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16. ABSTRACT

Identification of Port Communication Equipment Needs for Safety, Security, and Interoperability is a big concern for current and future need. The data demonstrates that two-way radios should be the most effective method of communication in both routine and emergency situations. Other effective communication methods during routine situations include the Internet, wireline, wireless, phone and paging systems. Safety is defined as promoting a safe environment for the user of the communication device. It involves the ability to to communicate with team members at all times, whether the reason is for backup or additional information. There are also interoperability implications in the cases that involve communication with user from other regions. On scene radio communication using portable simplex communication would not be possible between user with radios on some frequency and specific equipment used by these agencies exhibit limit compatibility, primarily since all agencies have repeaters and radios operating on the UHF band. However, it is unclear as to whether they are tuned to compatible frequency channels in order to communicate if needed.

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Identification of Port Communication Equipment Needs for Safety, Security, and Interoperability

Final Report

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CSULB

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Preface

The purpose of this report is to identify the communication system needs of the Los Angeles port and Long Beach port public safety agencies for safety, security, and interoperability. It serves to establish a useful baseline for current and future needs. The report is organized as follows:

Part I is an introduction to the communication systems, including the definition of interoperability, security, and safety. The communication devices employed today are also discussed.

Part II is a summary of data collected by a survey of users within the California State University of Long Beach Police Department; the Port of Los Angeles Police Department, Fire Department, and security office; and the Port of Long Beach Police Department, Fire Department, and security office. Users were asked to select communication devices that they have used and rank them in terms of relevance to satisfy future needs. They were also asked to identify and describe excellent features in the communication devices that they currently use, and features that they would like to see implemented in the future.

The approach taken in preparing Part III of this report has been to survey and collect technical data on the various communication systems in use by local agencies and to verify the data against technical specification sheets provided by the manufacturers of those devices. Then, by using the interoperability guidelines established by Project 25 and reviewing manufacturer interpretations of Project 25 standards, it is possible to explain interoperability problems.

Conclusions and recommendations are given in Part IV.

Part I: Introduction

1. Introduction

Part I provides some fundamental insight into communication systems that are currently in use. Much as carpenters rely upon an assortment of chisels, drills, and hammers to do their job, modern communication system designers and operators use very high frequency (VHF), ultra high frequency (UHF), and satellite communication tools, and rely on the unique capabilities that each provides to meet specific requirements. Terminology is defined in the following section.

2. Category Overview

2.1 Interoperability

"Interoperability is the ability of public safety service and support providers—law enforcement, firefighters, emergency management service (EMS), the public utilities, transportation, and others—to communicate with staff from other responding agencies, to exchange voice and/or data communication on demand and in real time[1]." According to [1] and confirmed by this study, there are five primary roadblocks to effective interoperability: incompatible communications equipment, limited funding, limited planning, lack of interagency cooperation, and a fragmented radio spectrum. The focus of this report is on equipment compatibility, and somewhat on the fragmented radio spectrum.

- Incompatible Equipment – Equipment from different agencies may have different vendors with proprietary technology, different acquisition dates with different technology, or may operate on different frequencies.

- Limited Funding - Radio equipment is expensive and agencies have independent priorities for funding equipment updates and replacements.

- Limited Planning – Money for planning is scarce, and competition for those dollars hampers interagency coordination.

- Lack of Interagency Cooperation – Agencies often do not share costs and infrastructure in order to manage their own communication systems.

- Fragmented Radio Spectrum – The Federal Communications Commission (FCC) has allocated incontiguous frequency bands for public safety.

2.2 Security

Security issues related to radio communications are eavesdropping and unauthorized access/use of the system. With digital communications, these problems are easily solved through use of encryption and secure authentication, respectively. Secure authentication is provided by master access keys (MAK) and identification numbers, which verify the radio's rights of access. Encryption is the conversion of data from plaintext format to ciphertext, unauthorized users cannot easily understand the transmitted data. Complicated ciphers use sophisticated computer algorithms to rearrange the data. A decryption key is required to easily decrypt the ciphertext. Over-the-air rekeying (OTAR) gives authorized radios the correct key via the radio network, thereby eliminating the need to physically change anything on the radio.

2.3 Safety

Safety concerns regarding communication systems involve topography and radio dead spots, which are locations where the public safety worker cannot access the radio network. Lack of access to the radio network is caused by lack of infrastructure, mountainous terrain, or an incompatible network. Also, interference on frequencies with neighboring agencies or the Nextel network in the 800 MHz band can interrupt communication.

