THE OPERATIONAL IMPACT OF 900 MHz RADIO SYSTEMS ON LAW ENFORCEMENT COMMUNICATIONS

AN ON-SITE REVIEW OF CURRENT SYSTEMS
IN MIAMI, FL, ORANGE COUNTY, CA AND CHICAGO, IL

BY

THE ASSOCIATED PUBLIC-SAFETY COMMUNICATIONS OFFICERS, INC.

PROJECT 16A - TASK II

BRUCE M. KARR
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DONAL D. KAVANAGH
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PREPARED UNDER GRANT NO. 78-SS-AX-0021

FROM THE

LAW ENFORCEMENT ASSISTANCE ADMINISTRATION
UNITED STATES DEPARTMENT OF JUSTICE

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ACKNOWLEDGMENTS

This Report on the operational impact of 900 MHz Radio Systems on Law Enforcement Communications 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 study to make the benefits of operating radio systems in this region of the radio spectrum realizable by law enforcement agencies throughout the country.

The accomplishment of this study was made possible by the voluntary membership of APCO. Many of these individuals gave freely of their time and experience by participating in the discussions and task group meetings, providing technical and policy guidance.

Much of the credit for the accomplishment of this Task is due to the dedication of APCO's Board of Officers, constituted as Task Group I. They are:

Nathan D. McClure, III, President
Director, Winnebago County, IL
Emergency Services & Disaster Agency

Sanford H. Smith, President-Elect
Telecommunications Manager
City of Greensboro, NC

Henry L. Crutcher, 1st Vice President
Telecommunications Systems Manager
CA Department of Parks and Recreation

Russell V. Robinson, 2nd Vice President
Sergeant, Police Department
City of Detroit, MI

Particular gratitude is due to the following members of the agencies surveyed:

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Orange County, CA	-	Mr. Don Poorman Mr. Neil Jones Mr. Gary David Gray Lt. Pete Savigny
Chicago Police Department	-	Mr. William Miller Mr. Victor Jautokas Mr. Alex Kutchik Mr. John Lambert

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Bruce M. Karr
Project Engineer

EXECUTIVE SUMMARY

In 1976 the Federal Communications Commission's Docket No. 18262 made available to the land mobile communications community 30 MHz of spectrum between 806 MHz and 866 MHz. This long-needed relief was viewed by law enforcement agencies as the potential solution of the frequency congestion problems that have existed for many years.

The lack of experience with these newly authorized frequencies and the new regulatory concepts under which they were made available posed several questions to those considering implementing systems within this portion of the spectrum. APCO's Project 16, conducted under a grant from the Law Enforcement Assistance Administration (LEAA), evaluated the technical, economic and regulatory questions associated with this new portion of the spectrum. It pointed out the opportunities and challenges posed by the requirement for trunking these systems requiring more than 5 channels. It analyzed the economic costs and presented an overview of the developmental progress of equipments suitable for these new frequencies.

Project 16 also analyzed, from a theoretical viewpoint, the propagation characteristics that could be expected of this portion of the spectrum and made forecasts regarding their potential for contribution to the communications needs of the law enforcement community. The project concluded that coverage adequate for urban law enforcement users should be expected. It referred to experimental results showing potential problems of fading, coupled with the opportunity for better signal penetration through buildings and tunnels, that might be the result of the scattering effects of these short wavelengths.

As part of APCO's Project 16A, the development of a functional requirements statement and identification of potential users of this system, the LEAA has funded a grant to APCO to review the operational experience of law enforcement agencies that have used these frequencies during the past several years. This Report is the result of these investigations.

APCO conducted a survey of the operational and maintenance experiences of the law enforcement agencies of Chicago, Illinois; Miami, Florida; and Orange County, California. These three communities have had experimental type 900 MHz systems in operation for several years. Questionnaires prepared by the APCO Project Office were completed by personnel of the law enforcement agencies of these communities. Discussions with members of these departments were held by representatives of the APCO Project Office and the conclusions developed reviewed by the APCO Task Groups participating in the Project.

The systems selected for analysis represent three different operational uses of the 900 MHz portion of the spectrum. The Chicago system is a 5-channel mobile data information system used to communicate with mobile digital terminals in police vehicles. It provides coverage throughout this major, urban community. The Miami system is a single channel, administrative telephone network used

primarily for administrative communications throughout this urban/suburban semi-tropical community. The Orange County, CA system is a single channel, 900 MHz voice network used for maintenance and administrative purposes throughout the entire county.

The three systems were installed by the using agencies primarily to evaluate the suitability of the 900 MHz portion of the spectrum and the equipment recently available for law enforcement public safety purposes. The data collected under this task has shown that such systems are eminently suited to the purposes for which they were designed. Much of the fears of propagation loss due to foliage, difficulty of communications because of fading and "holes", and problems of maintenance and reliability of the new equipments, have not been borne out by experience. The three using agencies have reported very satisfactory results with their equipment, good reliability, and equal or improved coverage compared to lower frequency systems.

All three communities have ordered or are planning to order expansions of their 900 MHz systems.

The conclusion reached as a result of this Task II of APCO's Project 16A is that the technical characteristics of the 900 MHz portion of the spectrum is highly suitable for law enforcement communications needs. Equipment reliability and maintainability compare favorably with that long in use in the lower bands, and price differentials, where they exist, may be justified by the increased availability of channels.

