flexible organizational response. The ability to address individual units or groups of units within the system is inherent in the trunked system concept. This ability permits the configuration of groups of mobile units, each monitoring all communications between that group and its control point, but independent of the other groups in the system. If a given patrol area is identified by a

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1/ Present standards call for channel loadings of 75 mobiles per channel in systems using over ten channels. 1200 units would require 24 conventional channels or 16 trunked channels plus one control channel in a trunked system. The channel saving theoretically possible, therefore, is 24 less 17, or 7 channels.

particular group address, then all the units in that patrol area could monitor all communication in that area, but not other areas. However, should a unit need to be reassigned to another area, it would only need to switch its group address to that of the other area. For special or tactical type communications, the mobile unit need only switch its address to a tactical group code and then be in contact with those units participating in that tactical group net at that time.

b) Priority designations. The address format can contain priority identifications permitting designated groups to seize access to RF channels regardless of their use by other, lower priority users. This feature can include several levels of priority to include an emergency alarm.

c) Automatic ID and status information. Each unit control channel response can include status and ID information needed to interface with Computer Aided Dispatch systems.

d) Improved system privacy. The automatic frequency changing that occurs with each message increases the level of system privacy. While total system security (secure techniques can also be incorporated) would not result, the nature of the frequency changing makes monitoring by casual observers difficult.

e) Selectable "lockout". At the discretion of the system controller, unwanted units or groups can be "locked out" of the system. For instance, a stolen unit could be permanently locked out. Should an emergency create an unusual communication requirement by one or more groups, less essential groups can be "locked out" of the system to minimize channel loading by those groups not involved in the emergency.

f) High reliability. Loss of a single channel only raises the occupancy level of the remaining channels. As such, the probability of increased waiting times may increase but the system continues to operate otherwise normally. Under normal conditions, the system users would probably not be aware of the outage. The need for maintenance could be made known by automatic alarms, lights, printouts, or other selected means.

g) Management information availability. The nature of the system control mechanism provides a readily available source of needed management data. Printouts describing the individual channel usage could provide system users with data describing the number of calls vs. the time of day, total system loads, number of calls per channel, and similar items useful in making management analysis of systems performance. This feature is of particular value during the test and evaluation phase of systems implementation as it can provide factual data on channel occupancy vs. channel loading, amount of waiting time vs. number of channels available, peak loading factors, and similar data needed for the design of future systems.

h) System adaptability. All mobile units of a system can possess the capability of participating in all activities of the system, simply by changing their address codes to that of other groups. For instance, maintenance vehicles included in the system might have their own group address. As such, their communications would be between members of their maintenance group. However, should the need arise, the central system controller would add their group address to those involved in handling an emergency so that the maintenance vehicles could provide an additional resource for use in response to an emergency.

i) Orderly growth capability. A trunked system lends itself to an orderly growth process. As system requirements increase, additional system control capacity and needed additional fixed site capability can be added without outmoding existing equipment. The inherent design of the frequency selection process in the mobile units could permit any frequency in the designated section of the spectrum to be selectable on command. This capability makes possible the development of a total public safety or local government service communication system, having each element operating within its own group and unaffected by the participation of other groups. Such an approach would distribute the channel occupancy peaks between the busy times of the various users while preserving the priority status of the emergency services through priority designation and the optional, selectable lock-out features of Items b) and e) above.

These operational possibilities, and others that may be developed as the result of operational experience, are not without cost. Following are several of the more dominant factors that must be evaluated in making a decision regarding the suitability of trunked technologies for a given community:

1) Single site coverage. The complex frequency selection process inherent in trunked systems limits presently practical system configuration to a single fixed transmitter site. The needed control and switching complexity that would be necessary to permit remote repeater type operation would raise the system complexity and cost to a level not now considered realistic. "Simulcasting" or simultaneous broadcasting by two or more transmitters is a possibility; however, the degree of transmitter frequency and audio control necessary has not yet been demonstrated at 900 MHz in a practical public safety system. While such precision is within the scope of development, at the present time practical application of trunked systems appears to be limited to those localities that can be covered from a single fixed transmitter site.

   It should be noted that this limitation does not apply to satellite receiver systems. These can be remotely located just as with conventional systems, and the audio resulting from a voting process relayed to the fixed site via microwave or land lines in a normal manner.

2) Developmental risk. No operating public safety trunked systems have been demonstrated as of this time. While the individual components of this technology have all been in hand for some time, i.e., frequency selection systems and digitally controlled systems, no system incorporating all these elements has been built as of late 1977. Therefore, until an operational system has been installed and tested in the practical world, there exists a finite level of risk in building the first one. This degree of risk is difficult for an individual public safety agency, or even a local unit of government, to assume.

3) Costs. While the inherent operational capabilities of trunked systems make price comparisons with "like type" conventional systems difficult, they are likely to be somewhat more expensive. A "bare bones", five channel trunked system might not cost any more than a conventional system of like capacity, i.e., a six or seven channel system. However, a "bare bones" trunked system does not appear capable of satisfying the public safety users needs. Nor does it seem, in light of the greatly enhanced capabilities of a somewhat more sophisticated system, to be a particularly cost effective choice.

Relative system costs are difficult to establish since they are highly sensitive to factors such as numbers of mobiles, site preparation costs, numbers of channels, and other considerations. Such cost estimates are made even more tenuous due to the lack of actual experience. However, gross estimates available at this time indicate that trunked systems might cost about 1¼ times to a maximum of 2 times as much as a conventional system, the amount of difference being a function of the degree of sophistication and capability required.

4) Lack of portable equipment. Just as 900 MHz conventional portable equipment is not available, no trunked portable equipment is on the market. The development of such trunked equipment is sure to be more difficult than the development of conventional equipment. Logic circuits must be configured to fit in the portable package with power drains that are compatible with existing battery life requirements. While such developments are foreseeable, it can be assumed that a large market will have to exist before the vendors can be expected to venture the development costs necessary. This is certainly several years in the future. Therefore, early trunked systems can be expected to operate in a mobile only mode initially.

5) Inter-system incompatibility. There are a number of trunked system concepts now being proposed. It can be expected that units for one vendor's system will not be compatible with another vendor's system. As a result, vehicle to vehicle compatibility between different systems is not likely. Such communications will require point to point links between the system's fixed control or dispatch locations or the ability of elements of the system to operate in a conventional mode when so required.

From the above summary of trunked system considerations, both positive and negative, it can be seen that these systems can, in fact, satisfy the public safety users needs if they are carefully configured to meet these needs. There are certain elements of technological risk to be faced. But this has been true of every advance in communication systems capability. In some ways the risk associated with trunked system implementation is no greater than that already taken in moving from the VHF high band to UHF, or in implementing computer-aided dispatch systems, integrated data networks, or other sophisticated technological tools. It also appears that system costs may be somewhat greater, at least initially. However, considering the greatly enhanced capabilities possible, and also the possibility of the eventual consolidation of numerous municipal systems into consolidated, flexible, mutually supporting systems, long term costs may eventually be less.

3.4.4 Trunked System Applications

The heterogenous nature of their public service activities is characteristic of most communities. Highway maintenance can be a function of state government; emergency medical services can be provided by private hospitals, individual entrepreneurs, or community government; fire services can be provided by volunteer groups or local governments.

This mix of services and political responsibilities is due to the varied political and sociological structure of the nation's communities and municipalities. They can and do use large numbers of frequencies in support of specific functional requirements.

In such cases the concept of trunking may offer significant improvement in spectrum utilization, in addition to increased operational flexibility. One can conceive of an entrepreneur or governmental agency providing a single centralized trunked system which serves several agencies of more than only one political entity as customers (or in trunking terminology, groups). Should trunked repeater or simulcast systems become practical, one can also conceive of a significant improvement in spectrum utilization by combining such resource demands throughout a geographical region of independent communities. Analysis of the minimum numbers of units and/or agencies needed to be combined to justify the capital outlay required for trunked systems would have to be conducted. Such a study, of course, would include considerations of equipment cost, equipment availability, terrain, geography, and political relationships, in addition to the primary consideration of functional needs.

If such a concept were to be pursued, it seems reasonable to believe that the managerial and system planning problems attendant thereon would be as great if not greater than the technological problems that must be overcome. Research has indicated that the technology for a trunked system is proceeding apace. The organization, planning and cooperation necessary to develop and provide support of such a system throughout complex political and bureaucratic divisions would pose a procedural challenge of significant dimensions.

The large numbers of mobile and portable units presently involved in the law enforcement communication systems of the major metropolitan areas might seem to make them likely candidates for the early implementation of trunked systems. The problem of obtaining the economies of scale are quickly solved in such systems. However, the question of operational suitability is not so easily laid to rest.

Channel loadings on presently used dispatch channels in the major metropolitan areas are already so great that they offer little hope for significantly increased operational efficiency through trunking of one agency's system. (New York City Police Department's channel loading standard is 150 mobile units per dispatch channel; Chicago's is 100 mobile units per dispatch channel.) Making a channel from Area A available to units in Area B offers little hope for improved communications if Area A and Area B channels are both fully loaded practically 100% of the time or at least at the same time.

As theoretical studies discussed in Chapter II show, little improvement can be expected from a trunked system when all the available channels assigned to that system are fully loaded. The opportunity presented by the trunking concept is that enough channels can be made available to relieve this dense channel loading by combining channels currently assigned to other municipal agencies whose utilization is not as great. Such an approach takes advantage of trunking's ability to "level out" the load.

Technological, operational and economic constraints prevent many of the major urban areas from moving their public safety communications to the 900 MHz band in the immediate future. However, the same constraints are not affecting the other eligible users of this band.

The very population density of these urban areas that creates the need for large public safety requirements also generates the greater number of non-public safety users of this spectrum. In the absence of block allocations to assure the public safety users the availability of channels when needed, serious consideration must be given to the possibility that sufficient channels will not be available when circumstances permit public safety agencies in the major metropolitan areas to move to the 900 MHz band. Should this prove true, then the same high level of individual channel loading can be expected, with the resulting lack of improvement in level of service, whether the system is trunked or conventional.

3.5 SPECTRUM MANAGEMENT CONSIDERATIONS

3.5.1 General

The concept of spectrum management used by those responsible for the management of this valuable resource determines level of "spectrum efficiency" that will be attained. Advances in technology notwithstanding, the management concepts used will determine the extent to which the spectrum will be available to satisfy the public's needs, interests, convenience, or necessity.

The introduction of Docket No. 18262 revolutionized the spectrum management concepts that the Federal Communications Commission has followed for the past four decades. Recognizing some of the inherent inconsistencies and inefficiencies in the block allocation concept, the FCC launched a new and innovative approach to the assignment of frequencies in the 900 MHz band. It allocated 100 channels on a nationwide basis for use by conventional systems, 200 channels for trunked systems, and held 300 channels in reserve. Section 3.5.2 of this Report will treat these spectrum management policies and their effects upon the law enforcement community.

3.5.2 Conventional System Spectrum Management

Having dispensed with the concept of block allocations, the Commission announced, in its Second Report and Order in Docket No. 18262, that frequencies in the 900 MHz band would be assigned to applicants on a first come, first served basis and that each channel would be loaded in accordance with Commission standards based upon numbers of mobile units per channel. (For detailed discussion see Chapter I.) The Commission, in its early public announcements regarding spectrum management at 900 MHz, said that no further use would be made of service-oriented coordinating committees and that their services would not be required, since the selection of frequencies would be done by the Commission.

Full utilization of the 900 MHz spectrum's potential is more demanding of careful spectrum management than any other segment available to the land mobile community. Full use of the low noise, sensitive receiver front ends that makes possible the needed range of communication is dependent upon preservation of a low noise environment in the vicinity of the receiver antenna. This requires that conscious efforts be made to prevent electromagnetic pollution of potential antenna locations. Careful selection of frequencies, based upon intermodulation calculations, is necessary at each common installation site. Adequate consideration of such important engineering needs are not likely to result from a mechanistic frequency assignment process.

The Commission, the Land Mobile Communication Council (LMCC), and APCO subsequently acted to clarify and refine these policies and make them more responsive to the spectrum management needs of the land mobile communications community. As a result, the Commission re-visited the subject of spectrum management at 900 MHz. Subsequent "clarifications"1/ and other pronouncements by the Commission have indicated that the Commission intends to assure that these channel assignments will be made on a non-mechanical, reasonable basis.

In April, 1977, the Commission published Docket No. 21229 soliciting

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1/ Clarification of New Policies and Practices Governing the Assignment and Licensing of 'Conventional' Systems of Communication at 900 MHz. FCC, November 24, 1976.

comments to assist it in arriving at a spectrum management philosophy that will satisfy the needs of the land mobile communications community and at the same time ensure proper protection of the public's vested interest in spectrum efficiency. In pursuit of solutions to these problems, the Commission has shown a growing sophistication in its understanding of the complexities of frequency allocations in the public safety sector. While the ultimate results of these deliberations cannot be projected at this time, every evidence indicates that the Commission is leaning toward again relying upon service-oriented frequency coordinators to assist in the complex task of relating frequency assignments to user needs.

Concurrent with the Commission's development of growing awareness of the complexities of spectrum management in the field of public safety has been its recognition of a major increase in planning sophistication resulting from the stimulus provided by the LEAA. APCO's Projects 13 and 13-A have developed planning guidelines for the development of long-range plans that can result in integrated, mutually supporting, compatible public safety systems. The complexity of public safety communications and the need for integrated activities and operational coordination has mandated a modern, management-oriented approach to communication system design. States are now developing goal-oriented statewide plans in response to these guidelines. The objective of these plans is to stimulate development of systems that match the growing technology and management needs of the public safety agencies at all levels on a statewide basis. These plans are not only intended to recognize the particular needs of individual communities but also to accommodate the mutual support responsibilities of agencies throughout a State.

In addition to these operational needs for coordination, these plans are being developed with the objective of optimizing spectrum utilization. They are further intended to insure compatibility of equipment between related agencies. They have as objectives the assurance that individual agencies throughout the various political jurisdictions will evolve their systems in a manner that satisfies the needs of those agencies and their political jurisdictions in a manner compatible with the ultimate evolutionary goals of the statewide system. The intent of these plans is to assist the individual systems to grow so as to be mutually supportive of other systems, rather than in conflict with them.