3. Voice and Data Communication Systems

3.1 Wireless Phone

A mobile radiotelephone that uses a network of short-range transmitters located in overlapping cells throughout a region, with a central station making connections to regular telephone lines. Also called a mobile or cellular telephone. It is completely compatible with regular wireline phones and wireless phones on other networks.

3.2 Wireline phone or Landline Phone

Wireline phones use copper wires connected to a switched network (public switched telephone network, PSTN) to transmit voice over the network. Voice can be transmitted to any other wireline phone since worldwide networks are interconnected. Calls can also be made to wireless phones since wireless phone networks connect to wireline phone networks.

3.3 Internet Phone

Voice over internet protocol (VoIP) is a new technology for transmitting voice, such as ordinary telephone calls, over packet-switched data networks (i.e. the Internet). The Internet phone operates and is used in exactly the same fashion as wireless and wireline phones.

3.4 Two-way Radio

A voice network that provides an always-on connection enabling the user to just "push the button and talk." Also called "dispatch radio," two-way radio has traditionally been used by police, fire, taxi and other mobile fleets. A two-way radio uses radio waves to transmit voice or data to another two-way. They can only communicate with other two-way radios on the same frequency and channel. Two-way radios have limited range based on their transmitting power, terrain, and the radio network available in that area.

3.5 Internet

The Internet is the worldwide, publicly accessible system of interconnected computer networks that transmit data by packet switching using the standard Internet Protocol (IP), providing services including e-mail and file sharing.

3.6 Wireless Data

Cellular digital packet data (CDPD) is an example of wireless data. It is an open wireless transmission standard allowing two-way 19.2-Kbps packet data transmission over existing cellular telephone channels. It uses idle network capacity caused by pauses in phone conversations and gaps between calls placed to transmit data. Since it is packet-based, it does not require a continuous circuit, like a voice call.

3.7 Pager/SMS Device

Pager
A pager is a pocket-sized one-way or two-way radio receiver that sounds a tone or vibrates when it receives a transmission, and displays a numeric and/or alphanumeric message. Some pagers are also capable of sending messages.

SMS
Short Message Service (SMS) is a feature available with some wireless phones that allows users to send and/or receive short text messages. Nearly all digital phones can receive SMS messages. Most phones can also send them. The network must also support sending of text messages. Basic SMS messages are addressed to a mobile phone number. Most U.S. carriers now allow sending to mobile phone numbers of other carriers. Most phones and carriers also support sending SMS from a phone directly to an email address.

4. Communication Theory and Concepts

4.1 Frequency and Wavelength

Radio signals are a type of electromagnetic radiation, which are described mathematically as waves. Terms used to describe waves include wavelength, cycle, period, frequency, and amplitude. Wavelength is the distance at which the waveform repeats itself. Diagrammed in figure 4.1, a cycle is a single repeating pattern of the wave. The period of a waveform is the time required for the pattern to repeat. Frequency is the number of cycles per unit time, and is measured in Hertz (Hz) or one cycle per second. Amplitude is the maximum value the wave possesses away from the mean value.