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THE OPERATIONAL IMPACT OF 900 MHz RADIO SYSTEMS

ON

LAW ENFORCEMENT COMMUNICATIONS

I. INTRODUCTION

The growing demand for public safety services and the increasing requirement for the application of sophisticated technologies in support of law enforcement objectives require a greater degree of capabilities from law enforcement communications systems. These increased capabilities necessitate the utilization of a "new" portion of the radio spectrum, the 900 MHz band.1/ The Associated Public-Safety Communications Officers, Inc. (APCO), under a grant from the Law Enforcement Assistance Administration (LEAA), determined in their Project 16 that this band could support the increased needs of law enforcement communications systems.

APCO's Project 16A, funded by a LEAA grant, carries the findings of Project 16 further toward implementation through the development of a trunked radio system for law enforcement. This Report, a part of Project 16A, surveys the law enforcement systems currently using the 900 MHz band and focuses on their operational experience in this new region.

Its purpose is to assist decision makers in evaluating benefits vs. costs to be derived from implementation of this new portion of the spectrum.

APCO's Project 16 is an overall program directed toward the evaluation of 900 MHz in support of law enforcement objectives. Its further goal is to advance the application of modern technologies, many of which are made possible by the opening of this new spectrum. One result of the initial Project 16 study was the identification of the potential for greatly enhanced capabilities inherent in the trunked system concept. A second result is an appreciation of the particular benefits that these frequencies may offer in the suitability of their propagation characteristics to law enforcement needs These propagation characteristics, while heretofore considered only theoretically understood, offer the potential of significant problems coupled with great opportunities. The shorter wavelengths, while theoretically absorbed by foliage and subject to pronounced shadows due to propagation path obstructions, offer the opportunity for much more thorough coverage, particularly within urban areas, due to the scattering effect causing better penetration of buildings and tunnels.

At the outset of APCO's Project 16, little practical experience had been

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1/ This Report uses the term 900 MHz, as did the Federal Communications Commissi in its Docket No. 18262, when referring to the band of frequencies allocated to the land mobile services between 806 MHz and 866 MHz.

gained in the use of these frequencies. In the subsequent months, however, experience was gained with three systems operational in the law enforcement communications environment. The City of Chicago made use of a 5-channel 900 MHz system in support of a mobile digital communications network operating throughout the boundaries of that city. Orange County, CA implemented a single channel voice network, on a test basis, primarily for the use of maintenance technicians. The City of Miami, FL installed a single channel telephone-type administrative network to provide mobile communications throughout the boundary of its responsibilities. These latter two systems were installed primarily on a test basis, to evaluate those factors affected by this new spectrum of interest to law enforcement agencies.

The purpose of this study is to document the experiences of these agencies and to make this information available to other potential users of this band. It is intentionally highly subjective in that much of the information presented is based upon subjective opinions of system users. While the information has been collected and documented in a manner that supports analysis, the intention has been to record those personal reactions and attitudes of operational agencies in comparing usage factors of 900 MHz with other lower frequency systems with which they have had experience.

The comparisons cited in this Report are intended to depict the degree of satisfaction or dissatisfaction that the operating official in the field, not necessarily communications oriented, experiences in the use of 900 MHz. It is intended to provide guidance as to whether, in fact, a move to these frequencies may or may not be justified by other agencies in the future. It is also intended to determine if many operational or management techniques may necessarily be installed as a result of the characteristics of this 900 MHz equipment.

This research effort was conducted by APCO as "Task II" of Project 16A, APCO's development of functional requirements data pertaining to the application of trunked, digitally addressed systems. Data acquisition was accomplished from responses to survey questionnaires prepared by APCO's Project Management personnel and by personal interviews with those officials of the three communities having knowledge and experience with the systems.

The following Report details the information and opinions acquired during the program Task. It presents those opinions expressed by responsible law enforcement officials that support the conclusion that 900 MHz does indeed offer significant new opportunities for expanded law enforcement communications systems. The technical challenges presented are solvable, and the costs compare favorably with similar equipment at lower frequencies. Maintenance and installation problems, while requiring competent technicians familiar with UHF techniques, are not significantly different from those experienced in the past.

The most significant deficiency of the 900 MHz portion of spectrum is the fact that, as of the time of writing, no commercially produced portable

equipments are available. This absence of portable operational equipment precludes the accomplishment of a most important portion of this Project, i.e., the evaluation of coverage by portable systems at 900 MHz. Such an evaluation should be conducted as soon as this type of equipment becomes commercially available.

This Report constitutes another step in the development and introduction of advanced technology in the solution of law enforcement communications problems by the Associated Public-Safety Communications Officers, Inc. It further represents another significant contribution to the state of the art that has been supported by the Law Enforcement Assistance Administration. All the members of the public safety community should be grateful to these agencies for their contributions.

II. OBJECTIVES OF PROJECT 16A

The purpose of APCO's Project 16A is to continue support of a program leading to the implementation of high technology and enhanced capability of modern communications systems. The specific Tasks under this Project are:

Task I - to identify those model communities suitable for and capable of implementing demonstration type, digitally addressed, trunked 900 MHz communications;

Task II - an evaluation of the operational experiences gained by the cities of Chicago, IL; Miami, FL; and Orange County, CA in the use of their developmental 900 MHz systems;

Task III - the development of a functional requirements document defining those capabilities that a digitally addressed, trunked communications system in support of law enforcement communications needs should have.