Spectrum efficiency is only one, albeit vital, consideration in the development of these plans. They are not written by the FCC, nor are they prepared only in response to its needs. They are prepared by individuals responsible to the community's taxpayers and responsive to the needs of these taxpayers. These plans are by necessity of long-term implementation. In addition to spectrum management and operational needs, they also respond to legal mandates established by the legislative leaders of the individual communities and other statutory requirements often beyond the perogatives of federal agencies or, in some instances, even the state government.

It is important that the Commission's regulatory decisions and procedures take notice of these plans. It is also important that the Commission be assured that reasonable consideration has been given in the development of these planned systems to the needs of spectrum efficiency. By mutual cooperation of the LEAA and the FCC, steps are now being taken to satisfy these needs.

The 900 MHz portion may be the last frontier of the land mobile community. There does not appear to be any remaining, as yet untapped, portion of the spectrum that has the propagation characteristics needed to accommodate land mobile communication needs. It is vital, therefore, that the spectrum management concepts employed possess the means to accommodate both present and future requirements of the public safety users within this portion of the spectrum.

A major objective of the public safety community, particularly at 900 MHz, is formal recognition by the Commission that arbitrary, mechanistic approaches to spectrum management cannot satisfy the complex and highly integrated requirements for long-range planning and modern operations in public safety communications. Once this is recognized, then the next step is to develop those new mechanisms and resources needed to assure orderly implementation of future planned systems.

3.5.3 Trunked System Spectrum Management

The current regulatory environment of trunked systems in the land mobile radio service is sparse, since hardware is not available and experience is, therefore, nil.

Regardless, two policies directly affect trunked systems in the Commission's present 900 MHz rules. The first reserves 200 of the 300 channels presently available for assignment to trunked systems. The second requires that any 900 MHz system requiring assignment of more than five channels be trunked.

The first of these policies has little immediate impact in view of the 100 channels available for assignment to conventional systems. It does give notice, however, of the Commission's determination to promote the trunked systems concept. This poses a problem to the development of long-range plans by large municipalities. In the major population centers there is concern by law enforcement agencies that the few (100) conventional channels provided will be quickly occupied by the more fiscally flexible, profit-oriented elements of the land mobile communication community before the future public safety communication needs for conventional channels can be planned and implemented.

This problem is particularly troublesome in light of the possibly questionable applicability of trunked system technology to many public safety communication requirements. In view of the present status of trunked system development, and in view of the cost benefit considerations discussed in Section 3.4, current long-range planning must rely on the assumption that conventional channels will be available in sufficient numbers to satisfy the communities' needs until such time in the future as cost effective trunked systems are developed. Since 100 conventional channels seem unlikely to be sufficient for the needs of the other land mobile users in many densely populated locations during the next decade, public safety users must rely upon eventual access to conventional channels in the reserve pool at such time as their needs are adequately demonstrated.

The mandatory requirement for trunking of those systems needing more than five channels has a present, chilling effect. Those agencies, long strapped for necessary communication support, now find themselves in a "Catch-22" situation. Pressing needs spring from growing populations demanding larger and more effective communication systems. Lack of adequate spectrum in the lower bands has prevented the needed expansion of existing systems. Now that added spectrum has been made available at 900 MHz for multichannel, high performance systems, the Commission has nevertheless mandated use of trunked techniques in those systems that require capabilities for such performance (more than 5 channels). But trunked technology is not available today, and the expected costs, possible operational complexity, and technological risks make it appear to be an unattractive solution until an operational system has been successfully demonstrated.

A further problem associated with the mandatory requirement for trunking of more than five channels is the inhibition it places on the rational growth of systems. A 5-channel system has a practical limit on expansion, for if it should have to grow to more than five channels, existing equipment might have to be replaced with trunked equipment. Such a policy, if stringently enforced, would make the 900 MHz spectrum of little use to medium-sized law enforcement agencies (300 or so vehicles) in the solution of their present day problems.

3.6 SPECIALIZED MANAGEMENT APPROACHES

3.6.1 Management of Conventional Systems

Technical considerations associated with implementation of conventional type 900 MHz public safety systems present no management problems significantly different from those presented by lower frequency systems. The addition of still one more band using equipment that cannot cover lower band frequencies further complicates the existing interagency coordination problem. This is a situation long experienced at lower frequencies. The problem is not different; only its scale has changed.

The frequency assignment policies now being followed by the FCC may require the development of new management relationships among channel-sharing agencies. Under present policy, agencies having fewer than the number of mobile units necessary to fully load a channel may be required to share that channel with other agencies. Such sharing can present special management problems that must be solved to assure compatible operation on a non-interfering basis. Some agencies are now using these techniques on the VHF and UHF bands as tools to improve coordination and to reduce costs. Consolidated and cooperative dispatch centers are becoming more prevalent.

For many valid reasons there has been little use by public safety agencies of "community repeater" type service provided by vendors or entrepreneurs. While many of the consolidated and/or cooperative dispatch organizations have features similar to the community repeater type of operation, management and control is vested in tax-supported agencies. The reasons for this include: responsibility to elected officials; compliance with legal requirements; reliability of service; and standardization of procedures, just to name a few.

3.6.2 Management of Trunked Systems

The nature of trunked systems is such to require large capital investment. The hoped-for spectrum efficiencies can only be obtained by systems employing many hundreds of mobile and portable units. There is only a relatively small number of public safety agencies of such large dimensions.

The FCC recognized this relationship between spectrum efficiency and the size of a trunked system in its Docket No. 18262 proceedings and established the Special Mobile Radio System (SMRS) concept described in Chapters I and II. Such a concept could make possible the implementation of single, large, trunked systems that provide base station facilities for groups of licensable agencies. By serving the needs of many using agencies through a single base station system, the needed economies of scale may be attainable. Through such integration of users the possibilities of increased spectrum efficiency are enhanced. However, the immediate application may be limited by the necessity of single transmitter sites. (See Section 3.4.3.1, Page 3.15.)

The nature of a trunked system, with its continuously operating control channel and associated group addressing, permits a number of operational possibilities heretofore not possible. Such systems would possess the ability to configure the network to meet varying needs of the users on a moment's notice. This can be done simply by adjusting the priority of certain groups of users at the system control point. All of these features allow the possibility of centralized management, responsive to the policies and direction of that level of government having overall responsibility for and authority over all users of the system.

A special feature of the trunked system concept is the individual system integrity and privacy possible, despite the common use of RF channels. Since system users only receive those transmissions addressed to units with authorized addresses, group privacy is assured by restricting address assignments so that other users of the same channels are excluded. Thus, each user group has access to the system as if it were completely private and dedicated only to his organization.

The FCC authorized profit-making entrepreneurs to provide these SMRS services but does not limit their licensing to only profit-making entities. It is reasonable that a unit of government could establish a tax-supported agency to provide SMRS services limited to those activities under its direct jurisdiction. No SMRS has been licensed to provide such services to date.

Until trunked system hardware has been made available and trunked systems implementation begun, there seems little motivation to initiate such management approaches. Should use of trunked techniques become widespread, the SMRS appears to be a viable vehicle by which their capital costs could be shared by an appropriate number of using agencies.

3.7 NEEDED EQUIPMENT CAPABILITIES

3.7.1 General

The opening of the 900 MHz spectrum to the land mobile community presents an opportunity for the introduction of significant functional innovations in public safety communication equipment. The step function advance in technology initiated by the opening of this new portion of the spectrum and the innovative spectrum utilization concepts implemented simultaneously, provide a special opportunity to incorporate a number of additional features, long sought by the public safety community, in forthcoming equipment.

The following discussion of desired capabilities is the result of in-depth analysis of needs developed by the professional membership of APCO. These expressed needs are a distillation of the comments, suggestions and presentations provided by representatives of the APCO membership at seminars held around the country.

3.7.2 Needed Technologies

3.7.2.1 Trunked Systems Signalling Standards

As described in Section 2 of this Chapter, there are several currently envisioned approaches to the development of trunked technologies. As of the time of writing, at least two major manufacturers now propose trunked systems equipment. It is certainly foreseeable that, in response to the stimulus of the FCC, many manufacturers will eventually participate in the development of trunked systems for the land mobile radio community. Even though this equipment may not be available in the immediate future for application to public safety communication needs, its ultimate wide-spread use is inevitable, barring major changes in FCC policy.

Least cost procurement is an inherent requirement of, and a continuing problem to, tax-supported agencies in the public safety communication field. This results in a national policy to stimulate maximum vendor competition in tax-supported procurements.

Competitive efforts of the several vendors now developing trunked systems are both technologically and economically helpful. It is to be hoped that competition can continue to expand in the years to come. However, this technological competition should not be permitted to develop to the point that it becomes self-defeating. Under present conditions, an agency that procures a trunked system from a vendor is forever after locked into a sole source procurement position with that vendor in the event of need to expand or improve its basic system. Once an agency has procured a system from one vendor, that vendor would be the only commercial entity in a position to provide additional equipment compatible with its basic system.

This problem can be alleviated in the same manner the Commission has used to stimulate competition in other services -- through the promulgation of technological system standards. Just as the Commission has established television broadcasting system standards so that all manufacturers' equipments are capable of operating within the basic system, so should the Commission establish system technological standards for trunked systems.

These standards, developed after extensive testing, analysis and consultation, should define the software language and system operational philosophies to assure that all vendors' equipments could be competitively introduced into existing systems.

An ancillary but no less important need for this standardization is to permit compatibility between adjacent systems.

Within the public safety field there is an operational requirement for immediate and intimate coordination among many related services and agencies. Should a babel-like plethora of technologies be permitted to be randomly implemented, then the ultimate result of the introduction of trunked technology into the public safety field could be the erection of unscalable technological barriers between contiguous agencies.

3.7.2.2 Portable Radios for Trunked Systems

If the trunked system concepts are to be fully useful to the public safety community, portable radios meeting current physical and operational criteria must be available for use in such systems. The technology needed to provide trunked capabilities in mobile systems is either at hand or under development (see Chapter II). However, the incorporation of this technology in the small physical size and with the low power consumption required for portable equipments has not yet been demonstrated.

The complexity of the technical problems to be solved will be significantly affected by the configuration of the system in which the portable units must operate. The number of channels on which the portable must operate, the complexity of its logic, the battery life expected, and other circuit requirements will be greatly determined by the organization of the entire trunked system.

It is necessary, therefore, that together with basic trunked systems development, parallel programs be instituted to assure the eventual availability of portable units capable of operating with these systems.

3.7.2.3 Single Point Test Capabilities

The development of standardized, single point test philosophies will be especially compatible with the 900 MHz technology. The promulgation of a standard plug design and pin configuration would permit the development of universal test sets, compatible with equipment provided by any vendor. Such a single point test philosophy would result in significant reduction of maintenance costs and equipment-down times by making possible the rapid identification of defective sub-assemblies. The replacement of defective sub-assemblies, with their eventual repair by skilled technicians with specialized facilities, would greatly simplify the routine maintenance problems associated with modern, sophisticated equipment.

3.8 TECHNICAL CONSIDERATIONS FOR DATA SYSTEMS

There is nothing inherent within the 900 MHz spectrum that precludes its use for data transmission. A 900 MHz mobile data system has been in operation (Chicago Police Department) for some time. The previous discussions regarding propagation and technology for voice systems apply equally to data transfer systems. However, data systems are more stringent regarding continuity of coverage. A data system lacks the ability to integrate intelligence and extrapolate between known factors possessed by a voice communications network. When the data system signal drops out the information is lost, and either an incomplete transmission results or the transmission must be repeated. Therefore, the coverage phenomena described previously as "picket fencing" must be resolved if a data system is to provide the degree of reliable service needed. A reliable, high speed data system demands a degree of reliable coverage for which the system must be designed.

3.9 RELIABILITY AND MAINTAINABILITY CONSIDERATIONS

There is no inherent reason why 900 MHz equipment should be less reliable than equipment on the lower bands. Given a reasonable level of experience and system "ringing out", it can be expected that 900 MHz systems will prove to be highly reliable in the public safety environment. As a matter of fact, since they represent a new generation of technology, many innovative component features are now being incorporated in such systems. A continuing increase in use of microelectronics and chip technology is improving the reliability of all modern communications equipment. Therefore, it can be expected that 900 MHz equipment will be as reliable if not more reliable than present day equipment, not because it is 900 MHz but rather because it will employ the latest techniques of ever-improving technology.

Much of the 900 MHz technology is the same as in lower bands. Modulation, IF, RF, audio circuits, power and control cabling, are generally the same as used at lower bands. However, the final transmitter RF amplifier, the receiver front end circuitry, and the antenna coaxial cable concepts may involve changes. The techniques are similar to those used at 450 MHz, if perhaps somewhat more demanding. Particular attention will be required to RF coaxial cable connector cable installations. Defects that would have minor effects at VHF and be merely a source of reduced performance at UHF, can make a system completely inoperative at 900 MHz.

Most present test equipment designed for VHF will either work at these frequencies or can be adapted. Technicians familiar with UHF should have little difficulty learning 900 MHz systems.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

4.1 INTRODUCTION

The preceding Chapters have described the regulatory and administrative background of the opening of the 900 MHz spectrum for use by the land mobile community. They have presented the technological, economic, and management factors that affect the application of these frequencies to the communication needs of the public safety community, and they have described what these needs are and how such factors can be applied to these needs.

This Chapter presents the conclusions and recommendations that result from analysis of the considerations presented in the preceding Chapters by the APCO membership as represented by their project participants and elected officers. They relate the application of the 900 MHz spectrum to law enforcement communications problems, under the conditions defined by the FCC in its Docket No. 18262 proceedings. Since law enforcement communications are an inherent part of the total public safety communications environment, some conclusions presented will be expressed in terms of all public safety communications needs. This does not imply that such conclusions might have limited applications to law enforcement systems, but rather, that they apply to the total public safety communications problem, including law enforcement needs.

There are four broad areas under which conclusions are presented. These are the technological suitability of 900 MHz to the land mobile problem, the role of trunked systems in improving spectrum availability, the role of trunked systems in enhancing operational capabilities, and the effect of the present regulatory environment on 900 MHz system implementation. Each of these areas has its own set of conclusions that pertain to specific considerations.