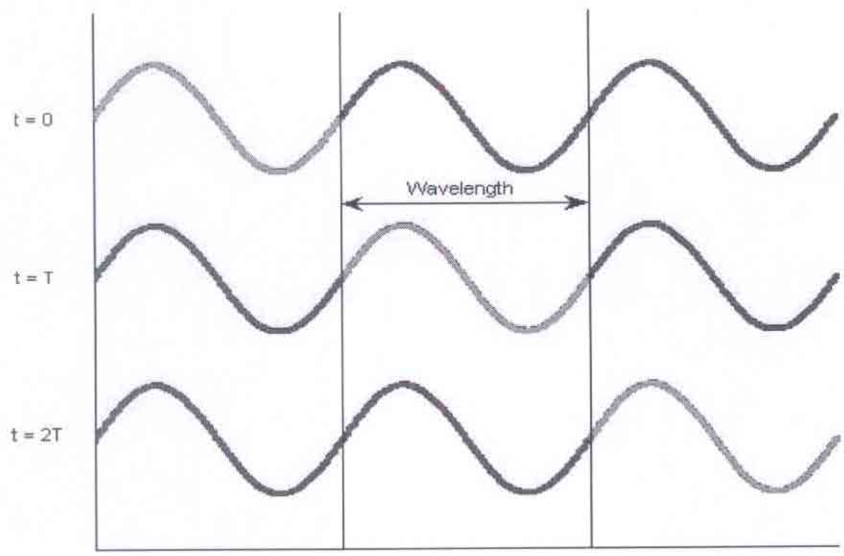

Figure 4.1 Wave Properties

4.2 Spectrum and Public Safety Bands

The electromagnetic spectrum is the full range of frequencies that characterize electromagnetic waves from radio waves to gamma waves. The radio spectrum and gamma waves are labels given to a range of frequencies or bands in the spectrum. The radio communications spectrum is a limited resource and ranges from 30 kHz to 300 GHz. The incontiguous radio frequency bands used for public safety are high frequency (HF), very high frequency (VHF), ultra high frequency (UHF), super high frequency (SHF), and a UHF region called the 800 MHz band. Bands are partitioned into channels with defined central frequencies and permitted bandwidth. The central frequency is the frequency used to transmit data and bandwidth is the range of frequencies around the central frequency permitted for that signal. Frequencies outside this range must have power outputs below a specified threshold.

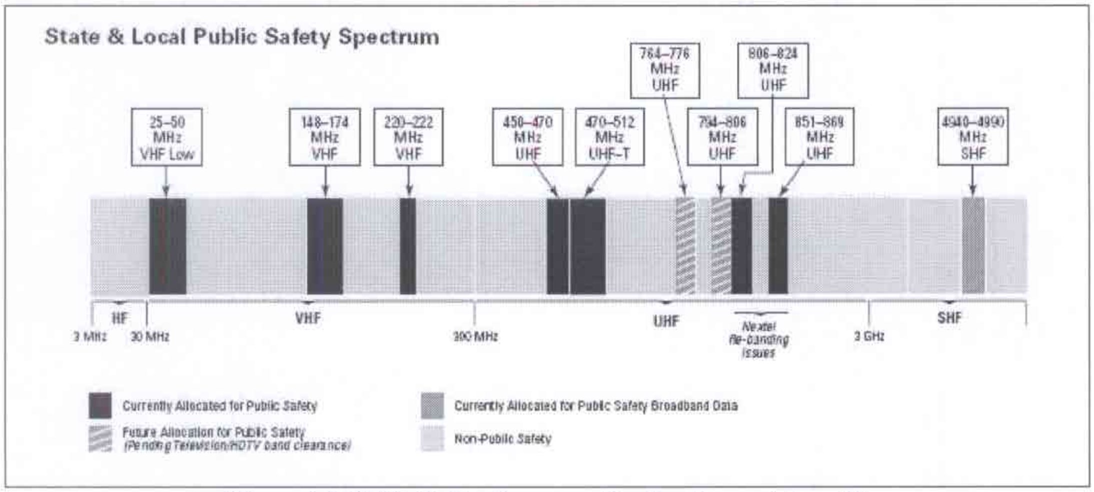

Figure 4.2 Public Safety Frequency Bands referenced from [2]

4.3 Analog, Digital, and Modulation

An analog signal is a waveform with continuous values for a continuous range of time. A digital signal is a waveform with discrete values at constant time intervals. All data in digital systems is represented by a series of zeros and ones. Communication systems use modulation to transmit information over spaces. Modulation is the process of introducing perturbations to a signal in order to add information. The central frequency, also known as carrier frequency, is the only frequency of the modulated signal until the addition of information. Information adds frequencies to the signal on both sides of the central frequency.

The modulating signal in analog systems can be voice data or modem tones, whereas the modulating signal in digital systems is the sequence of ones and zeros. The advantages digital systems have over analog include noise immunity, flexibility to transmit any type of information, system optimization for channel resources, error correction, and security.

4.4 Voice and Data

Analog audio is converted to digital data by vocoders, which use mathematical algorithms to compress the information required to model sound patterns. Digital voice data is then modified by various codes such as error correction codes before modulating the carrier signal. Digital data from a mobile data terminal (MDT) is handled in a similar fashion. The data is used to modulate radio waves, which in this case use the information to change the frequency of the transmitted radio waves. At the receiver, the data is demodulated and information contained in the signal identifies the data type, destination, and algorithms used to modify the data. The information within the signal instructs the system about actions it should take regarding the signal.

4.5 Multiple Access: FDMA and TDMA

The amount of information that can be transmitted is limited by time and bandwidth. Therefore, channel time and channel bandwidth are two resources that can be partitioned to give simultaneous access to multiple users. Frequency-division multiple access (FDMA) is the division of frequencies for individual users, which are available for all channel time. Time-division multiple access (TDMA) gives a user access to the full bandwidth during small increments of time.