The following Report is the product of the second of these tasks.

III. TASK II DATA COLLECTION PROCESS

The management of APCO's Task II was vested in the Project Management Office at the National Office of APCO. This office is managed by the Executive Director of APCO. The Project Management Office was supported in this Task by a special group of APCO volunteers constituted as APCO's Task Group I. This Task Group was made up of the APCO Board of Officers.

The Project Management Office, consisting of the Director of Projects and the Project Engineer, provided day-to-day operational supervision of the Project.

This office, assisted by Task Group I, developed questionnaires that were

forwarded to each of the participating law enforcement agencies. These questionnaires were followed up by meetings of the Project Engineer with representatives of those agencies at which the questionnaires were discussed and other matters relating to the operation of these systems developed.

The Project Engineer, working with the members of Task Group I, analyzed these reports and developed the following documentation.

This data acquisition process bears special credibility because of the intimate participation of the knowledgeable users of the system. While the comments made may often lack technical sophistication, they bear the credibility of professional opinions expressed by experienced operational personnel.

Of particular value are the practical day-to-day aspects of the recommendations made by which those operational peculiarities created by these frequencies can be overcome by management techniques.

The results of the survey and interviews have been analyzed and incorporated in the various Sections of this Report. The professional level and experience of the respondents is of particular importance, to-wit:

- over 115 years of technical radio experience is represented by the engineer/technician category of users, with their average years of experience being 17.6;
- 85 total dispatcher/communicator years are represented, an average of 12.2 years each, all having more than 1 year experience at 900 MHz;
- more than 16 years of supervisory experience is included in the supervisor category of respondents;
- 15% of the respondents have seen service as police officers.

In most cases, the questions were aimed at comparing the user's current 900 MHz system with his other radio communications system(s) employing the 40 MHz, 150 MHz and 450 MHz bands. Responses were generally qualitative rather than quantitative in nature, i.e., "How does your 900 MHz system compare with your other band systems?" Choices are: better - worse - no change.

In addition to the basic questionnaire answered by all, additional questionnaires were sent to those having specialized responsibilities in the 900 MHz communications field. Throughout this Report comments and conclusions are referenced to the questionnaire from which the information has been obtained by citing the question number and the particular questionnaire in accordance with the following key:

B - Basic questionnaire (replied to by all)
C - Communicator questionnaire
D - Designer questionnaire
S - Supervisor questionnaire
T - Technical questionnaire

i.e., #T-60 indicates Question #60 on the Technical questionnaire. Copies of each questionnaire are included in the Appendix showing the number of individuals giving the indicated response to the question shown.

IV. REPRESENTATIVE SYSTEMS

A. General

To date, none of the three systems surveyed use their 900 MHz system as a voice radio directly in police patrol operations. Of similar significance is the fact that 900 MHz portable operating experience was not available as, at the time of the survey, 900 MHz portables were not commercially available.

Each of the three agencies selected for analysis represent a unique use of 900 MHz in law enforcement. Although the answers supplied are valid representations of their experience at 900 MHz, there can be little direct comparison of operational characteristics between these three systems from the data presented. The intent of this Report is to offer representative information, describing the performance of the systems, reflecting their individual geographic, organizational and environmental conditions.

B. Miami, Florida

1) The terrain in the vicinity of Miami is flat. Coverage of an area of approximately 500 square miles is required. The population of the area of responsibility is approximately 345,000 and is predominately urban/suburban in nature.

2) The 900 MHz radio system, at the time of the survey, consisted of one 500 watt ERP base station located in the Federal Building in downtown Miami at a 294 foot elevation. The system supports ten 30-watt mobiles in an executive telephone network while undergoing a period of evaluation and testing.

3) The city is in the process of procuring a 150 unit mobile digital system utilizing two channels in the police service. System coverage extends approximately 27 to 28 miles into nearby Dade County. In an area of shadow, to the north, the range is reduced to approximately 25 miles. There are plans to move the base station to an adjacent higher building (320 feet) to eliminate this shadow effect. Notwithstanding, the system coverage performance equals or betters the design criteria.

C. Orange County, California

1) The Orange County terrain ranges from sea level to 6,000 feet, covering an area of approximately 186 square miles. The population of 1,800,000 ranges through the urban, suburban, rural classification.

2) The 900 MHz radio system is undergoing test and evaluation. It is used as a mobile relay supporting communications technicians. The primary base station is located at the 5,600 foot level of Santiago Peak. Due to the proximity of Mexico, the transmitter Effective Radiated Power (ERP) is limited to the main antenna lobe and 25 watts towards Mexico. An auxiliary site is located on a nearby peak 1,300 feet above sea level. Twenty 30-watt mobiles were in service at the time of the survey.

3) Current planning calls for system expansion as funding and additional site licensing problems are solved. The system has met design coverage goals.

D. Chicago, Illinois

1) The Chicago terrain is relatively flat, covering a service area of approximately 300 square miles. The population is 3,115,000 and is generally urban/suburban in nature.

2) The 900 MHz radio system consists of a 282 watt ERP base station at 1,179 feet above ground level elevation on the Standard Oil Building in downtown Chicago. There are 150 mobiles with 30 watts rated output power used in a digital communications network called SMART (Special Mobile Automated Remote Terminals). Five channels are available.