Clear, absolute boundaries between the four fundamental sections are not always possible. There are numerous interrelationships between the conclusions reached under each of the four major headings. Such relationships serve well to demonstrate how complex are the elements of this subject. Regulatory policies regarding frequency coordination may be significantly dependent upon technological considerations affecting equipment performance. Spectrum conservation considerations resulting from the introduction of trunked concepts may be closely related to the degree of improved operational capability they provide and that therefore justifies their cost to the taxpayer.

In the interest of brevity, each conclusion is supported by a summary statement of the rationale leading to its development. For complete justification, the reader is referred to the preceding Chapters. The recommendations that spring logically from these conclusions are presented following the associated conclusions. For the convenience of the reader, the recommendations are summarized at the end of the Chapter.

4.2 TECHNOLOGICAL SUITABILITY OF 900 MHz

4.2.1 The technical characteristics of the 900 MHz spectrum are suitable for use by public safety communications agencies. The propagation phenomena associated with this portion of the spectrum, coupled with current developments of equipment suitable for these frequencies, provide a significant contribution to spectrum availability for public safety communications networks. Coverage achievable closely parallels that attained in the lower portion of the UHF spectrum. (See Section 4.2.3.)

Recommendation: Public safety communications system designers consider use of the 900 MHz spectrum in developing new systems, making additions to present systems, and the development of future plans.

4.2.2 The somewhat shorter range of propagation to be expected using the 900 MHz spectrum, compared to the lower frequencies, together with the improved building penetration and shadow fill-in coverage attainable, indicates that these frequencies are particularly attractive in urban areas. They might also be suitable for suburban and rural areas due to the lack of availability of lower frequencies or other system-related considerations.

Recommendation: Those urban areas confronted with building penetration or shadow effect problems consider planning to implement 900 MHz systems at such time as replacement of existing systems becomes feasible. Such plans should be filed with the FCC at the earliest appropriate moment.

4.2.3 The operational impact of the propagation characteristics of the 900 MHz spectrum are not precisely known at this time. The effects that "picket fencing" and deep "holes" might have on operational procedures and the specific engineering criteria that may be required to overcome these problems have not yet been documented. [illegible] law enforcement communications systems using these frequencies have been or are being implemented. The experience gained with these systems will be of great assistance to other network designers in the future.

Recommendation: A study be conducted to assemble the knowledge gained from experience with these newly implemented systems to make this knowledge available to all public safety agencies.

4.2.4 The proper performance of a 900 MHz system is dependent upon prevention of noise pollution of the environment. If IM products and other noise sources are permitted to proliferate, the usefulness of 900 MHz will be significantly reduced.

Recommendation: Site management programs be developed to prevent noise pollution that might affect use of 900 MHz systems in the future.

4.2.5 Technology is now available for conventional 900 MHz law enforcement communications systems. Major vendors' catalogs now list 900 MHz base station and mobile equipment similar to that available on lower bands. Manufacturing costs are quoted as being approximately 10% to 20% higher than lower band equipment. No portable units are presently listed as available. Those agencies considering 900 MHz early implementation must therefore exclude the portable concept until portable units become available some time in the future, or resort to crossband operation.

Recommendation: The vendor community proceed with the early development of 900 MHz portable equipment.

4.2.6 The availability of optimum 900 MHz sites may be limited in a given community. High antenna locations are necessary to provide required coverage, while long transmission lines between transmitters or receivers and their associated antennae degrade system performance. Therefore, practical considerations suggest increased emphasis upon the use of tall buildings and mountaintop sites for transmitter/receiver locations.

Recommendation: Those agencies foreseeing the possible use of 900 MHz should plan early to reserve necessary facilities atop existing or planned sites and to implement appropriate site management measures. (See Section 4.2.4.)

4.2.7 Conventional 900 MHz equipment will not present maintenance requirements significantly different from those posed by UHF systems. 900 MHz systems use technologies similar to present UHF technology, requiring somewhat more care in their application. Those agencies familiar with UHF systems maintenance and operation should experience little difficulty in the transition to 900 MHz.

Recommendation: Agencies employing 900 MHz systems utilize personnel familiar with UHF maintenance techniques.

4.3 THE ROLE OF TRUNKED SYSTEMS IN IMPROVED SPECTRUM UTILIZATION

4.3.1 Precise means of determining the number of frequencies needed to provide a required level of service using trunked technologies has not been demonstrated. Present calculations are based on telephone experience and do not necessarily reflect the unique needs of the service required by complex law enforcement command/control communications systems. Therefore, the number of channels needed in a trunked system cannot be predicted with the accuracy necessary for law enforcement system design until operational experience has been obtained.

Recommendation: Develop a demonstration law enforcement trunked system in which different levels of system performance that are the result of variations in the number of trunked channels available under various operational conditions can be measured.

4.3.2 Under appropriate conditions, trunked systems can provide significant increased capability (see Chapter III and Section 4.4). Their costs may be expected to be higher than conventional systems, the amount depending upon design features incorporated. While the individual mobile units may be more expensive, some savings can accrue from the reduced number of base station transmitters and satellite receivers that might result from the fewer frequencies needed.

Recommendation: Implement a demonstration program under which actual cost figures can be determined. Those cost elements now associated with development risks that are incorporated in current trunking systems estimates could then be eliminated.

4.3.3 The amount of spectrum usage improvement to be expected from trunked system implementation is a function of the number of users of the system. Very little can be gained by trunking systems of 300 1/ or fewer units. No upper limit on the number of units a trunked system might accommodate has been demonstrated.

Recommendation: Those large, heavily loaded metropolitan systems approaching saturation should not plan trunked systems (not considering possible operational advantages) except when sufficient frequencies can be incorporated in the system to reduce channel loading below saturation levels.

4.3.5 Heavily loaded major metropolitan systems will benefit from trunked technologies only if less heavily loaded frequencies are incorporated. (See 4.3.4.) Those communities with heavily loaded law enforcement communications systems can be expected to derive spectrum benefit from trunking if other municipal agencies, having either less heavily loaded systems or different times of maximum utilization (peak load period) are incorporated into the system.

Recommendation: Major metropolitan areas initiate comprehensive long-range planning for the ultimate development of combined communications systems.

4.3.6 No one community can be expected to assume costs associated with the research and development needed to implement the innovative technologies associated with trunked systems. A selected community might provide facilities and personnel and assume certain hardware-related costs associated with the equipment to be used by the community. Those costs associated with the technology transfer aspects of such systems, to include feasibility studies, functional requirements development, and test and evaluation, are the responsibility of the federal government.

Recommendation: The federal government participate in a development and demonstration program of trunked systems technologies as described in Chapter V of this Report.

4.3.7 Trunked public safety systems should only be installed where improved system performance will result. The taxpayers of the individual communities should not be required to bear additional costs of trunked systems implementation solely to attain the objectives of improved "spectrum efficiency". If the only justification for a specific trunked system is improved spectrum utilization which, in turn, means making available channels for some other (perhaps non-tax supported) use, then the propriety of expenditure of these tax-provided monies is questionable. It is even more questionable to require such expenditures in areas where eventual spectrum congestion within the radius of coverage of the public safety system is only remotely conceivable.

Recommendation: The decision to implement trunked technologies in a public safety system design be based upon the needs of the system and the community involved, not upon an arbitrary standard established for general application.

4.3.8 The development of trunked portable equipment may be costly and time-consuming. The physical size and battery life constraints imposed on portable equipments pose significant challenges to the engineering of

1/ See Section 2.3.2 for analysis supporting this figure.

such equipments. Given the foreseeable, limited market for such equipments, it is likely to be some time before the vendor community risks the engineering and development costs necessary to provide such equipment.

Recommendation: A program be initiated by the federal government to develop trunked portable 900 MHz equipment. Specific performance criteria for these units would be determined by the demonstration program specified in Section 4.3.6 above.

4.3.9 Trunked systems are presently best suited to those communities that can be served from single base station sites. While it is not practical at the present time to use trunked technologies in conjunction with multiple site repeater type systems, studies indicate that trunked technologies would be compatible with "simulcasting" techniques; "simulcasting" at 900 MHz has not been demonstrated in a practical environment. This does not imply that satellite receiver concepts are not compatible with trunked technologies.

Recommendation: A program should be initiated to demonstrate simulcasting at 900 MHz in connection with trunked systems.

4.4 POTENTIAL FOR IMPROVED OPERATIONAL CAPABILITIES USING TRUNKED SYSTEMS

4.4.1 The digital addressing techniques inherent in currently conceived trunked system concepts provide the potential for significant advances in the operation and control of law enforcement communications systems. Digital addressing techniques can be applied to system design in a number of ways. Many of these techniques can provide totally new approaches to law enforcement communication system configuration, management and operation. A major problem with this new array of potential techniques is the need to select for implementation those that best provide the needed capabilities in a realistic and cost effective manner.

Recommendation: A study phase be incorporated in the demonstration program (see Section 4.3.2) to identify the specific functional capabilities made possible using trunked techniques in a model operational law enforcement communications system.

4.4.2 A demonstration trunked system can provide information regarding channel loading, channel utilization, peak load requirements, emergency requirements, and the number of channels required to support a specific agency under various operational situations. Such data could provide the basis for many calculations, heretofore unavailable, needed to provide an objective basis for spectrum management decisions.

Recommendation: The trunked system demonstration program (see Section 4.3.2) include a clearly identified test program and the associated resources needed to accumulate that factual data necessary to provide the basis for future system design and spectrum management decisions.

4.4.3 In the absence of nationally established standards, trunked system development by different vendors will result in noncompatible systems. It can be expected that the current command channel languages developed by different vendors will be incompatible with each other. Unless the regulatory agencies specify a standardized language format for system organization, the introduction of trunked technologies will eventually result in a major problem of system compatibility.

Recommendation: The FCC adopt a standard command channel format for trunked systems to assure system compatibility.

4.5 EFFECTS OF THE REGULATORY ENVIRONMENT ON 900 MHz SYSTEM IMPLEMENTATION

4.5.1 The implementation of the 900 MHz system requires detailed engineering and frequency coordination. Successful use of these frequencies depends to a significant extent upon the lack of noise pollution. The problems of frequency selection and IM minimization can become extremely complex. Therefore, RF power level, antenna locations and heights, frequency selection and other factors must be carefully considered to suit the technical and operational needs of each installation.

Recommendation: The FCC Rules reflect the needs for local coordination for each 900 MHz license application.

4.5.2 The role of cellular systems will not be significant in serving public safety radio needs in the foreseeable future. Notwithstanding the present developmental effort, it will be a number of years before such systems are implemented throughout much of the country. The nature of law enforcement radio communication systems is significantly different from the public switched telephone network. Law enforcement radio systems are configured to provide routine dispatch service and also command control support. They must be capable of handling routine and emergency traffic. The need to recognize the priority of public safety communications makes it impractical to share channels or facilities with users from the general public.

Recommendation: The role of cellular systems in support of public safety requirements be considered only when such systems have been implemented and have demonstrated the degree of technical sophistication, reliability, and capability suitable to the needs of the public safety community.

4.5.3 The SMRS concept can provide a useful tool for the management of community-wide tax-supported systems. This concept provides one more approach to assist the present trend toward consolidated and cooperative systems. It should receive consideration when trunked systems become more common.

Recommendation: Public safety users initiate a policy to support the SMRS concept wherever determined appropriate. (See Section 3.6.)

4.5.4 The present standards for conventional and trunked system channel loading fail to reflect the needs of spectrum management or the user. Current standards are based upon unsupported estimates and founded on administrative convenience. They do not relate to the user's operational doctrines, philosophies or to the community's needs. They can permit inadvertent wastage of the spectrum on one hand and inhibit agency operation on the other.

Recommendation: The FCC develop channel loading standards that reflect those considerations needed to measure the level of service required by the using agencies.

4.5.5 The requirement to implement trunked systems now contained in the Rules does not reflect the needed operational capabilities, the responsibilities of tax-supported agencies for cost effective design, or provide for the flexibility needed to configure system design to user needs.

Recommendation: The requirement for trunked system implementation in the public safety sector be removed from the Rules and provisions made for trunked systems implementation based upon a case-by-case analysis of the needs of the using agency.

4.5.6 The rules pertaining to licensing of 900 MHz systems have been developed on a generalized nationwide basis and therefore may not be optimum in a specific application. The problems associated with licensing of such systems vary significantly in different portions of the country. Available channels are rapidly being consumed in the densely populated urban areas. These are the same areas of high crime rate where sophisticated communications systems of the future will be required. On the other hand, there are many communities whose geographic and demographic situation makes inconceivable the foreseeable saturation of the 900 MHz spectrum. Yet both types of communities are bound by the same rules requiring trunking systems implementation, and one-by-one channel assignments, to attain an arbitrary standard of channel loading. (See Section 4.5.5.)

Recommendation: The Commission's Rules requiring trunked systems at 900 MHz should be revised to recognize the different spectrum allocation problems and needs in different portions of the country having different geographic and demographic situations.

4.5.7 The Commission's Rules currently make little provision for the implementation of planned systems. Consequently, they inhibit long-range communications systems planning. Large scale, sophisticated systems that are configured to optimize utilization of spectrum while concurrently satisfying the users' operational needs are time-consuming to prepare, approve, fund and implement. They must be developed based upon the availability of specific frequencies, and such frequencies must be reserved so that they are available when the plan is implemented.

Recommendation: The FCC assign resources necessary to review, approve and monitor the implementation of long-range plans. Procedures be established to protect the integrity of such plans by recognizing their frequency requirements during the period of their implementation.

4.6 SUMMARY OF RECOMMENDATIONS

4.6.1 Technological Suitability of 900 MHz

- Public safety communications system designers consider use of the 900 MHz spectrum in developing new systems, making additions to present systems, and the development of future plans.
- Those urban areas confronted with building penetration or shadow effect problems consider planning to implement 900 MHz systems at such time as replacement of existing systems becomes feasible. Such plans should be filed with the FCC at the earliest appropriate moment.
- A study be conducted to assemble the knowledge gained from experience with these newly implemented systems to make this knowledge available to all public safety agencies.
- Site management programs be developed to prevent noise pollution that might affect use of 900 MHz systems in the future.