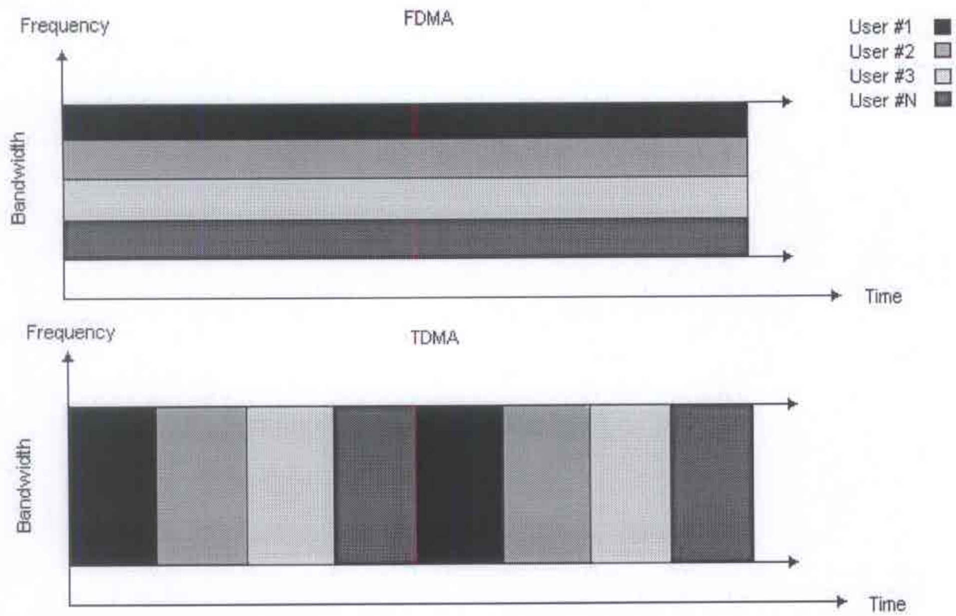

Figure 4.3 FDMA and TDMA Transmission

4.6 Conventional and Trunked Communication

Currently, digital radio channels use FDMA, which previous analog radio systems implemented. These radios systems can operate in either conventional, trunked, or a hybrid of both modes. Conventional systems have fixed frequency channels. This requires the operator to manually change the radio to the desired channel for transmission and reception. Also, the operator must wait for transmissions to end before making a call, since the infrastructure can only handle a single call at a time.

Trunked systems are used in regions with a large user base competing for a limited number of channels. In trunked systems, individual radios are assigned group numbers and a computer controller automatically assigns channels. According to [6] a conventional channel, dedicated to instruction, status, and group identification numbers is constantly scanned by the radios. When a radio transmits, the controller temporarily assigns an open channel for that radio's group, or places the call in a queue. When a channel is available, the computer instructs all radios within that group to the assigned channel. Following transmission, all radios revert to monitoring the control channel.

A hybrid conventional/trunked system has channels allocated to conventional use and separate channels for trunked use.

5. Land Mobile Radio System

A simple diagram of land mobile radio (LMR) systems is depicted in Figure 5.1.