3) The SMART system is being expanded to 300 units in the near future. System operation is totally digital with keyboard and 3 line display terminals in the cars. Data is exchanged with the SMART switching computer. This computer accesses the Chicago Police Department's computer banks. Information exchange between cars is possible with the system. Officers receive 8 hours of training with the system prior to using it in the field. The system coverage meets design goals - city-wide.

V. OPERATIONAL CHARACTERISTICS OF 900 MHz SYSTEMS

A. General - Summation of user comments

Current users of 900 MHz systems are well pleased with the many apparent improvements over other bands. These improvements include better building, tunnel and basement penetration, better overall signal

quality, and within the design contours, better signal reliability with fewer problems of weather and man-made noise. Coverage is now possible in many areas not possible using 450 MHz systems.

A very low or non-existent level of background noise contributes to improved intelligibility and greater user satisfaction. Reliability and maintainability have compared favorably with the 450 MHz experience.

It should be borne in mind that all reports to date are without the benefit of 900 MHz portable experience.

To assist the reader's reference to survey data, summary comments are followed by reference to survey questionnaires and specifically relevant questions that can be found in the Appendix.

B. Coverage

1) The majority of the users stated that coverage of the 900 MHz system is equal to or better than that experienced with their 450 MHz systems. The "fill-in" is superior, and in urban or built-up areas this scattering effect results in very good coverage. #B-2, S-17, D-46

2) Where shadowing effects are existent, they are more harsh. Where obstacles that could provide a scatter or reflector effect are not present, the shadow can be severe. The reported dead spots have these characteristics (in descending reporting frequency): #B-30

- car cannot hear other units;
- the dispatcher cannot hear car;
- car cannot hear dispatcher.

3) Fading comparisons fare better with the majority of the respondents giving higher marks to 900 MHz than to 450 MHz or other bands. Fading was experienced by less than half of the sample. When experienced, it consisted of a rapid fade while moving. In some cases users reported having to stop the vehicle to receive. For transmitting, the fading is reported as the same as for 450 MHz. In fringe areas, if you experience some receive problems due to fading on 450 MHz, you will probably experience them on 900 MHz. The remedies, such as moving the vehicle slightly, result in these rankings:

- move vehicle more than 100 feet;
- move vehicle less than 10 feet;
- move vehicle slightly. #B-5, 13, 18, 19

4) Building penetration is deemed superior to 450 MHz coverage. #S-20, 21

5) The range to be expected of the 900 MHz signal is similar to that of a 450 MHz signal. Comparisons of 900 MHz with other bands by the respondents indicated 900 MHz results are equal to or better than other bands. #S-17, B-1, 2, 9

6) Foliage was not determined to be a problem of the respondents. However, the basic nature of the southern California countryside and Chicago and Miami cities might not yield as much of a foliage problem as more foliated communities. This potential problem, to which so much attention has been addressed, has not yet proven to be an operational impediment.

C. Noise #B-3, 6, 14-17, S-22

1) Set noise appears to be reduced from levels previously noted with 450 MHz and 150 MHz equipments. The subjective comments received imply improved audio quality and reduced distortion.

2) Man-made noise appears to be less a problem than on other bands. Theory predicts that ignition systems power lines, and similar man-made noise sources should be less harmful at these frequencies. Intermodulation problems are not significant at this time since there are relatively few users of 900 MHz systems in the sample areas and the opportunities for IM do not exist to any great degree. As more systems are operated in the 900 MHz band, the intermodulation potential will rise. Frequency assignment policies on 900 MHz indicate that all types of users will be assigned and the other protections realized from block assignments will not be available. Therefore, many 900 MHz systems will have to be designed to operate under an intense intermodulation environment. #B-14

3) Atmospheric noise contributions were noted by some of the respondents during weather disturbances in areas having marginal signal levels.

D. Signal Reliability and Fading #B-5, 13, 16, 17

1) Over half of the respondents state that 900 MHz is more reliable than other bands with the remainder giving 900 MHz equal marks.

There appears to be noticeably poorer performance by 900 MHz reported by 1/3 of the respondents during rainy spells, humid, hot, and windy times, although less than 20% of the total made an overall yes-no comment to the question: "Are there days when the system does not seem to perform as well as on other days?"

2) Fading has been experienced by less than 23% of the respondents. This fading was experienced most noticeably when moving, and was rapid in character. #B-18, 19, 29

3) Fresnel zones: there were no comments received attributing problems directly to fresnel zones. Some responses indicate the effect of these zones may be an area needing further investigation.

4) Picket fencing: there were no comments received indicating picket fencing as a problem. Although this phenomena has been reported elsewhere in several studies, it was not observed or identified to any significant degree by the respondents.

E. Distortion #B-6, S-22, 23

General comments from users indicate a high degree of satisfaction with received audio quality and the lack of distortion. Whether this is attributable to 900 MHz directly or to improved audio circuitry has not been determined. Specific ratings of 900 MHz indicate over 50% of the respondents believe the audio quality to be better than on any other system, and 90% believed it to be equal to or better.