- The vendor community proceed with the early development of 900 MHz portable equipment.

- Those agencies foreseeing the possible use of 900 MHz should plan early to reserve necessary facilities atop existing or planned sites and to implement appropriate site management measures.

- Agencies employing 900 MHz systems utilize personnel familiar with UHF maintenance techniques.

- Develop a demonstration law enforcement trunked system in which different levels of system performance that are the result of variations in the number of trunked channels available under various operational conditions can be measured.

- Implement a demonstration program under which actual cost figures can be determined. Those cost elements now associated with development risks that are incorporated in current trunking systems estimates could then be eliminated.

- In those systems in which a single agency lacks a sufficient number of units to justify the application of trunked techniques, give consideration to combining compatible users, other factors permitting. Such communities foreseeing future needs for increased communications capability should begin planning for cooperative trunked system development.

- Those large, heavily loaded metropolitan systems approaching saturation should not plan trunked systems (not considering possible operational advantages) except when sufficient frequencies can be incorporated in the system to reduce channel loading below saturation levels.

- Major metropolitan areas initiate comprehensive long-range planning for the ultimate development of combined communications systems.

- The federal government participate in a development and demonstration program of trunked systems technologies as described in Chapter V of this Report.

- The decision to implement trunked technologies in a public safety system design be based upon the needs of the system and the community involved, not upon an arbitrary standard established for general application.

- A program be initiated by the federal government to develop trunked portable 900 MHz equipment. Specific performance criteria for these units would be determined by the demonstration program specified in Section 4.3.6 above.

- A program should be initiated to demonstrate simulcasting at 900 MHz in connection with trunked systems.

- A study phase be incorporated in the demonstration program to identify the specific functional capabilities made possible using trunked techniques in a model operational law enforcement communications system.

- The trunked system demonstration program include a clearly identified test program and the associated resources needed to accumulate that factual data necessary to provide the basis for future system design and spectrum management decisions.

- The FCC adopt a standard command channel format for trunked systems to assure system compatibility.

- The FCC Rules reflect the needs for local coordination for each 900 MHz license application.

- The role of cellular systems in support of public safety requirements be considered only when such systems have been implemented and have demonstrated the degree of technical sophistication, reliability, and capability suitable to the needs of the public safety community.

- Public safety users initiate a policy to support the SMRS concept wherever determined appropriate.

- The FCC develop channel loading standards that reflect those considerations needed to measure the level of service required by the using agencies.

- The requirement for trunked system implementation in the public safety sector be removed from the Rules and provisions made for trunked systems implementation based upon a case-by-case analysis of the needs of the using agency.

- The Commission's Rules requiring trunked systems at 900 MHz should be revised to recognize the different spectrum allocation problems and needs in different portions of the country having different geographic and demographic situations.

- The FCC assign resources necessary to review, approve and monitor the implementation of long-range plans. Procedures be established to protect the integrity of such plans by recognizing their frequency requirements during the period of their implementation.

CHAPTER V

THE DEMONSTRATION PROGRAM

5.1 INTRODUCTION

5.1.1 General

The preceding Chapters of this study develop the conclusion that the 900 MHz spectrum will provide a necessary and valuable resource for public safety communications. Propagation phenomena associated with this portion of the spectrum offer potentially attractive characteristics for its use in both urban and suburban communities. Benefits to be derived from the application of trunked system technologies offer an opportunity to enhance the operational capabilities of public safety systems and the possibility of improved spectrum utilization. However, a trunked system has yet to be configured and tested in an operational law enforcement environment.

Though technology is available, the design and implementation of an initial system involves innovation. As with any untried technology, engineering problems must be resolved and implementation difficulties overcome during installation of the first operational system. The optimum configuration that fully exploits trunked concepts potential for improved operational capabilities can only be determined by designing a system to meet a specific need and then building and evaluating that system's performance.

The practical demonstration of an operating system will be of benefit to all potential users throughout the United States. Development of the operating procedures, engineering data, operational concepts, and system performance standards associated with such systems will provide subsequent systems designers with the necessary foundation upon which they can base the design of future systems that satisfy their individual needs.

The risks and costs associated with the implementation of an initial trunked, 900 MHz system are beyond the responsibilities of an individual local community. Only the federal government is in a position to provide the initiative, resources, and level of responsibility needed to resolve these issues in a manner having application to all potential users. The federal government's role in developing technologies for use by communities throughout the country gives it responsibility for establishing the objectives of a development program, monitoring program implementation, evaluating results, and disseminating the technological knowledge obtained.

The nature of trunked systems is such that large amounts of redundant mobile equipment are required in a system large enough to illustrate the principles involved and to demonstrate the objectives sought. Once such a system has reached an operational status and its test and evaluation have been completed, the economic investment involved demands that it serve on-going needs. It is therefore appropriate that the community selected for the demonstration system bear the costs of the hardware that will ultimately be used in an operational system. On the other hand, the federal government should provide those funds associated with those program requirements peculiar to the development and demonstration of the new technology, its evaluation and test.

The following program, therefore, is based upon the assumptions that a designated, cooperative community will bear equipment and facility-related costs associated with the satisfaction of its needs, and the federal government will provide those funds associated with the development of the innovative technology, its test and evaluation, and for the technology transfer program needed to benefit the rest of the country.

5.1.2 Objectives of a Demonstration Program

This study has analyzed the ability of trunked 900 MHz systems to meet law enforcement needs and concluded that such systems are feasible and will contribute significantly to the level of capability of law enforcement agencies throughout the country. A review of technology has shown that the capability now exists to implement such systems. Before individual communities can address the significant planning, management, funding and engineering problems associated with such innovative systems, a practical demonstration of the implementation and operation of such systems must be accomplished.

The analysis conducted in Chapters II and III of this study indicates that there are three objectives to be satisfied by such a demonstration program. These are:

a) Identify the degree of increased spectrum utilization that can be expected to result from the implementation of trunked technologies. While analytical studies may yield evidence of spectrum savings that might result from implementation of trunked systems, the actual extent of such savings can only be determined with a reasonable degree of certainty by measurements made in an operational environment. Such factual data must be accumulated before accurate cost benefit judgments can be made for follow-on systems.

   The demonstration system employing trunked technologies should identify acceptable channel loading standards for a trunked system in an operational environment and compare such loading with those standards appropriate to conventional systems.

b) Demonstrate specific operational capabilities made possible by trunked technologies, and the effects that such operational improvements can have upon using agencies' capabilities. Trunked technologies offer an opportunity for a new approach to law enforcement communication system design, and the potential for significant improvements in their performance. A suitable demonstration program should develop these concepts, demonstrate their usefulness, and provide a functional model for other agencies to follow in systems of their own.

c) Resolve engineering and procedural problems. The demonstration program should resolve possible engineering problems that can arise in the implementation of new technologies. Procedural and organizational policies that may be necessary to fully exploit the potential of new technology should be identified. Upon completion of such a program, other agencies can then adapt these concepts and technologies to their own needs.

5.1.3 Program Outline

The development of a new technological capability and its subsequent application to practical problems must follow an orderly process. While various system development and technology transfer program outlines have been developed, most include similar steps. In view of considerations of economy, the status of technology, and the management structures likely to be involved in the development of 900 MHz trunked systems, a program consisting of five phases is recommended. These five phases are:

Phase 1. Feasibility Determination

A program to introduce untried technology or procedural concepts should first determine the technological and operational feasibility of the ideas involved. Such a determination requires analysis of the proposed technology and determination of its potential applicability to the problems needing solution. Assuming that the analysis indicates the feasibility of the technology, it is then necessary to identify those questions and/or problems that can best be resolved through practical demonstration. Once the feasibility has been established, the outline of a plan for implementation and test of a demonstration system should be prepared.

Phase 2. Functional Requirements Development

A demonstration program requires the definition of specific functional objectives to be satisfied by the demonstration system. A site for the demonstration model must be selected and the specific functional requirements of the system to be implemented in that environment identified. A detailed schedule for implementation, including costs and management concepts, should be prepared.

Phase 3. Implementation Program

Based upon the functional requirements and program schedule developed in Phase 2, an organization responsible for implementation management should be designated, specifications prepared, and procurement activities resulting in equipment design, test and production accomplished. After successful testing of the developmental system hardware components, full scale production and installation can proceed. Once installation is completed, the individual components of the system can be tested to assure compliance with specifications. This step is necessary prior to overall system evaluation to assure that subsequent system performance measurements are uncorrupted by data clouded by faulty component performance.

Phase 4. Test and Evaluation

The test and evaluation program has two objectives. The first is to determine if the individual pieces of equipment perform as specified and then to determine if they combine properly into a system that fulfills the functional requirements established at the outset. The second objective is to determine the extent by which these functional requirements contribute to the original goals of the program, for example, improved agency effectiveness, increased resource utilization efficiency, improved spectrum utilization, etc. The test and evaluation program determines how well the system, taken as a whole, satisfies the operational needs. It provides a basis for cost/benefit decisions by future users of the technology. It also provides information needed to specify system parameters so that they can be applied by other users in developing systems of their own.

Phase 5. Technology Transfer

Data acquired during implementation, test and evaluation must be made available to potential users of the technology. It should therefore be developed in a manner that will provide maximum assistance to other agencies who might benefit by application of the demonstrated technologies.

The cost and duration of each of these Phases are functions of the system to be developed and the problems to be solved. The following demonstration program for a trunked 900 MHz law enforcement telecommunication system describes each of these five Phases in terms of the objectives presented in Section 5.1.2. Since it constitutes the next step of a recommended program, Phase 2, the Requirements Development, it is presented with a degree of detail. Phases 3, 4 and 5 are each presented in diminishing detail as they are progressively further in the future.

5.2 PLAN FOR THE DEMONSTRATION PROGRAM

5.2.1 General

The following Section discusses each of the above five Phases as applied to a 900 MHz trunked system program. The objectives of each Phase are described, and the steps that must be accomplished to attain these objectives presented. Budgetary and schedule considerations are contained in Sections 5.3 and 5.4.

5.2.2 The Feasibility Study

The objective of Phase 1 of the 900 MHz program is to evaluate the feasibility of the proposed technical concepts as they may apply to the problems presented. The analysis, conclusions and recommendations presented in the preceding Chapters of this study constitute such a study and represent Phase 1 of a program to develop and introduce to the law enforcement and public safety communication communities the innovative concepts and technical advances inherent in the development of 900 MHz trunked communication systems. It has described these new technologies and their potential to contribute to the operational capabilities of the nation's law enforcement agencies. It concludes that such technologies are feasible and within the present state of the art. It points out the objectives of a practical demonstration. It provides the basis upon which to make decisions to proceed with the next step, i.e., the need for identification of the specific functional requirements of a demonstration system.

5.2.3 Requirements Development

The objective of Phase 2 of the demonstration program is to provide a detailed description of the functional requirements that must be met by the model system. This statement of specific functional requirements should be in sufficient detail to permit accurate budgetary forecasting and the development of contract specifications. To do this, the community in which the model system is to be implemented must be selected. The specific operational functions that must be performed by the law enforcement communications system of that model community have to be defined. Phase 2 also includes an information acquisition phase during which information pertaining to the operational impact of 900 MHz propagation phenomena is accumulated. This information will be of significant importance to those making system configuration decisions for follow-on programs.

5.2.3.1 Site Selection

The selection of an appropriate community to be designated for the conduct of this demonstration program is one of the first steps that must be taken in this Phase. The criteria for this selection are as follows:

a) the selected model community must be a voluntary participant in the test program;

b) a new law enforcement communication network should be needed by that community. An appropriate standard might be that the community's present system be in excess of seven years old or that significant, new requirements have developed that require the implementation of a new system.

c) The electromagnetic environment should be such that the 900 MHz portion of the spectrum will prove suitable coverage. The need for repeater transmitters to fill shadow areas makes the introduction of trunked concepts technically difficult at this time and could cause costs not directly related to the objectives of the demonstration program. Therefore, the area of required coverage should lie within a radius of 20-25 miles and terrain be such to permit coverage from a single transmitter location. (This does not preclude a second site for backup, reliability purposes, or the use of satellite receivers.)

d) The community must be willing to commit funds needed for the capital outlay required to support its share of the project costs. These funds may include local monies, other Federal (LEAA Block Grant program) funds, or combinations thereof. The community must also be willing to provide project management personnel, site facilities and locations, and other resources necessary for such a program.

e) Officials in the community should be willing to work with the LEAA and/or its designated representatives in the conduct of the test and analysis portions of this project.

f) The community should be representative of a typical urban metropolis that might utilize the 900 MHz spectrum. While it must be large enough to demonstrate the usefulness of multichannel trunked systems, it should not be so large as to require an excessive level of redundant hardware to produce the needed test results. A law enforcement agency (or combination of agencies) employing more than 300 mobile units would be appropriate.

g) Since trunked portable units are not likely to be commercially available in time for the demonstration program, the community's law enforcement communication operational concept should be such that portable units will not be required for several years or that the requirement can be satisfied by a hybrid (trunked mobile and conventional portable) system.

The final decision regarding the site to be selected should be made by the LEAA.

The selection of an optimum site for the demonstration of a technologically and operationally complex system is important. Much of the success or failure of the program and the ultimate costs associated therewith will, to a great extent, depend upon the appropriateness of the demonstration site selected. To assure that all suitable candidates are considered, a nationwide survey to identify all cities meeting the specified criteria should be conducted. The survey could be accomplished by providing specific criteria in accordance with the contents of Par. 5.2.3.1 to the Chapters of APCO. These Chapters are in an excellent position to identify those cities within their regions meeting the above minimum criteria.

From this list of voluntary participants, discussions could be held with community representatives to further refine mutual understandings of the opportunities and responsibilities involved. From these discussions a list of those cities (approximately five) willing and able to participate would be presented to the LEAA for its final determination.

5.2.3.2 Management Relationships

Once a site has been selected, representatives of the agencies participating in the program should develop a Memorandum of Agreement defining the roles and responsibilities of each of the participating agencies. This Agreement should identify overall project management responsibility (which should be vested in the law enforcement agency actually procuring and using the system) and the areas of participation by other participants in the project. It would also outline the development program, identify schedules and specify funding responsibilities.