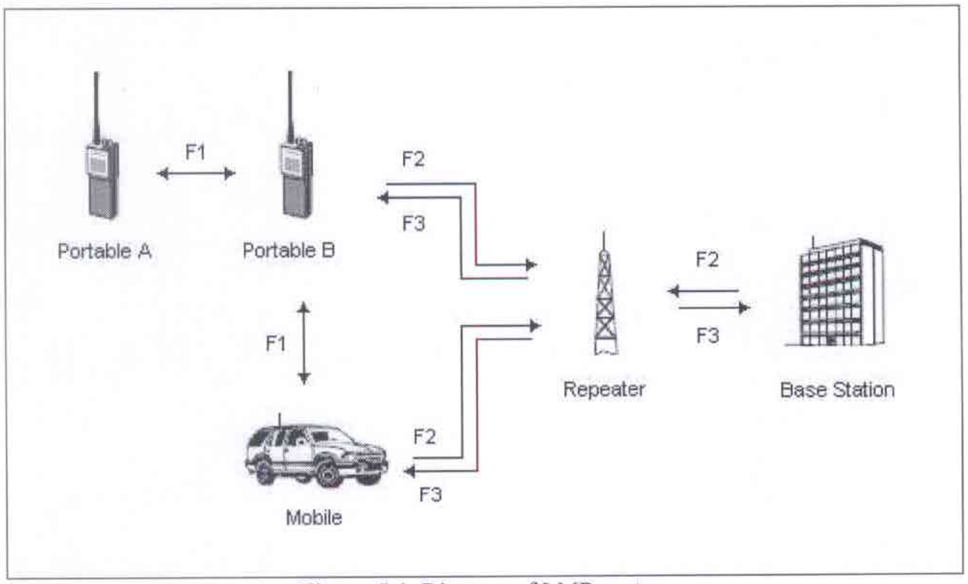

Figure 5.1 Diagram of LMR system

5.1 Simplex Communication

Simplex communication is direct, line-of-sight (LOS) communication between two radios, which means it bypasses the repeater infrastructure. This mode is bi-directional, operating on a single frequency (F1), so simultaneous communication is not possible. This frequency differs from the frequencies used to communicate with the repeaters, thus this mode is often called talk-around.

5.2 Half Duplex Communication

The land mobile radio systems used by public safety agencies are half-duplex. This means that the repeaters transmit on different frequencies (F3) than the base-stations/mobile/portable radios (F2) allowing communication in both directions, but not simultaneously. The mobile and portable radios transmit on the repeaters' receive frequency and the repeaters transmit on the mobile radios' receive frequency.

5.3 Full Duplex Communication

Full-duplex radios can transmit and receive signal simultaneously on different frequencies. These are typically found in base stations. They are rarely used elsewhere since they are expensive and consume more power.

Part II: User Survey

6. User Survey

6.1 User Survey Data

The categories used to describe communication systems in this survey are effectiveness, safety, security, and interoperability. These categories are further divided into use during daily/routine activity and emergency/critical incidents. Ranks indicate the level of importance of a category for future features/considerations of each listed device. The ranks range from one to five, with five being the highest rank.

- **Effectiveness** – The ability a particular device has for communicating in the user's day-to-day and emergency/critical situations.
- **Interoperability** – The ability to communicate with other agencies in day-to-day and emergency/critical situations.
- **Safety** – The ability to promote an environment conducive to the well-being of the user in day-to-day and emergency/critical situations.
- **Security** – The ability to prevent unauthorized access to the system and transmitted data in day-to-day and emergency/critical situations.

The communication equipment listed on the surveys includes wireless phones, wireline phones, internet phones, two-way radios, internet, wireless data, pagers/SMS devices. Wireless phones includes cellular and satellite varieties, which transmit on commercial infrastructure. Wireline phones transmit voice data over wires. Internet phones use voice over internet protocol (VoIP) to transmit voice data over the internet. Two-way radios use private networks to transmit data. Internet communication requires access to a computer and includes email. Wireless data refers to the use of cellular or radio technology to transmit data instead of voice data and includes DataTak, Mobitex, cellular digital packet data (CDPD), and general packet radio service (GPRS). Pagers use radio transmissions from a paging network to notify users of calls, and recent devices have the ability to send alphanumeric messages. Short messaging service (SMS), is available on devices such as mobile phones and personal digital assistants (PDA) and enables communication via short text messages.