VI. EQUIPMENT RELIABILITY AND MAINTENANCE EXPERIENCE

A. Police officers and users have fewer complaints about 900 MHz equipment compared to other types they have used. Trouble is generally indicated by the observable symptoms (not specified), and these troubles are similar to those encountered in lower frequency systems. The newness of the equipment has kept maintenance problems to a minimum. Probably the only significant point to date is that the equipments in Miami and Orange County have microphones and cables. These deteriorate at approximately the same rate for 900 MHz as in other equipments used in law enforcement service. #B-7, 10, S-23, T-63-67

B. Test equipment and techniques for 900 MHz are more critical, particularly in the areas of frequency stability, selectivity, and test set-up. The subject of test equipments was not specifically commented on by users except indirectly as part of their comments about new servicing techniques, reported under training. #T-70

C. Specific needs for coaxial cable checks were discussed by Chicago personnel. One coaxial servicing technique which they have found useful is TDR (Time Domain Reflectometry), also known as cable pulse testing. This technique provides a measurement of impedance discontinuity or change, and locates the defect in the cable under test. It should prove very useful in evaluating cable and connector installation quality.

VII. COMPONENTS AND QUALITY

A. The survey of users did not yield a significant number of comments concerning component quality. 30% of the technical respondents stated that components were of better quality than those used in lower band

systems. An additional 50% observed that components are equal in quality to other band equipments. Comments concerning components included:

- troubleshooting and repair is more touchy;
- layout of components is critical;
- coaxial line and connectors are critical

#B-10, S-23, D-53-55

B. Coaxial line: high quality coax should be used for base stations. Either double shielded or solid shield is essential. This is especially significant at multiple transmitter base station sites to reduce the intermodulation potential. Solid shield (seamless) cable effectively stops energy from being detected except at the connector interfaces; however, this does not preclude induced longtitudinal currents due to poor grounding techniques.

C. Connectors: users commented that " . . .the UHF series of connectors used by some manufacturers are unsatisfactory. While they are rugged, they are poor electrically at the frequencies involved." RF connectors are of major importance to system operation and contribute significantly to the interference potential. Careful attention must be paid to their design, installation and maintenance.

D. Antennas: no significant comments were obtained concerning the quality of 900 MHz antennas. Their small size permits rugged mechanical construction; however, small defects or bends contribute a proportionally large share to faulty operation. Antenna installation and cabling should be accomplished with care and precision.

VIII. INSTALLATION CONSIDERATIONS

A. Connectors can be a significant problem at 900 MHz. They can introduce high impedance discontinuities due to poor basic construction or poor workmanship during installation. BNC connectors may show a tendancy to vibrate due to the bayonet and ears clamping method. This can introduce noise into the system.

B. TDR (Time Domain Reflectometry) techniques discussed under Section VI-C should prove valuable in evaluating the quality of coaxial cable connector fabrication and installation.

IX. PERSONNEL TRAINING NEEDS

A. General

When new procedures are adopted to make better use of a 900 MHz communications system, they should be disseminated to all the users of the system, including police officer, communicator and technician/engineer.

There needs to be emphasis placed on teaching each new procedure and its relationship to the total communication system to all system users.

B. Police Officer Training Needs #B-23-28, C-89, T-70

1) 36% of all respondents felt that some training should be conducted in radio propagation characteristics. Officers need to understand that if radio communication is poor at one location, they should change location slightly and try again. Often one or two feet will be sufficient.

2) Officers should report major areas of poor communications to their supervisor and/or the telecommunications technical staff.

3) The communicators replying to the questionnaire emphasized the need for training user personnel in such subjects as:

a) the capabilities of the equipment;
b) techniques for improving intelligibility;
c) the need for familiarity with the working of the dispatch center;
d) the use of standard procedures and codes.

While only Item a) may have specific applicability to 900 MHz systems, no training program would be complete without addressing all four subjects.

C. Dispatcher/Communicator Training Needs #B-22-27, T-70, C-90

1) Dispatchers/communicators need to know capabilities of the equipment in the dispatch center and of the police officers' equipment in the field.

2) Dispatchers/communicators need to know the characteristics and capabilities of backup equipment.

3) Dispatchers/communicators need to know and use proper procedures and codes.

4) Dispatchers/communicators need to know the patrol area(s) intimately, and periodically review field conditions with the patrol officers.

D. Technician Training Needs #B-22-27, T-70

The technician should be trained in

1) advanced troubleshooting;
2) strip line servicing techniques;
3) frequency stability techniques;
4) interference remedies;

5) specific equipment characteristics and troubleshooting;
6) better methods and skills for working with coaxial components;
7) symptom/remedy identification.

E. Engineer Training Needs #B-22-27, T-70

The engineer should be trained in

1) propagation considerations;
2) coaxial component characteristics;
3) intermodulation reduction techniques;
4) system propagation/phasing delay characteristics.

X. CAUTIONS FOR NEW OR PROSPECTIVE USERS OF 900 MHz

A. Initial Considerations

1) 900 MHz provides some 600 channels of radio spectrum. These channels are not allocated in the same manner as the lower band channels. Rather, they are assigned sequentially on a first come, first served basis with specified loading criteria. There are currently 150 channels available for assignment to conventional systems and 200 available for trunked systems.

2) Because of the number of available channels and the comparatively limited area of coverage, system planners in the less densely populated areas may have more freedom in considering the operational needs of their agency, channel usage, and future expansion through the life of the system. In the majority of areas channel capacity is there to handle the law enforcement needs.