5.2.3.3 Propagation Data Analysis

The feasibility study conducted under Phase 1 of this program (APCO's Project 16) raises questions regarding potential operational problems that can occur under certain conditions of propagation. The extent and nature of these problems should be determined, based upon the practical experience of the agencies now employing such systems. Concurrent with the site selection activity, a survey of those principal 900 MHz law enforcement systems that have become operational as of the outset of Phase 2 of the program should be conducted. Data describing the operational experience with these frequencies should be accumulated. Any information available regarding the techniques used to overcome such problems should also be acquired.

This data should be available by the time the final system configuration decisions are made. In this way the data will be available for analysis and application to the individual requirements of the model community at the time the functional requirements are prepared.

5.2.3.4 The Development of Functional Requirements

Once the community in which the model system is to be installed has been selected, those functional requirements of the law enforcement communications system that must be satisfied to meet the needs of that city can be determined. Such functional needs must be developed in close cooperation with the authorities of the city selected. They must recognize the operational procedures and responsibilities of the agencies involved. They should exploit the many potential capabilities inherent in the digitally addressed, trunked system concept that will best serve the needs of the community, are technologically and economically practical, and serve the objectives of the demonstration program. They must also be developed in a manner to insure the orderly transition from the existing system, with its established procedures, to the new system.

These functional requirements must include the need to develop procedures, train personnel, provide documentation, and define maintenance requirements as part of the implementation of the new system. The innovative nature of trunked systems and their potential for new operational capabilities require that the development of the functional requirements include concepts beyond the usual scope of law enforcement systems development activities. Individuals familiar with the potential capabilities of trunked systems and their operation should be selected to participate in the development of this functional requirements document. Those individuals with broad experience in law enforcement communication systems and also having the technical background needed to appreciate the potential benefits to be derived from such systems should be chosen.

5.2.3.5 Summary

Phase 2 of the program will yield the following specific results:

a) selection of a community for the demonstration program and the development of necessary management agreements;

b) the accumulation, consolidation and analysis of available information regarding the operational impact of 900 MHz propagation based upon practical experience with installed systems;

c) a functional requirement statement specifying those system performance requirements that must be met by the 900 MHz trunked system to be demonstrated. This document will provide the basis for the development of the statement of work and specifications for hardware development and installation.

5.3 IMPLEMENTATION PHASE

5.3.1 General

The implementation program will involve the development of equipment that requires new configurations of existing technologies. A complex portion of this program will be the development of the software (control language) needed to accommodate the functional requirements of the system. The statement of work and equipment specifications can be prepared based upon the functional requirements document prepared in Phase 2 of the program. Upon commitment of funds by responsible agencies, this statement of work can be issued to the vendor community as part of a request for proposals. A competitive source selection process would then be conducted to select a development and implementation contractor.

A working model of the system must be demonstrated before production is authorized to test equipment design and to de-bug the software. This can be done by specifying a multi-phased hardware development and procurement program, in which the vendor is required to demonstrate a working model of the system, including the control channel, command language, base station RF equipment, and two or more mobile units (as a minimum) before receiving approval to proceed with production of the total system.

Once the system is installed, the individual components of the system should be tested, then the entire system tested as a whole. Review and analysis of the test results by the using agency will provide the basis for system acceptance.

5.3.2 Specification Development

Given the approval of the functional requirements document developed in Phase 2 of the project, hardware performance specifications should be prepared to provide vendors with the specific technical and environmental requirements upon which to base their proposals. These specifications should be prepared by a team of individuals familiar with the overall program and its goals and objectives, representatives of the model community knowledgeable in the needs of their agency, and consulting technical specialists qualified in RF equipment and trunked system design.

The specifications should also define those hardware capabilities and the test points or interfaces needed to permit measurement of those individual hardware and system performance factors identified in the test program (see Section 5.5 below). It would contain the following sections: General Conditions, Special Conditions, Scope of the Specifications, Equipment Specifications, Performance Verification, Training, Maintenance, and Schedule.

5.3.3 The Statement of Work (SOW)

The SOW should be prepared by the same team that prepares the specifications and incorporated as a part thereof. It should outline a phased program, i.e., demonstration of a working model (probably at the vendor's facility), installation of the system, test and checkout of the system, and system cutover from the existing system to the new trunked system. The SOW should also identify the requirement to demonstrate a working sample of the system before full scale production is authorized. The procuring authority should have the option to terminate the contract in the event of unsatisfactory performance of the model, at minimum cost. An important element of the SOW will be the definition of what constitutes an "acceptable system" and how it will be demonstrated.

The SOW should specify maintenance support of the system for a minimum period (probably one year) after system acceptance, and include "over the shoulder" training of maintenance personnel if in accord with the maintenance concepts of the using agency. It should include the requirement for the development of any specialized system management and/or operational procedures that might be necessitated by the new technology. It should also include training personnel in any new operational techniques.

The work statement should incorporate those phases of the test and evaluation program (see Section 5.5 below) that can best be accomplished by the development contractor. This would include testing of individual hardware items, identifiable systems, and overall system operation.

A cutover program should be defined, specifying the maintenance of the required level of operational capability by the using agency during the transition period. Vendors should be required to submit detailed plans for cutover as part of their proposals.

5.3.4 Procurement, Installation, Test and Acceptance

Procurement responsibility for the system should rest with the community in which the demonstration system is to be installed. A procurement team should be established, under the direction of a Project Director who has been designated by the agency that will eventually be the user of the system. This procurement team should include technical and operational representatives of the using agency in addition to personnel experienced in the demonstration program itself, as representatives of the sponsoring federal government agency.

This procurement team should act as the source selection board, supervise contract activities, monitor contractor progress, review contractor tests, and make recommendations regarding hardware and system acceptance. This team should be the only group having authority to recommend contract changes.

The procurement team, under the direction of the Project Director, should monitor installation, acceptance testing, and cutover activities. It should also have access to the resources and administrative channels needed to coordinate installation and cutover activities.

Those members of this team representing the sponsoring federal government agency should be responsible for preparation of and submission of test reports that will document for future use by others, the technical data and program-related experiences obtained during the implementation phase of the project.

5.4 THE TEST AND EVALUATION PROGRAM

5.4.1 The Overall Testing Concept

The complete test program for a 900 MHz trunked system incorporates four levels of test and evaluation, several of which are interleaved with other phases. The first level of tests determines the adequacy of the basic system design and hardware configuration prior to serial production. These tests will demonstrate the validity of the engineering concepts employed by the vendor and identify possible interface problems. Upon successful demonstration of this mock-up system, production and installation can proceed.

The second level of testing, conducted by the contractor after installation is complete, is a component-by-component test to demonstrate that the individual elements of the system function in accordance with their design specifications. In the event that inadequacies are found, the contractor should be held responsible for their correction.

The third level of testing is the overall system test. This test, also conducted in conjunction with the implementation contractor, demonstrates that the system "plays together" as designed. These tests show that interfaces have been properly configured and the system performs as required.

The fourth level of the test program provides an evaluation of the functioning of the system, showing its ability to meet those operational goals established in the functional requirements statement. This phase of the test and evaluation program will be conducted under Phase 4 of the program. It includes analysis of data acquired during preceding Phases to document the solutions to the problems and the answers to questions posed at the outset of the program. Performance of the system in the operational environment must be monitored to evaluate the extent by which the system meets its objectives. The test and evaluation Phase should yield a document, or series of documents, suitable for publication and future use by all who might benefit from applying trunked system technologies to the problems of their own agencies. Such documentation should include a description of the system's performance, its technical operation, suggested operational procedures, and any other topics that might be of assistance to those agencies who could benefit from implementation of the concepts developed.

This evaluation phase is to be conducted after the system has been cut over and is functioning in an operational environment. The data collected, as outlined in the test program, will provide a factual basis by which the performance of trunked systems can be compared with conventional systems. This information would describe average delay times as a function of number of units per channel and similar factors that affect level of service. The number of RF channels available for use would be varied during various conditions of operational loading and the effects on message delay measured. The figures recorded would show average amount of air time vs. channel occupancy, and system and component reliability. The information acquired during this evaluation will provide insight into the potential for enhanced operational capability of trunked systems, and constitutes an important source of relevant data upon which to base future spectrum management decisions.

A test and evaluation program as outlined must be conducted by a technically competent group, familiar with the trunked systems program and also familiar with the operational needs of law enforcement agencies. This group would work under the sponsorship of the government agency that provides overall direction of the program. The results of its work constitute the source data for the following technology transfer program.

5.5 TECHNOLOGY TRANSFER

Once a demonstration system has been implemented and its test and evaluation completed, the remaining task of the program is to make the knowledge and experience gained available to the entire community.

There are three elements to such a task. The first is to accumulate the engineering and operational data in a manner useful to the several levels of individuals involved in implementing such systems in their own communities. These levels include the executive personnel who make decisions that determine the availability of implementation funding, the operational personnel whose judgments determine functional suitability, and the engineering personnel whose skills make possible the design and operation of such systems.

The second requirement of a technology transfer program is publicity. The information collected will be of scant value if potential users are unaware of its existence. A concerted effort should be launched by involved government agencies to make state and local officials aware of the results obtained from the program. This can be done by publication in the trade press and participation in appropriate professional and government-related association conferences, meetings and seminars.

The third element of a successful technology transfer program is the availability of those individuals whose participation in the program gave them experience and knowledge that would be of significant value to other agencies contemplating the installation of trunked systems of their own. Such people should be considered a valuable program-related asset, and their identity, location and availability should be provided to potential system users.

5.6 SCHEDULE

Chart 5.1 shows the recommended schedule for the demonstration program. This schedule assumes the sequential implementation of each phase of the project to insure continuity of personnel and agency involvement. It also assumes the availability of funds (see Section 5.7) in time to authorize the beginning of each step of the program immediately following the completion of a preceding step. It further assumes that activities necessary to secure funds and authorizations necessary for each phase of the program are accomplished in conjunction with the preceding phase.

This schedule is intentionally generalized. It depicts only major phases and tasks so as to present a view of the overall scope and duration of the demonstration project.

5.7 BUDGET

The program budget is based upon the same assumptions listed under Section 5.6. The budget presented further assumes the continuation of present costs and a competitive source selection process for hardware development, production and installation, and the participation of individuals representing the model city at no cost to the project.

Costs of the program are divided between the federal government and the model city. The division of costs is based upon the assumption that those program costs related to development, evaluation and technology transfer are allocated to the federal government. Those costs involved in the production, installation, and acceptance of system hardware are to be borne by the using community.

Under this concept, the federal government will be responsible for Phase 1 and Phase 2 of the project. That portion of Phase 3 that includes development and test of the mockup model is also a federal responsibility. Costs of hardware production, installation, cutover, and training costs are assigned to the model city. Costs of Phase 4, Test and Evaluation, and Phase 5, Technology Transfer, are shown as costs to the federal government.

Phase 1, the Feasibility Study, has been accomplished with the submission of APCO's Project 16 report and, therefore, funds associated with this task are not shown. Since no date for the beginning of each task can be reasonably assumed at this time, cost schedules are related to the program time frame in which the task is to be accomplished, not to a specific fiscal year.

The costs of equipment production and installation are dependent upon the size of the model city selected, the number of mobile units to be used, and the number of RF channels to be used in the system. For the purpose of this budget, a system employing 300 mobile units and six RF channels will be assumed.

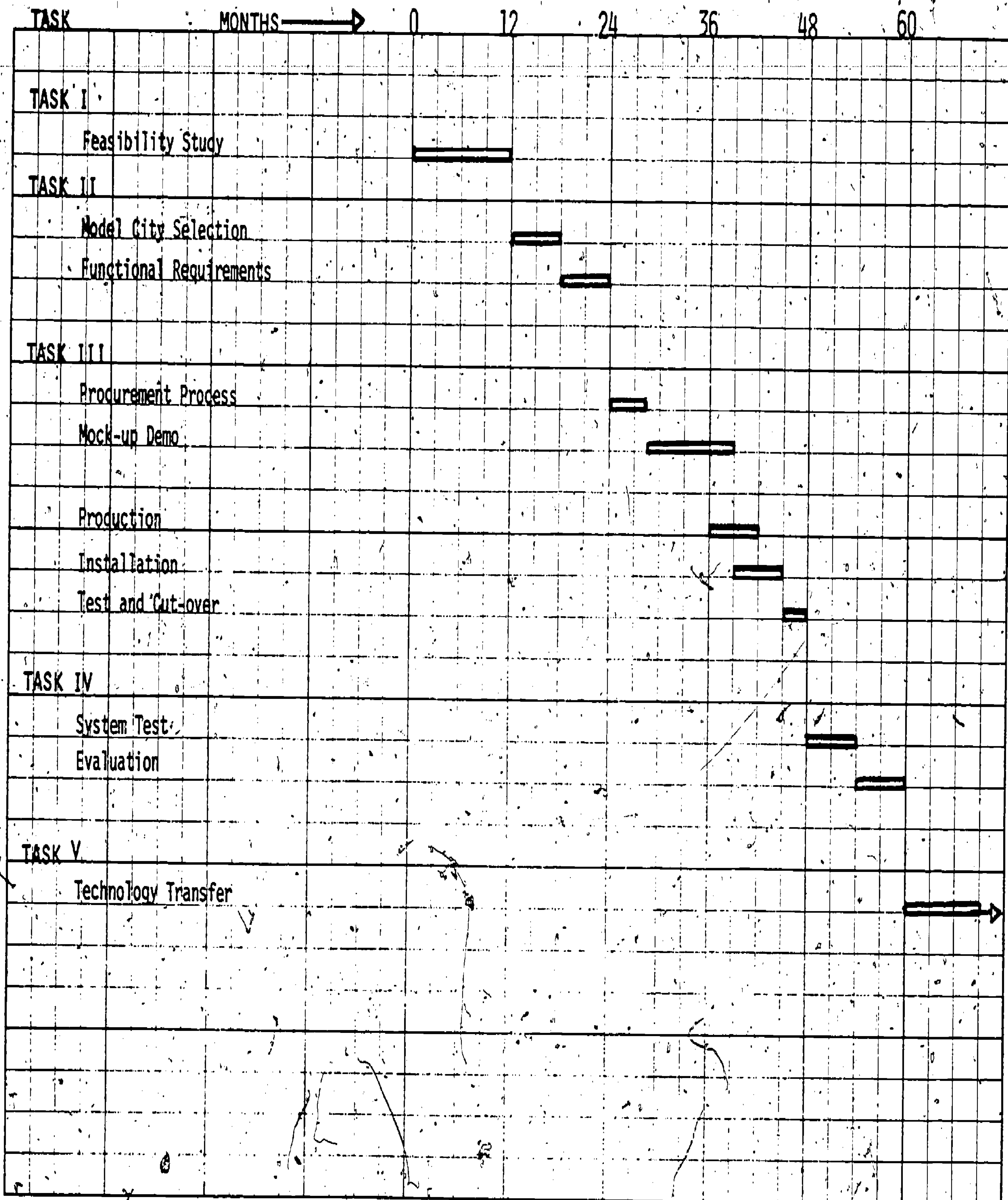

CHART 5.1 - PROGRAM SCHEDULE

BUDGET SCHEDULE

Time Period	Task	Federal Funding (Discretionary)	Local Funding
	PHASE I		
1st year	Feasibility Study	COMPLETE	
	PHASE II		
2nd year	Model City Selection		
	Operational Data Acquisition		
	Functional Requirements	$ 150,000	$
	PHASE III		
3rd year	Procurement Activity and Monitoring	200,000	
	Produce Mock-up and Test	275,000	25,000
4th year	Production, Installation Phase		
	315 mobile units (5% spare)		630,000
	6 RF Channels and Control Unit		75,000
	Installation, Cut-over, Training and instruction manuals,		215,000
	Program Monitor, Test and Checkout, Documentation	175,000	50,000
	PHASE IV		
5th year	Test and Evaluation	150,000	
	PHASE V		
6th year	Technology Transfer (Printing and Travel)	25,000	