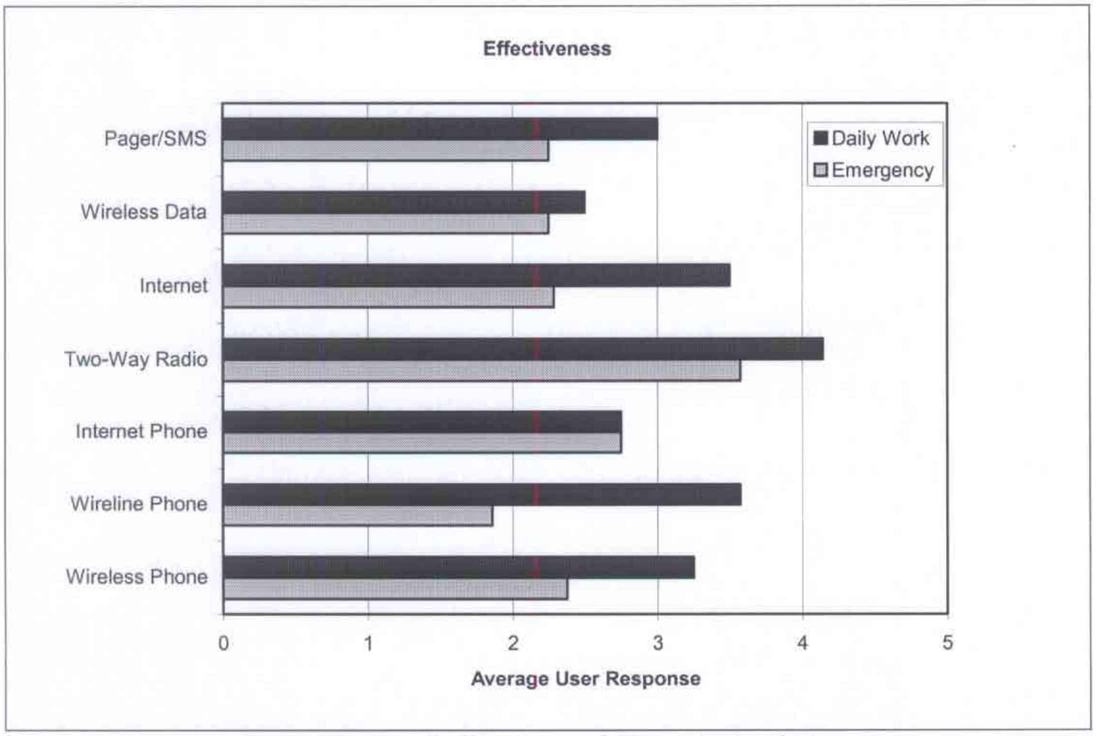

Figure 6.1 Overall effectiveness of communication devices.

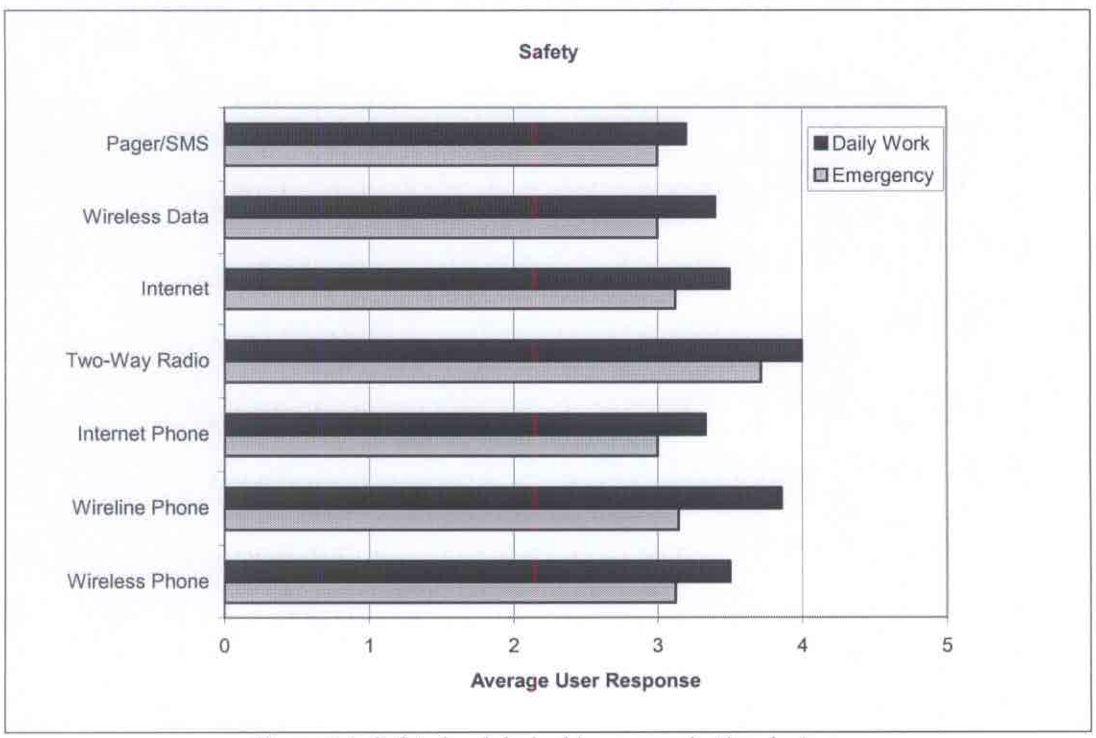

Figure 6.2 Safety level desired in communication devices.