3) Systems requiring more than 5 channels must be trunked (FCC Rules and Regulations). The trunking of public safety systems will be studied, tested, and reported in this and subsequent projects (APCO's Project 16 series). Trunking concepts and the digital addressing techniques appear to offer a most attractive method of meeting complex public safety communications requirements. The results of the Project 16 series should be closely scrutinized by agencies considering 900 MHz systems.

B. There is a Need for Detailed System Planning #T-70

1) Radio coverage requirements should be thoroughly determined and the critical areas for operational deployment well defined.

2) The need for multiple base stations and control capabilities should be considered.

3) Base station sites must be carefully selected to insure adequate near obstacle clearance, appropriate antenna heights, and minimum RF cable lengths.

4) Future system needs must be considered to provide for later expansion. These plans should determine ultimate channel requirements.

5) Until 900 MHz portable units become readily available, methods of incorporating lower band portable units into the 900 MHz system should be carefully considered.

6) Portable radios operating on 900 MHz are not available, as of this writing. Portable radios for "trunked" systems are not expected for several years. Users having a current need for portable operation should consider additional interface methods such as separate portable systems, mobile repeaters, or appropriate other techniques.

C. Additional Training

Additional training of users over that normally given is needed to insure the best results of the system. This is more fully discussed under Personnel Training Needs, Section IX.

D. Physiological Effects

The physiological effects of 900 MHz radiation have not been determined, although some effort is currently underway by various agencies. To date it would appear that no more effects than are evident from 450 MHz are likely. The results of on-going studies in this field should be watched carefully.

XI. RESULTS OF EXPERIENCE GAINED

900 MHz users are convinced that public safety operations in this band will be as good or better than on the lower bands. Although extensive operational experience is not available to evaluate propagation in heavily wooded countryside or in steeply cross-canalized areas, the current users are satisfied that 900 MHz serves well under most conditions. One can expect service ranges to be equal to or better than existing UHF systems.

The current lack of portables at 900 MHz leaves doubt as to how a total 900 MHz system would be configured. There are several methods by which public safety users can incorporate existing portable systems into 900 MHz mobile systems.

The inefficiency of portable antennas when receiving and mobile antennas of 1/4 wavelength must be considered by system designers. It imposes a particular need to maintain a low level of interference. Particular atention must be paid to channel selection and potential UHF TV spectrum pollution in high density areas.

XII. CONCLUSIONS

900 MHz is well suited to law enforcement radio systems, providing better urban and suburban penetration than heretofore realized on other bands.

900 MHz systems will be able to take advantage of the new systems' operational techniques such as trunking, discrete addressing, and cellular, without fear of unusual propagation problems.

Law enforcement operational procedures may require minor revision in some communities to obtain maximum benefits of 900 MHz systems. Generally, no special procedures are needed.

Law enforcement agencies contemplating or implementing 900 MHz systems should increase the initial training hours of police officers and communicators to insure an understanding of 900 MHz propagation, field expedients, and procedures, as part of the implementation program.

Communications technicians should be given in-depth training in the special servicing techniques relating to 900 MHz equipments. They should also become familiar with the characteristics of 900 MHz systems as they may relate to troubleshooting.

Technicians should receive additional training in coaxial component makeup and installation techniques.

System designers must exercise care in specifying the quality of components.

Early planning, with an in-depth evaluation of current and future needs, is essential. Future facilities, configuration, should be developed along with an implementation program wherever possible.

APPENDIX

900 MHz USER SURVEY QUESTIONNAIRES

This Appendix presents those questions asked in the survey questionnaires that were used to develop the data upon which the Project 16A Task II Report was based. Opposite each question asked is the number of the indicated responses received to that question. Where questions required subjective replies, a statement is presented that summarizes the replies received.

This data acquisition questionnaire program was conducted with two objectives. The first was to establish the information regarding the subjective experience of system users of the 900 MHz equipments. The second was intended to establish the extent and type of experience of the respondent. The purpose of this dual approach was to assure that the data received, intentionally subjective in nature, could be validated from the perspective of the professional status of the respondent.

Five questionnaires were used. A basic questionnaire was developed to obtain standardized responses concerning opinions about system performance that should be commonly experienced by all classes of users. Four additional questionnaires were developed to establish the specialized field of professional experience of the respondents.

The questionnaires have numbered questions and are referred to the Report with a letter prefix as follows:

B - Basic questionnaire

D - Designer quality questionnaire

T - Technical quality questionnaire

C - Communicator/Dispatcher quality questionnaire

S - Supervisor quality questionnaire

BASIC

AGENCY Respondents: Orange Co., CA
Chicago, IL
Miami, FL

YOUR NAME _____

YOUR JOB _____

	Chose One - - - - -	Better	Worse	No change
1.	Within the equipment restraints imposed (i.e., no portables), does this 900 MHz radio system perform as well as your other radio system?	11		3
2.	Coverage (shorter distance, gaps)	8	1	3
3.	Noise (squelch problems or other)	12		2
4.	Reliability (when you call you get heard)	8	1	4
5.	Fading	9	1	4
6.	Distortion and garbles	7	1	6
7.	Repair or downtime	6		5
8.	Vehicular installation problems	2		6
9.	Dead areas	6	1	4
10.	Component quality (opinion)	3		8
11.	Unfamiliarity/lack of use	2		11
12.	Training (you received)			12