CHART 5.2

APPENDIX I

COMMENTS OF ASSOCIATED PUBLIC-SAFETY COMMUNICATIONS OFFICERS, INC. (APCO)

IN THE MATTER OF

INQUIRY INTO THE PRACTICES AND
PROCEDURES FOR SPECTRUM MANAGEMENT
IN THE LAND MOBILE SERVICES GOVERNED
BY PARTS 89, 91 AND 93 OF THE COMMISSION'S RULES

DOCKET NO. 21229

(EXHIBITS OMITTED)

BEFORE THE

Federal Communications Commission

WASHINGTON, D. C. 20554

In the Matter of Inquiry into the Practices and Procedures for Spectrum Management in the Land Mobile Services Governed by Parts 89, 91 and 93 of the Commission's Rules.	)	Docket No. 21229

Comments of Associated Public-Safety Communications Officers, Inc. (APCO)

The Associated Public-Safety Communications Officers, Inc. (APCO), by its attorneys, submits the following comments in response to the Commission's Notice of Inquiry herein.[1/]

Introduction to APCO and Its Spectrum Management Activities

APCO is well known to the Commission as the nation's oldest public safety radio organization. Through its thirty active chapters and 3100 members, APCO has been a major force in public safety communications for the past forty years. APCO members are drawn from police, fire, local government, highway maintenance, emergency, and forestry conservation agencies; and many members have worked as volunteer frequency coordinators for

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1/ Notice of Inquiry, Docket No. 21229, FCC 77-287, released May 17, 1977 (hereinafter cited as "Notice").

various public safety radio services. The association has participated in lengthy and thorough investigations of numerous public safety radio topics including frequency coordination and implementation of statewide public safety telecommunications planning.1/

Through its activities in support of effective public safety radio systems, APCO has taken the lead in recognizing and adapting to changes in the functions and technical capabilities of public safety radio systems. APCO supported the introduction of digital technology, for example, as a means of performing tasks like vehicle monitoring and telemetering of emergency medical data. APCO has encouraged the trend toward integrated public safety radio systems which combine police, fire, ambulance, and emergency services into planned and coordinated systems necessary to meet their public responsibilities for saving lives and property. Finally APCO and its chapters have served as one of the official frequency coordinators for public safety applicants in the 470-512 MHz band as well as in lower bands.2/

1/ APCO's Frequency Coordination Manual (Project 5) and the recent investigation of statewide telecommunications planning (Project 13 and 13a) funded by the Law Enforcement Assistance Administration are particularly applicable to the Commission's endeavors. An earlier manual of Public Safety Standard Operating Procedures (Project 3) is also pertinent to this inquiry and will be referred to at various points. A list and brief description of APCO's 16 projects and studies in the public safety communication field are included as Exhibit II.

2/ See, Land Mobile - UHF TV Sharing, 30 F.C.C.2d 221, 232; 27 F.C.C.2d 371 (1971).

The Commission's *Notice* requests comments on matters at the heart of APCO's ongoing activities. The *Notice* announces a new regime in land mobile spectrum management to be comprised of a nationwide data base of land mobile systems, standardized frequency coordination procedures followed by private (non-FCC) groups, and monitoring of land mobile transmission to chart channel utilization. (paragraph 1). Much of the analysis in the *Notice* is drawn from the Commission's experience with the Chicago Regional Spectrum Management task force which attempted a centralized and computerized approach to frequency assignments and spectrum management. The Commission has determined to carry over the concept of a computerized data base and channel monitoring from the Chicago plan, while turning to private frequency coordinators for the bulk of the work in advising applicants and recommending frequencies. (paragraph 21). Comments were requested on each element of the plan, particularly the organization of the data base and the format for channel monitoring and use of channel occupancy data. (paragraph 20, 34). Standards and guidelines for frequency coordinators are to be promulgated by means of a rulemaking proceeding devoted to that topic (paragraph 22).

The Commission's plan for spectrum management is ambitious and far-reaching; it calls for serious and thoughtful efforts on the part of the Safety and Special Radio Services Bureau and the land mobile community. To respond to the proposals and topics set forth in the Notice, APCO has assembled a special task force made up of members with experience in spectrum management and frequency coordination matters. The task force includes representatives of all geographic regions of the country and of state and local public safety organizations. Some members were active in the Chicago area regional spectrum management experiment from which much of the data and proposals in the Notice were drawn. The comments presented by APCO reflect the collective judgments of the task force, the officers and the National Office, made after extensive study and debate.

Summary of Comments

The Commission has requested comments on three distinct but related phases of an overall spectrum management program: the organization and use of an FCC data base; a system of private frequency coordination; and a program of monitoring actual spectrum usage. For convenience, APCO will direct its comments to each of these elements in turn.

The FCC Data Base can be analyzed in terms of its three primary elements: a) what information belongs in the data base? b) how to acquire and accurately maintain the needed data? and c) how and to whom should the information be made available? The Commission has made excellent progress in developing a number of elements for its data base, and it has recognized that the primary responsibility for building and operating the data base rests with the FCC alone. APCO has made certain suggestions regarding the list of data items developed by the Commission which are attached as Exhibit 1.

At the same time, we feel that the Commission's list of data items fails to come to grips with the basic issues of deriving meaningful channel loading criteria and incorporating the data that determines compliance with that criteria in the data base. That is, determination of the constituent elements of channel loading criteria is basic to any rational decisions regarding spectrum management, and this determination cannot rest on number of mobiles alone. The monitoring data acquired by the Spectrum Management Task Force (SMTF) and set out in Appendix B shows the lack of correlation between numbers of vehicles assigned per channel and channel occupancy in terms of air time. Further, neither of these factors describes channel utilization in the context of how that utilization pertains to the ability of public safety systems to meet their responsibilities in the public "interest, convenience, or necessity." Until measurement of channel utilization in relation to needs is established, decisions regarding channel assignments must be arbitrary and devoted to the minimal objective of preventing interference between channel users rather than structuring a spectrum management program that accounts for the wide range of public safety responsibilities.

In the absence of comprehensive criteria relating channel usage to the licensee's needs, then the level of service, i.e., the waiting time or probability of delay that is acceptable to each channel user, should be the criteria by which the maximum or optimal channel loading can be measured. Numbers of vehicles per channel is only one factor that determines the level of service that can be expected. Average message length, message handling time, and frequency of messages per unit bear just as heavily upon channel availability as does the number of vehicles assigned to the channel. Since these considerations are fundamental to channel usage and critical to frequency assignments and channel sharing concepts, this information or its algorithm should be derived for each service and incorporated into the data base.1/

In sum, APCO believes the Commission should employ tools that measure channel loading in terms of the licensee's service needs and activities, and incorporate the appropriate data items in the data base. Additionally, procedures to validate data base information periodically need to be adopted.

Once the structure of a data base has been established, the next problem is to develop the machinery and procedures needed to acquire and maintain such data with the degree of accuracy required. It is APCO's position that the acquisition and

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1/ See, APCO's An Introduction to the Theory of Waiting Times, Thomas Church and Janis Church, December 15, 1973. This study contains information needed for a mathematical calculation of waiting times for a public safety system.

maintenance of such a data base is clearly the responsibility of the Commission, since only the Commission has the authority through its licensing procedures to insist that such data be provided by the users of the spectrum and to apply sanctions to those who fail to comply. Once the data is collected, the organization and storage of such data is a purely mechanical function that can be accomplished by systems developed by the FCC or by a private data processing organization under contract to the Commission.

Finally, the data base must be made available to those most needing it. As long as the Commission must depend upon others to fulfill its responsibility by coordinating frequency selections, the Commission has the duty to support those coordinators with the tools they need. Since public safety coordinators serve the Commission on a voluntary basis, the Commission must assume the responsibility of providing them the means of access to its data at virtually no cost. A toll free number by which a coordinator can obtain immediate access to the data base may be adequate in many cases. In others, a terminal accessing the data base at the coordinator's location may be appropriate. In all cases, updated printouts of licensees and activities in the pertinent areas should be provided to each coordinator on a periodic basis.

Turning to frequency coordination, APCO has long maintained that the responsibility for frequency assignment and spectrum management rests with the Commission. Under present and foreseeable levels of Commission resources, however, APCO wholeheartedly concurs with the Commission's recognition of the role that must be played by volunteer service coordinators. APCO will continue to participate in such a program and support the Commission to the limit of APCO's abilities. Should the Commission determine that it is in its best interests to develop a single point of contact for public safety coordination, APCO is willing to provide such a service on a representative basis.

The role of coordinator is of such magnitude in spectrum management that plans and policies associated therewith must be based on a realistic evaluation of current resources. When the nationwide data base attains the necessary accuracy and completeness, coordination policies can be based upon the existence of such data. However, until such a data base becomes available, the coordination function and procedures should rely on the information that now exists and the present workable system. We also suggest that any program of coordination should incorporate the development of guidelines that define the responsibilities for and standards of all coordination performed under the auspices of the Commission, so that the Commission's "audit" function can be fairly performed.[1/]

1/ Guidelines for coordination procedures should be prepared by user groups in conjunction with the Commission staff. APCO offers its fullest support to the Commission in the development of such standards and guidelines.

Finally, the Commission is aware of APCO's belief that the development of statewide, municipal, and regional planning for public safety systems is beneficial to both the taxpayer and the Commission.[1/] Such systems enhance the operational capability that public safety agencies can provide from a given level of resources and, when conceived with sufficient consideration of spectrum conservation needs, work toward the Commission's stated objective of increased efficiency in spectrum utilization. The Commission's present procedures fail to accommodate the spectrum planning and long term implementation schedule often associated with such systems, and this deficiency should be corrected by the development of procedures and criteria for approval and implementation of public safety plans.[2/]

In terms of the Commission's <u>spectrum monitoring program</u>, APCO supports the Commission's determination to improve its spectrum management data and has suggested parameters for measuring public safety radio needs and uses. To the extent that the Commission considers its present, limited capability for spectrum monitoring within localized areas be of cost effective assistance to its accomplishment of its spectrum management responsibility, we support the Commission's decision. We do not,

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1/ See, <u>Notice of Proposed Rulemaking</u>, Docket No. 21350, FCC-77-523. August 30, 1977, at para. 5.

2/ See also, APCO's Comments in response to the <u>Notice of Proposed Rulemaking</u>, Docket No. 21350, filed October 7, 1977.

however, feel that any tool of such limited applicability should be considered to be a panacea; proper spectrum management must be based upon the Commission's commitment of adequate resources, continously available, on a nationwide basis. For the interim period, it should be noted that valuable channel utilization data can be obtained from the licensees by requiring relatively inexpensive and unsophisticated monitoring devices, entries in station logs, channel recorders, and other steps.

Discussion

I. An Accurate and Accessible Data Base is Essential to Any Long Term Spectrum Management Plan.

In discussing the Commission's d
long-term scheme for frequency assignments
ment in the land mobile services, one poir
directly and on a threshold level. An eff
ment plan is critically dependent on an ac
data base organized and maintained by the
the information on which spectrum decision
other party is in a position to compile ar
hensive data base because no one but the F
ment of all frequencies, licensing and rer
the enforcement of technical standards. N
authority to establish standards and to im
non-compliance. Thus it is readily appare
holds the key to the success of its spectr
the establishment and maintenance of an ac
and accessible data base.

The utility of the data base in
under current spectrum management policies
accurate information as to the present occ
the technical and operational characterist
and the extent of their use of the channel
tem of assignments of frequencies to each

local frequency coordinators and the FCC Staff could keep fairly simple records of channel assignments and occupancy. Major additional complexities arose, however, when the concepts of pools of kindred services and mandatory channel loading standards in terms of mobile units were introduced in Docket No. 18261.1/ For assignments from the General Access Pool and the 900 MHz channels,2/ the frequency coordinator is presently totally dependent upon the FCC for information as to which channels have been assigned to the various services and licensees. The FCC responsibility for day-to-day coordination and frequency selections has grown proportionately.3/

1/ The Commission determined to assign frequencies by service pools rather than individual services in its decision to allow sharing of certain UHF-TV assignments. The frequency coordination systems in the lower bands adapted to the service pool concept by expanding the services performed by major coordinating groups. Land Mobile - UHF-TV Sharing, 27 F.C.C.2d 371, 30 F.C.C.2d 232 (1971).