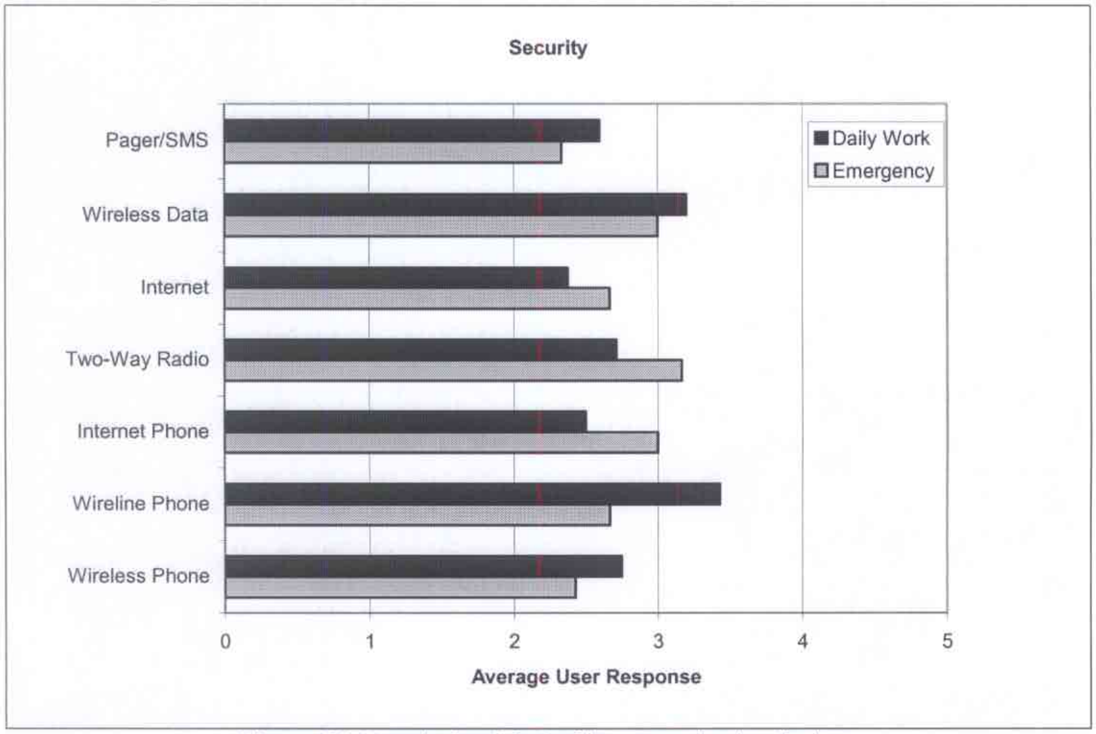

Figure 6.3 Security level desired in communication devices.

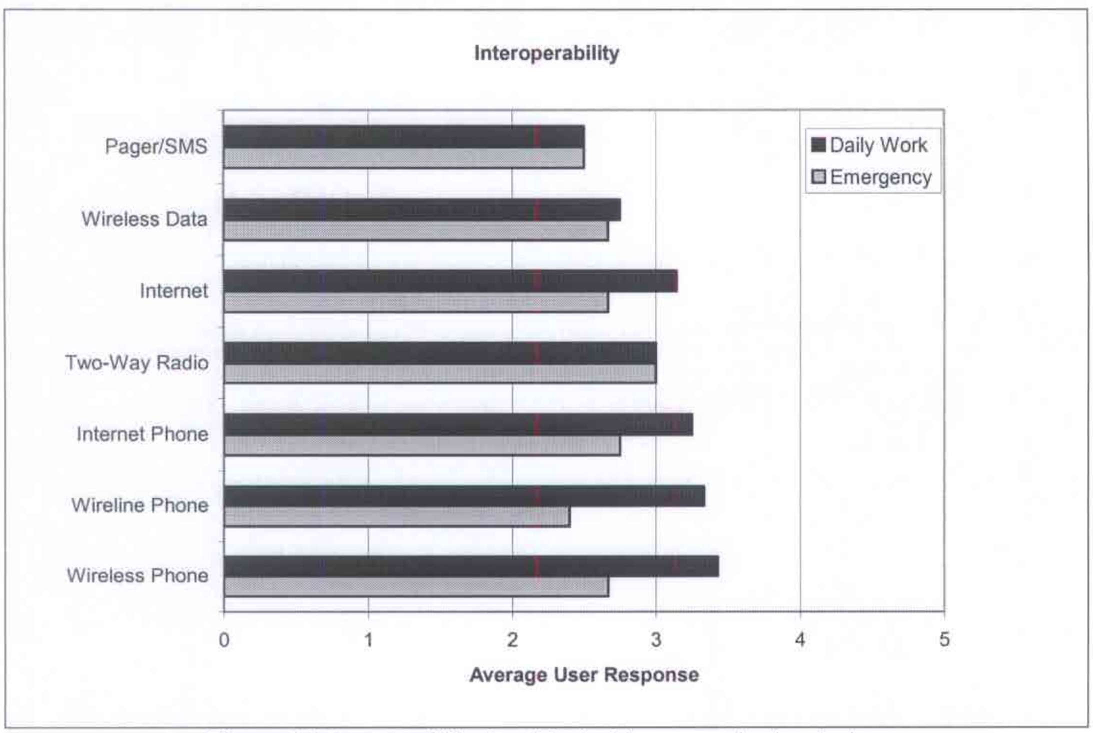

Figure 6.4 Interoperability level desired in communication devices.