		One or more answers as appropriate		
		Compared to other systems No change	Yes	No
13. a.	Have you experienced fading of signals?	1	3	10
b.	Rapid		2	4
c.	Slow?			6
d.	Combination?			5
e.	Is it noticeable when you are moving?		2	5
f.	Is it noticeable when you are stopped?			7
14.	Have you noticed any noisy areas on 900 MHz?		4	6

Where are they? During weather disturbances in marginal cover areas, near radar in Air Search

Describe static-popping

15.	Do you experience any (new) unidentified voices (or bursts of noise? occurring periodically on the system?	2	13
16.	Are there days when the system does not seem to perform as well as other days?	2	12
17.	Can you die this poorer performance to weather conditions such as:		
a.	Rainy?	3	6
b.	Overcast, no rain?		9
c.	Humid - hot?	2	7
d.	Windy?	3	6

	Compared to other systems/ No change	Yes	No
17. Continued			
e. No wind?			9
f. Cold?			10
g. Ice/snow?		1	8
h. Ducting?			10
18. Do you have problems copying a vehicle when it is			
a. moving fast?	4		10
b. moving slow?	4		10
c. stopped?	4		10
19. Have you had to stop your vehicle to			
a. better transmit?	3		7
b. or receive?	3	3	3
20. Have you had to change your method of covering your assigned area because of the 900 MHz radio?	2		8

Describe No responses received to this section.

Car Orientation

21. Do you seem to get better distance or results transmitting or receiving			
a. over the front of your car?	1		7
b. back of your car?	1		7
c. or sides of your car?	1		7

		Yes	No
22.	Have you or your department developed procedures to overcome 900 MHz problems or taken advantage of new capabilities?	3	4
23.	Do these procedures include -		
	a) move vehicle if copy is poor?	4	1
	b) reorient vehicle, try again?	4	1
	c) say words twice?	2	2
	d) relay through another station?	2	2
	e) use a telephone?	2	2
	f) make note of where difficulty occured and report it?	3	1
	g) use another type radio, try again?	2	2
	h) move to higher ground, try again?	2	2
	i) go to an intersection, try again?	2	2
	j) Other	2	2

Please list establish additional relay sites.

24. In your opinion which of the above have little value?

23 c) - 2 votes

23 h) and 23 i) - 1 vote each

25. What procedures should be adopted as policy?

Note location and report it. Move only inches. Experience dictates moves.

	Compared to other systems No change	Yes	No
26. Should any of these procedures be amplified with special training classes (particularly for new recruits)?		2	3
List _____			
_____			
27. Would you recommend any other 900 MHz training?		2	4
Describe propagation characteristics			
_____			
_____			
28. Have you experienced any vehicular problems caused by the 900 MHz radios, such as			
a) windshield wiper causes problems?	5		8
b) braking problems?	5		8
c) sirens, p.a. cause problems?	5		7
d. none of the above, but _____	4		6
_____			
_____			
29. a) Do you hear tones when you are receiving?	4		8
b) Do these tones change pitch?	3		6
c) Does this change match a change in your vehicle speed?	2		6
d) Does this tone phenomena annoy you or interfere with reception?	2		6

	Compared to other systems No change	Yes	No
30. Do you have dead spots where		1	
a) you can't hear dispatcher?	1	5	4
b) you can't hear other units?		6	4
c) dispatcher can't hear you?	1	6	4

Where are these spots?_____

_____

_____

31. Are these dead spots			
a) in buildings?		2	2
b) near buildings?		2	3
c) in basements?		1	2
d) in wooded areas?		1	7
e. in suburban areas?		1	3
f) in open areas?		4	1
g) near base station (transmitter site)?			2

32. How do you get the message through in these spots?			
a) Move short distance (10' or less), try again?		5	
b) Move fair distance (100' approximately), try again?		5	
c) Move greater distance?		6	
d) None of the above?		1	

DESIGN

AGENCY Respondents: Orange Co., CA - 1
Miami, FL - 1
YOUR NAME Chicago, IL - 1

YOUR JOB

41. What specific judgments or empirical extras did you use in designing for coverage of your 900 MHz system?

Describe Test sites were existing sites. Maximum allowable power for site.
Chicago - channel loading criteria
- system response time
- antenna height gain
Miami - none specific

42. What fade margins did you use for path reliability?

Describe

43. What signal strength or power at the antenna terminal did you use?

Describe Orange Co. - 500 watts directional (away from Mexico) at Santiago Peak
- 200 watts directional at Lomas
- 35 watts -- mobiles
Chicago - 74 watts at antenna
Miami - none specific

44. What field intensity did you use for 50% reliability?

Describe Orange Co. - none specific
Chicago - 99.530 reliability required
Miami - none specific

45. What receiver threshold did you use?

Describe Orange Co. - none specific
Chicago - 0.35 MV for 20 dB quieting
Miami - none specific

		Yes	No
46. Were these levels adequate?	Chicago	[1]	[ ]

47. Which ones are proven conservative?

Describe

48. Which ones were or should be changed?

Describe _____

_____

	Yes	No
49. Has the noise contribution of the vehicle proven significant?	☐	☐ 3

50. What further tests or exploration would you like to do?

Describe _____

_____

51. Have you used the Excalibur antenna?	☐	☐

52. If yes, how does it compare to a standard 1/4 wave spike?

Unknown	Same	Better	Worse
☐	☐	☐	☐

53. Do you have any comments concerning coax connectors?

"UHF" series connectors "stink". They are rugged but poor at UHF.