2/ In Docket No. 20909, the FCC determined to place all remaining unassigned channels in the UHF-TV shared band, 470-512 MHz, into one General Access Pool rather than leaving unassigned channels in the service pools. Report and Order, FCC 77-226, April 18, 1977. The channels allocated at 900 MHz were placed in a single pool at the outset, with the FCC staff making all assignments. Second Report and Order, 46 F.C.C.2d 752 (1974).

3/ In order to improve 900 MHz frequency assignments, some frequency coordinators have petitioned the FCC to allow private coordination in 900 MHz frequency selections by assigning coordinators certain starting points in the channel pool. See, RM 2908, Comments filed July 20, 1977. For the General Access Pool, frequency coordinators are advised by the FCC when a channel has been assigned to their services, and coordination work starts anew from the channels assigned.

When the problems of increasing size and complexity of public safety systems are added to those of pooling channels and mandatory channel loading standards, the information required by the frequency coordinator and the FCC becomes more complicated. With inter-service, co-channel, and adjacent channel sharing, information is needed on the types of systems operated by each licensee, including: the antenna height and power of the systems; the functions performed by each system; the number of mobile or portable units involved; the location and antenna characteristics of remote receivers; the type and frequency of tone control devices employed; and any other unique aspects of each system. Those factors that affect channel availability, such as message length, messages per unit and number of units per channel, are some of the additional topics that must be considered in making channel usage decisions. A computerized data base offers the best mechanism for keeping accurate and accessible records of existing and proposed systems and their characteristics. The Commission is to be commended for moving toward the goal of a data base in which this vital information is coded, indexed, and stored for easy retrieval on a timely, inexpensive basis.

A. Items of Information Needed in the Data Base.

Turning to the specific items of information to be included in the data base, a number of items should be added to the list for the new application form in Appendix A. These items range from the telephone number of the applicant to the antenna pattern for any remote receivers. For the Commission's convenience, APCO's suggestions have been added to the format in Appendix A, and a revised list is attached to these Comments as Exhibit I. Most of the suggestions are self-explanatory, but a few items will be emphasized briefly here.

In the section Nature of Proposed Modification (Item 5), the list of technical characteristics should be revised to state (A) "change in power" and (E) "change in antenna height, gain or directivity" instead of "increases" in those factors. The assignment of channels may be affected by a reduction or other change in power, antenna height, gain and directivity, as well as by an increase therein, and information on any changes will be needed by the frequency coordinator. Other useful information includes an incremental estimate of mobile units (Item 6 II) and the number of portable-mobile units as a class of mobile units.

In technical data (Item 8), a category should be added for Coded Tone Squelch frequencies or systems, since the use and characteristics of these systems have a significant impact on adjacent and co-channel compatibility. Other items should be added to cover the antenna pattern and direction, the antenna's center radiation point and the antenna pattern of any remote receivers, since such characteristics affect the potential for interference to and from the system.

The above suggestions to Appendix A of the Notice are essentially minor in nature; APCO's major recommendation is that the Commission develop accurate and meaningful criteria for measuring channel loading and that this data be incorporated in the data base. In the public safety area, channel loading criteria in terms of numbers of mobile units or portables per channel are inadequate to describe the actual usefulness of the channel in meeting public safety responsibilities. Factors that affect waiting time before access to the radio system,[1/] such as average message length, message handling time, and frequency of messages are crucial determinants of whether a public safety radio system provides the support required by public safety personnel. In many cases, for example, a lengthy waiting period for access to the system can mean the difference between life and death for police officers, victims of crime and fire disasters, and others involved in emergency situations. The other named parameters of service have similar impacts on the actual functioning of public safety systems to meet their responsibilities.

APCO recognizes that a loading criteria based on the number of mobile units is simpler and easier to administer than parameters that determine waiting time, such as message length, frequency of messages and the like; but the simplicity of the present criteria should outweigh their severe drawbacks in accuracy. The Commission must devise a more accurate and sophisticated

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1/ See, APCO, An Introduction to the Theory of Waiting Times, Thomas Church and Janis Church. December 15, 1973.

measure of channel occupancy for public safety systems based on the role they play in public safety operations. Numerous studies have been made of police and other radio systems,[1/] and these resources are available to help the Commission in determining adequate channel loading criteria. Without this effort, however, the Commission's data base will not reflect public safety needs.

B. Access to the Data Base.

Access to the data base may depend in large part on the scheme of frequency coordination which the Commission adopts, as the frequency coordinators and the FCC Staff are seen as the primary users of data base. Nonetheless, a number ~~of general~~ observations can be made regarding the kind of access needed by any network of coordinators. First, some coordinators may need on-line access to the data base by means of a toll-free telephone network, or from low-cost terminals connected to a telex or TWX network. Such instant access to valid data may be a necessity in some areas to provide accurate, current information when the frequency coordination work load is heavy. Since the coordinators are performing a job that is essentially the FCC's, moreover, provision of the tools they need should be an FCC responsibility.

1/ APCO's Project 3 was one study of police radio operation. The summary portions of the Project 3 Report (Phase One) are attached as Exhibit IV.

Second, coordinators should be sent periodic printouts or microfiche of all pending and recently granted applications in their geographic service areas; alternatively, copies of all licenses, modifications, and renewals should be sent to the applicable coordinator. It is recommended that the printouts be monthly so that the reports will have sufficient currency to be useful.

Third, retrieval access to the data base should be possible by any interested party including engineering firms, equipment vendors and licensees, upon payment of appropriate fees if necessary.

As for modes of retrieval, the list of primary search key parameters in Appendix A (p. 10) is adequate for frequency coordination work. APCO's prior experience indicates that the licensee's legal name, service, call sign, frequency and geographic area are the most useful parameters, and these files should be cross-indexed with each other to assure easy reference. Information under these search keys should be available by geographic areas, including multistate or intrastate areas as appropriate.[1/]

1/ The frequency coordinator in Connecticut, for example, may need information on systems in Rhode Island, Massachusetts, New York, New Jersey, and Pennsylvania; while the coordinator in Los Angeles may need only Southern California data. An index of geographic areas for which data can be retrieved would be helpful.

II. Frequency Coordination Procedures in the Interval Until the FCC Data Base is Implemented.

As the Commission is well aware, APCO's basic position is that, in concept, frequency coordination is the responsibility and burden of the Commission as a necessary step in meeting the purpose for which it was created. However, unless and until the Commission is equipped to do the job properly and effectively, APCO will continue to be a strong supporter of frequency coordination performed by volunteers from the various radio services and has committed major efforts to that end. APCO members take part in local frequency coordination advisory committees for public safety radio applications in many parts of the country. As part of its emphasis on regional communications planning, moreover, APCO has stressed the role of frequency coordination in assuring effective use of frequency assignments.

Under present conditions, the Commission's decision to rely on voluntary frequency coordination efforts, rather than analyze all frequency questions by the Commission in Washington, meets with firm approval from APCO. At the same time, the fact that the volunteer coordinator is taking on a part of the Commission's burden should be recognized. Such volunteers must look to the Commission for support. As noted earlier, the establishment of a proper data base with provision for means of access borne by the Commission is one way in which such support can be provided.

A. Organization of a Frequency Coordination System.

In discussing frequency coordination systems, certain fundamental defintions and ground rules should be agreed upon by the Commission and private parties. APCO's experience with frequency coordination activities performed by area coordinators or committees of affected users has been favorable and successful. APCO proposes the following definitions and criteria as descriptive of those seeking to assume the critical role of a designated single point coordinating organization:

(1) Designated Coordinating Organization:

Definition: A national organization of radio spectrum users that is authorized by the FCC to provide coordination services on a national basis to license applicants in designated user services.

Purpose: To provide uniform administrative and supervisory support to its selected coordinators on a single point of interface between such coordinators and the FCC.

Elements:

1) An established organization having a national distribution of radio service user members.

2) A permanent national office employing a permanent staff.

3) A governing mechanism, responsive to the membership and authorized to exercise supervisory jurisdiction over the spectrum management related activities of its membership.

(2) Coordinator:

Definition: A member of a Designated Coordinating Organization, authorized to accomplish a coordination function for specified land mobile radio service(s) in a specified geographic area.

Purpose: To provide coordination service to appropriate radio frequency license applicants in a designated area.

Elements:

1) Authorized by the Designated Coordinating Organization.

2) Resident of or employed in the geographical area in which he acts.

3) Complies with established standards and procedures.

(3) Coordinating Committee:

Definition: A committee of coordinators authorized to coordinate for specified user services in a designated geographical area.

Purpose: To assure maximum utilization of the RF spectrum by spectrum management decisions of the committee.

Elements:

1) Comprised of authorized coordinators.

2) Membership includes those directly affected by spectrum management decisions of the committee.

(4) Coordination:

Definition: An approved procedure for processing requests for radio frequency recommendations.

Purpose: To achieve and maintain an optimum level of compatible communications systems in a given geographical area.

Elements: 1) Advisory in nature.

2) Provided by authorized individual (s).

(5) Advisory Procedure:

Definition: The process of making recommendations on technical, administrative and regulatory matters affecting utilization of the radio frequency spectrum.

Purpose: To assure that maximum operational benefit is derived from use of the spectrum available.

Elements: 1) Reflects local geographic and system related requirements.

2) Accomplished prior or subsequent to issuance of a license.

(6) Coordination Plan:

Definition: A document, approved by the FCC, that defines the procedures by which the coordination function will be accomplished.

Purpose: To define responsibilities, authorities, procedures and practices associated with the coordination process for the benefit of those affected by spectrum management decisions.

Elements: 1) A formal publication of a Designated Coordinating Organization.

2) Approved by the FCC.

3) Available to license applicants and users of the spectrum.

An organization seeking to become a designated coordinating organization should submit a plan for FCC approval that meets the above definitions and covers:

1) Eligibility:

   A) Name of organization
   B) List of its current officers
   C) Address of its principal business office
   D) Aims and objectives and geographic scope as documented by a copy of its by-laws
   E) Identification of its served radio services as specified by its by-laws membership qualifications

2) Ability:

   A) Resources: administrative:

      (1) Number of paid employees, job descriptions
      (2) Background and experience
      (3) Office space and equipment
      (4) Legal services

   B) Resources: membership:

      (1) Number of members by membership category
      (2) Number of members by radio service
      (3) Geographic distribution of members (chapters, etc.)
      (4) Typical job responsibilities of members
      (5) List of current coordinators, job titles, etc.

   C) Resources: financial:

      (1) Copy of last annual fiscal report
      (2) Copy of current budget
      (3) Indication of change, if any, caused by proposed coordination procedure

3) Activity:

   A) Services regularly provided to membership and others
   B) Participation in Commission proceedings
   C) Trade shows
   D) Seminars and schools
   E) Chapter, regional, and national meetings
   F) Projects and studies
   G) Other

4) Coordination procedure:

   A) As currently performed
   B) As proposed in attached documents

In APCO's view, the definitions and criteria set out above establish private frequency coordination efforts on a sound basis for the public safety radio services in all radio bands. We urge the FCC to adopt these definitions and criteria as part of its program to rely on a private frequency coordinating entity in the public safety radio services and to the extent appropriate in other services. In addition, certain other fundamental points should be included in proposed rules to formalize the scope needed for a public safety frequency coordination system.

B. Scope of a Public Safety Frequency Coordination System.

First, as noted above, APCO supports the use of private frequency coordination efforts in all radio bands including 900 MHz. It is our view that the frequency coordination process, with its detailed work before and after licensing of systems, is the best method of insuring the existence of compatible and effective radio systems. The 900 MHz spectrum is no exception in this regard.

Second, APCO supports frequency coordination for all public safety radio applications including those which are part of regional plans, which propose shared use of relay facilities, and which employ field engineering surveys. While we recognize that some applicants may choose to use a field engineering survey or that duplication may occur with multiple requests for a shared relay facility, the job of the coordinator can be seriously compromised by frequency assignments made on the basis of applications of which the local coordinator is unaware. Since the coordinator has been assigned the major responsibility for frequency recommendations, his work should be supported by requiring applicants to submit a copy of their applications to the coordinator at the same time a filing is made with the FCC. This contemporaneous notice is necessary for the coordinator to have an opportunity to comment on the application before it is granted and to avoid conflicting frequency recommendations during the interval between the filing of an uncoordinated application and the grant of the application.1/

Applications which are made in connection with comprehensive public safety telecommunications plans should also be subject to the frequency coordination process so that the coordinator can advise the participating agencies and be advised of any changes or modifications in the plan.2/ In addition to specifying frequency coordination for comprehensive plans, the new Rules should contain a process whereby the FCC and the coordinators monitor and participate

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1/ To preserve the options of field surveys while also keeping coordinators abreast of applications, the request for coordinators' comments should be combined with the FCC application form. With a space for the coordinator's recommendations and comments, the form would contain all the information needed both by the FCC and the coordinator. Whatever mechanism is adopted, the Rules should provide for the notice needed by the coordinator at the time the application is filed.

2/ APCO recognizes and has promoted the process of preparing, adopting, and implementing statewide plans. Frequency coordination should be an aid in identifying necessary modifications.

in the implementation of a plan that has been approved. The structure of an approval and implementation process is discussed further below. (pp. 30-31).

Third, in endorsing private frequency coordination efforts for all applications, APCO does not call for a delegation of authority from the FCC to the coordinators. Just as the FCC is the only entity that can organize and maintain the data base necessary for any system of frequency assignments, the Commission must also bear the ultimate authority for frequency assignments, monitoring, and enforcement of its license provisions. The frequency coordinator should make recommendations as to the channel assignments and technical or operational considerations affecting area use of the channel, but the coordinator should not be empowered to delay submission of an application unless or until his suggestions are adopted.[1/] Similarly, in cases of disputes between the coordinator and the applicant, including disputes over applications based on field engineering surveys, each party should have an opportunity to submit written comments in support of his view prior to an FCC decision. The Commission's decision should be confirmed in writing, accompanied by a brief statement of reasons, and provided to all parties to the dispute.