Type "N" connectors should be used.

_____

54. Comments concerning down-tilt antennas?

Coverage beneath antenna should be improved. Co-channel interference should be reduced - from past experience in Orange Co. Down tilts did not work at 460 MHz in Chicago.

55. Comments concerning coax?

High quality coax such as solid copper jacketed "Heliax" should be used.

_____

_____

TECHNICAL

QUALIFICATION QUESTIONS

Department Respondents: Orange Co., CA - 7
Miami, FL - 1
Name Chicago, IL - 1

Duties

Engineer/Technician

			Sometimes	Yes	No
#60	Q.	Are you employed as an engineer?		3	3
		Are you employed as a radio service technician?		6	3
61	Q.	Do you regularly work with the 900 MHz systems or components?	2	2	7
62	Q.	Do you receive the equipment for service directly from the police officer?		2	7
63	Q.	Do you obtain the symptoms of trouble directly from the police officer?	1	1	7
64	Q.	Do you find the trouble is generally indicated by the symptoms?		3	2
65	Q.	Are these different troubles/symptoms other than band radios?		1	3

			Same	More	Less
66	Q.	Do the police officers have more or less complaints about the 900 MHz equipment compared to your previous system?	2		2
67	Q.	Are these complaints because of 900 problems?			
		or just because it is a new system to learn and use?		1	

68 Q. What specific problems about this new (900 MHz) system cause you concern?

Trouble-shooting and repair is more touchy, layout of components, shadowing, receiver reliability, RS232 interfaces. Telco line reliability at 1600 band.

69 Q. Which of these problems should be passed on to a city or county user who is contemplating going on 900 MHz?

Systems planning concerns, interference-free coverage. Superior coverage in urban areas.

70 Q. What specific training for a 900 MHz system should be given to:

technicians? Advanced trouble-shooting, strip line servicing techniques, coaxial components, IM rejection, interference remedies, digital analog characteristics.

police officers? System propagation characteristics, shadowing remedies

dispatchers? Same as police officers

engineers/designers? Geographic coverage planning. System interfaces, coaxial component standards and practices.

71 Q. How long have you been a technician/engineer? 122 years total years
17.43 years average

		Yes	No
72	Q. Are you a ham?	6	3

COMMUNICATOR

QUALIFICATION QUESTIONS

Department Respondents: Orange Co., CA - 7
Miami, FL - Ø
Name Chicago, IL - 1

Duties

81 Dispatcher/Communicator

			Yes	No	
82	Q.	Works regular shift as dispatcher	8		
83	Q.	Works regular area board or sector	5	3	
84	Q.	Years as a dispatcher	3-30 years 106		range total
			Yes	No	
85	Q.	Have you also worked as a patrol officer?	2	6	
86	Q.	How long have you been using the 900 MHz radio circuit?	range 1 - 3 years		
			Yes	No	
87	Q.	Do you also have systems on other bands to listen to?	8		
88	Q.	Is ham or CB radio one of your hobbies?	3	5	

89 Q. What training should be given to a police officer who is going to use 900 MHz?

Procedures when out of contact, system capabilities, familiarity with dispatch center, methods to improve communications, basic procedures.

90 Q. What training should be given to a police dispatcher who is going to use 900 MHz?

Know system capabilities, spend time with patrol officers, know the area, basic procedures, use of back-up equipment.

SUPERVISOR

QUALIFICATION QUESTIONS

Department Respondents: Orange Co., CA - 3
Miami, FL - Ø
Name Chicago, IL - Ø

Duties

Supervisor Position (Patrol Chief, Detective Chief, etc.)

1. Number of officers under your direction? -
2. Number of patrol units under your direction? -
3. Length of time you have been in this position? -

		Yes	No
4.	Do you write regulations and directives? -	1	
5.	or recommend to others for adoption?	3	
6.	Have you recommended or written directives concerning operations which were caused by the new (900 MHz) radio system?		2
7.	Have you implemented any unwritten procedures because of the 900 MHz radio system?	1	
8.	Changes in deployment, operations, and communications have been made because of the 900 MHz radio system?	1	2
9.	Which? Deployment?		2
10.	Operations?	1	2
11.	Communications procedures?		2
12.	Communications techniques?		2
13.	Describe		
14.	Are there other changes which could be made because of the 900 MHz radio system?		3

15. Describe _____

_____

_____

		Better	Worse	No Difference
16.	Compared with the previous radio system, the 900 MHz radio system is	4		
				Same
17.	Do you believe the 900 MHz radio system is better, worse or the same in these respects -			
	area coverage	2		
18.	reliability	2		
19.	crowding of calls (channel loading)	2		
20.	building penetration	3		
21.	basement penetration	3		
22.	voice clarity	3		
23.	equipment characteristics	1		2
24.	ease of operation			2

25. I have no opinion. Ø

26. I am not in a position to evaluate. Ø

		Yes	No
27.	Are there cautions about 900 MHz systems which should be passed on to a city or agency planning to go to this frequency band?	Ø	

28. Some of these are _____

_____

_____

		Yes	No
29.	Are there benefits from 900 MHz systems that another agency should hear about?	2	

		Yes	No
30.	Some of these are _____		
	_____		
	_____		
31.	Do you have a means of documenting communications difficulties over a period of time?	[1]	[1]