1/ By the logic of APCO's position on this point, the frequency coordinator should not "administer" a public safety telecommunications plan. The mechanism for approving and implementing a statewide plan vis-a-vis FCC requirements should be an FCC process clearly set out in the Rules.

Finally, the FCC computer model for selecting frequencies, the Automatic Frequency Assignment Model or AFAM, should be available to provide assistance to the coordinator. As the Notice acknowledged (Paragraph 21), reliance on AFAM as the sole source of frequency selections in the Chicago region was unsatisfactory because of the individual judgments and human factors involved in many applications. Indeed, in crowded areas frequency coordinators tailor systems to an existing environment, an individual process that has not yet been programmed for computer solution. The computer's capabilities can be valuable to the coordinator if used for a first order approximation of all possible frequency selections from calculations of the applicant's coverage requirements and those of existing systems. A printout of AFAM's frequency recommendations and the supporting calculations should be available to the coordinator at his request for use in making a frequency recommendation. In cases where the coordinator's recommendation differs substantially from AFAM's selections, a statement of the unique factors of the application might be requested to explain the deviation. In this manner, the AFAM model can be used to assist the frequency coordinator as well as to assess his selections.[1/]

1/ APCO's program for frequency coordination in the Chicago region follows this approach. See, Exhibit II, infra. This program could be a model for future efforts with AFAM.

C. APCO's Program for Frequency Coordination in the Public Safety Radio Service in the Near Term.

The eventual frequency coordination system determined as best suited to the public safety services will depend upon the establishment of an FCC data base having necessary information, accuracy and currency, together with the means of access to it. It will require the adoption of fundamental definitions and ground rules, and the establishment of a frequency coordination process that results from future rulemaking proceedings on frequency coordination as announced in the Notice (Para. 1).

The question of guidelines and standards for frequency coordinators is one which APCO has previously addressed at some length. In 1971, an APCO task force drew up a Frequency Coordination Manual as a model for its local coordination committees. This Manual was designed as a guide to public safety coordinators in the unique aspects of public safety radio while recognizing that each local area may differ in applying the suggested procedures.1/ If the FCC determines that one organization should perform frequency coordination for all public safety radio applicants,2/ APCO has the

1/ The difference between public safety radio systems across the country have led APCO to operate its frequency coordination work by local committees under the administrative supervision of its National Office to a great extent. It is our view that efforts will always be required by public safety radio personnel who are well informed in local areas.

2/ A number of land mobile radio organizations have petitioned the Commission to establish four national coordination entities for coordination in the 900 MHz band. Rm 2908, Comments filed July 20, 1977.

capability to assume that role. The framework adopted would be sufficient unto itself but would provide for participation of other public safety organizations should they desire to do so. APCO is prepared to move toward a more comprehensive system of coordination, unified under its National Office and organized for Commission auditing, as may be necessary.

The Commission's comments about lack of standardization, however, must be considered in light of the widely varying characteristics of the radio services. Public safety radio systems have unique factors of governmental involvement in planning and budgeting, public responsibilities for safety of lives and property, and a need for all local and state organizations to coordinate with each other in degrees ranging from everyday working arrangements to a cognizance of abilities and functions in times of disaster and emergency. These unique factors mean, for example, that channel loading criteria in numbers of mobile units are not wholly appropriate for public safety systems, a point discussed in detail elsewhere. The public safety coordinator must be knowledgeable in the unique aspects of public safety radio systems and empowered by the Rules to make frequency recommendations that best fill the perceived needs. A frequency coordination program that is standardized for all services and limited by rigid channel sharing and loading rules will not yield the best results for public safety systems.

D. Frequency Coordination in the Chicago Region.

APCO is prepared to resume its frequency coordination efforts in the Chicago region on any date the Commission may set. APCO members have worked with the Spectrum Management Task Force throughout the Chicago experiment, and discussions have been held regarding possible procedures for increasing the role of private coordinators. Exhibit II attached to these Comments offers a proposal for private frequency coordination in the Chicago region, building upon the task force experiment.[1/] Our proposal envisions use of the AFAM model at a preliminary stage in the application process with the final frequency selected by the FCC staff from the AFAM calculations and the coordinator's recommendations. This APCO plan could be implemented by all radio services or only public safety services. It will be necessary, of course, for those performing coordinating activities to have access to the present data base of Chicago area licensees in order to start their work and to continue it. Access should be arranged on the basis described in Section I above, and this experience may offer field data for designing the nationwide access program.

1/ The proposal in Exhibit II is based upon discussions between APCO and Commission Staff officials shortly prior to termination of the Chicago experiment. There was basic agreement that such an approach would be tried. However, it was not implemented because of termination of the experiment shortly after the agreement was reached.

III. Spectrum Monitoring and Channel Usage Data are Tools in Effective Spectrum Management.

The third area of inquiry in the *Notice* involves the Commission's program of monitoring land mobile channels to compile data on actual channel usage. The *Notice* reports the preliminary experience with spectrum monitoring in Chicago and requests comments on the data to be gathered and the use of the data. As the Commission recognizes, a comprehensive program of spectrum monitoring is difficult to implement and uncertain in results. (*Notice*, Appendix B). For public safety radio systems, moreover, spectrum monitoring must recognize the characteristics of public safety systems and the way they differ from those of other radio services.

Public safety systems must operate 24 hours per day, seven days a week, to meet their public responsibilities; indeed, a large percentage of their activities occur outside of normal working hours.[1/] Monitoring of public safety systems should take into account this fulltime use. The monitoring data should also be read in light of other operational factors such as the need for instant communications when an incident occurs. A major performance criterion that must be satisfied in the design of public

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1/ Studies of crime statistics, for example, show large percentages of crime at night and on weekends. Similarly, large numbers of traffic accidents occur during the evening rush hour and on holiday weekends. Major civil disasters and emergencies call for 24-hour-a-day radio systems until the crisis is over. *See, e.g.*, *National Commission on Criminal Justice Standards and Goals, Police*, 1973, at 200-04.

safety radio systems is the waiting time of mobile or portable units before effective contact with the control point is established, since an unduly long waiting time can mean the difference between life and death in certain situations. Apart from such extreme cases, public safety communications in general must place a higher priority on quick access to a control point or to other mobiles or portables than many non-safety licensees, and the FCC channel loading criteria should recognize this need.

Another factor unique to public safety systems is the need for functional designation of one or more channels in a system. Detective or undercover police units, vice squads, and other police units may be assigned a channel for their use only to insure instant access to a control point or other points of communications and to protect the identifies or locations of undercover personnel. Another channel may be assigned only for dispatching purposes, so that dispatch orders and calls to all units can be made without delay or interference. These functional designations have a vital role that should not be overlooked in an attempt to evaluate spectrum use.[1/]

1/ APCO's Project 3, the study of public safety operating procedures, contains detailed support for the unique factors of public safety systems. A copy of the Summary from Project 3 is attached as Exhibit IV.

A fourth factor unique to public safety radio systems is the increasing use of comprehensive telecommunications plans. Working with the Law Enforcement Assistance Administration, APCO has encouraged the development and use of local and regional plans that provide for efficient use of frequencies and the development of operational compatibility between many city, county, and state public safety agencies. In previous filings with the Commission based on the extensive studies of Projects 13 and 13a, APCO urged the acceptance and accommodation of public safety plans in frequency assignments and channel loading requirements.[1/] Since this proceeding may lead to proposed Rules to aid spectrum management, provision should be made for a process of FCC approval of a public safety plan. The following definition of a public safety telecommunications plan should be recognized by the Commission as the first step in this process:

> Public Safety Telecommunications Plan
>
> A document which defines the use of portions of the radio frequency spectrum in a specific telecommunications system by a tax-supported agency or agencies. Such plan must be justified by analysis of operational requirements in light of channel utilization and by evidence of financial support and other factors which will insure implementation within a planned time frame. All Public Safety Telecommunications Plans should be accompanied by a statement from frequency coordinating committees indicating potential availability of frequencies.

1/ See, APCO's Petition for Reconsideration and Clarification filed in Docket No. 20909, May 2, 1977.

If a plan meets these criteria, it should be submitted to the FCC for review as to its licensing needs. Upon the Commission's concurrence, the agencies participating in the plan and the applicable coordinators should be given written assurance that frequencies will be made available, preferably those recommended by the coordinator, to implement the plan.

Apart from urging the Commission to recognize and accommodate the unique aspects of public safety systems in any spectrum management system, APCO supports a continuation of monitoring to the extent the Commission feels useful in major cities where a specific need for channel occupancy data may exist. It should be noted that a full-time, comprehensive system of monitoring would entail a commitment of resources and priorities far above the level contemplated in the Notices. Until the Commission is prepared to commit the resources needed, a number of interim steps can be taken to obtain accurate and useful data. These steps include increased requirements for entries in a station log, inexpensive recording devices or time keeping attachments to the station transmitter and receiving equipment.

Under any system of monitoring, public safety organizations and the frequency coordinators should have access to the monitoring data when requested. Any suggestions for increased sharing of channels should be made in close consultation with the coordinators.

Conclusion

The implementation of an effective system of spectrum management and frequency coordination for the land mobile radio services will be critically dependent upon the determination of the FCC to fulfill its responsibilities within the limit of its resources. The Commission is the only party that can assemble the information and resources to construct an accurate data base of licensees and provide low cost access to it. Similarly, the Commission is the only party which can organize and carry out a program of channel monitoring, taking into account the operational factors of the systems surveyed, analyze the data in accordance with meaningful criteria, and enter this data into the data base. In the public safety area, the data base and channel loading standards must take into account average message length, frequency of messages, and other factors which affect the waiting time for access to the system.

In the interim until establishment of an adequate FCC data base, certain measures can be taken to rationalize and upgrade the frequency coordination program. APCO has made suggestions as to definitions relating to frequency coordination activities. If the FCC determines that one organization should handle frequency coordination in the public safety radio services, APCO is prepared to assume that role through its National Office and local coordinating entities. APCO has unique qualifications to do so stemming from its organization, membership expertise, past studies, reports, and other projects bearing upon public safety matters, and other resources as discussed above. Further changes in the frequency coordination system should await the organization and availability of the FCC data base and the coming inquiry on frequency coordination procedures.

Finally, in any spectrum monitoring and channel loading program adopted for the future, APCO urges the Commission to recognize and accommodate the unique aspects of public safety radio systems. Chief among these factors are planned and integrated systems, the 24-hour, seven-day work week of our systems, and the need for functional designation of some channels and nearly instantaneous communications in many situations. For these reasons, channel loading criteria must be more meaningful than the number of mobile units per channel, and frequency assignments must be tailored for the operational requirements of public safety systems.

Respectfully submitted,

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ABBREVIATIONS

AMST	Association of Maximum Service Telecasters
APCO	Associated Public-Safety Communications Officers, Inc.
AT&T	American Telephone & Telegraph Company
AVL	Automatic vehicle location
CAD	Computer aided dispatch
db	Decibel
EIA	Electronics Industries Association
ERP	Effective radiated power
FCC	Federal Communications Commission
IACP	Internal Association of Chiefs of Police
IBT	Illinois Bell Telephone
ID	Identification
IF	Intermediate frequency
IMTS	Improved Mobile Telephone Service
ISM	Industrial, scientific and medical
LEAA	Law Enforcement Assistance Administration
LMCC	Land Mobile Communications Council
NABER	National Association of Business and Educational Radio, Inc.
NARUC	National Association of Regulatory Utility Commissioners
OTP	Office of Telecommunications Policy
RF	Radio frequency
SIRSA	Special Industrial Radio Service Association, Inc.
SMRS	Specialized Mobile Radio Systems
UHF	Ultra high frequency
VHF	Very high frequency
WARC	World Administrative Radio Conference

GLOSSARY

ambient noise	-Environmental or background electromagnetic noise
antenna gain	-An antenna characteristic that increases the power density in a given direction by concentration of radiated energy
authorized transmission	-A message whose content is in keeping with the authorized purposes of the licensee
automatic vehicle location	-A technique using RF energy to automatically determine the location of vehicles and to report their positions to a central control facility
channel loading standards	-FCC standards designating the number of mobile units that must be assigned to a single channel before that channel is considered "fully loaded", thereby justifying the assignment of additional channels
community repeater	-A base station used by more than one licensee to provide an extended area of communication with the licensee's mobile units. All users of the community repeater jointly share the community repeater's license responsibility.
coordinating committee	-A committee of coordinators authorized to coordinate for specified user services in a designated geographical area
coordinator	-A member of a designated coordinating organization, authorized to accomplish a coordination function for specified land mobile radio service(s) in a specified geographic area
fleet dispatch	-A communications process by which a number of mobile units monitor all transmissions from a common point to receive information that may pertain to only one or more units of the fleet in any given instant
foliage loss	-Attenuation of electromagnetic energy caused by the absorption by trees or other growth in the path between transmitter and receiver
frequency assignments	-A frequency authorized by the FCC for use by a licensee for purposes specified on the license
functional requirements	-Those capabilities a system must provide to fulfill the operational needs of the user
geographic re-use	-Re-use of a specific frequency made possible by geographic separation or shielding from undesired signals
isotropic radiator	-A radiator of electromagnetic energy that radiates equally well in all directions (a theoretical concept)
licensable	-An application for use of the spectrum that is in compliance with the FCC's Rules
paging	-A communication service in which a base station provides one-way communication to subscribers, usually involving only "beep tone" notification
path loss	-The attenuation of electromagnetic energy over the path between two points

peak loading	-The maximum traffic level to which a radio channel may be subjected. Peak loading of law enforcement channels usually occurs during periods of maximum criminal activity or major community emergencies
radio common carriers	-Those who provide radio communication service to the general public
satellite sites	-Remote transmitter and/or receiver sites connected to a central control station usually by landline or microwave links that provide radio communications coverage of selected areas that cannot be served adequately from the base site
simulcasting	-A technique of transmitting from two separate sites simultaneously on a common frequency. Careful control of both audio and radio frequencies at each site is required to preclude distructive interference in regions covered by more than one simulcasting transmitter
system configuration	-The arrangement of procedures, equipment and organizations that have been selected to accomplish the functional objectives of the system
wireline carriers	-Public service entities that provide wire type communications services. While the term implies telephone type wire connections, many such carriers use microwave systems within their systems

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