6.2 User Survey Analysis and Results

6.2.1 Effectiveness

The user data indicates that two-way radios should be the most effective method for future routine and emergency communication, with ratings of 4.1 and 3.5 respectively. Users indicated that the effectiveness of wireless phones, wireline phones, the Internet, and pager/SMS are effective for daily, routine communication. However, the rated effectiveness of these particular methods falls considerably in emergencies, dropping between 0.75 and 1.7 points to marginally effective. The ratings for Internet telephones and wireless data remain fairly constant at marginally effective in both daily work and emergency communication.

6.2.2 Safety

Safety issues are rated relatively highly for all communication devices, regardless of routine or emergency use. Safety is rated important for all methods, and all values lie in the range of between 3.0 and 4.0, with two-way radios leading all other devices in importance.

6.2.3 Security

According to the survey, security is important for a few devices including wireless data, two-way radios, Internet phones, and wireline phones. The importance of security varies with the situation. For wireline phones, security is an important issue for routine calls. The security of two-way radios and internet phones were rated important in emergencies, while the security of wireless data transfers were rated important at all times. Security in other forms of communication was rated marginally important.

6.2.4 Interoperability

Interoperability is an important issue for five of the seven listed modes of communication. This includes Internet use, two-way radios, Internet phones, wireline phones, and wireless phones. Of these modes, all were rated important for routine use. However, interoperability in emergency communication was rated important only in two-way radios. All other forms of communication have marginally important interoperability ratings.

6.2.5 Routine and Emergency Communication

In comparing the relative importance of routine and emergency communication to each category, routine communication is rated higher for most devices in all categories except security. The security of two-way radios, the Internet and Internet phones are the only combinations of communication methods and features in which importance is rated higher in emergency than in routine use.

6.2.6 Category Comparison

The data also exhibits information about the relative importance of each category compared to the others. The average rank of the individual categories from most important to least is safety, interoperability, security, effectiveness.

6.2.7 Quality Features in Current Communication Systems

Current attributes of the various communication systems that users preferred were lightweight, mobile equipment, clear coverage, and dedicated channels. One agency employs a command vehicle to facilitate communications at an incident site. Also, satellite communication is described as being effective in coordinating activities in the event of sudden emergencies.

6.2.8 Features Desired in Future Communication Systems

Specific changes users said they would like to see include a common spectrum for interoperability, more channels to communicate with other agencies, and a single radio capable of communicating with all people associated with an incident. Despite the low ranking of security in the survey, users listed encrypted channels as something they would like to see in the future. Other changes include the use of headsets to improve mobility at incident sites, since users are often engaged with hands-on activities. Still others would like simultaneous two-way communication and improved communication capabilities between two-way radios and email.

Part III: Technology Survey

7.1 Communications Equipment and Data

In this survey, the communication equipment used by the agencies and their properties are listed. Properties range from physical characteristics such as dimensions and weight to operating properties such as frequency bands, analog capabilities, and digital capabilities.

The first few tables, 7.1-7.3, the models used by each agency are listed and are color coded by agency. These tables indicate the feature capacity for each model and the feature settings in use by the agency. Information on feature capacity is available in data sheets provided by the manufacturers. The technology surveys provide information on settings used by the agencies. The following symbols are used in the first set of tables.

X – capable, but not in use
• – enabled
N/A – not applicable

The last tables in this section, 7.4 and 7.5, list the range of operating frequencies available to each radio. The first table lists the transmitting frequencies of mobiles and the receiving frequencies of the repeaters, while the second table lists receiving frequencies for mobiles and transmitting frequencies for the repeaters. The tables are setup in this fashion due to the half-duplex mode of operation in two-way radio systems. The following symbols are used in these tables.

o – receive
• – transmit

7.1.1 Portable Radios

Portable radios, also known as portable transceivers, are lightweight, handheld, wireless communication units with average dimensions of 7"H x 2.5"W x 2"D. The units incorporate a transmitter, receiver, microphone, speaker, power supply, and antenna. Portable transceivers, such as a walkie-talkie, feature a relatively low-powered transmitter of between one and five watts, and need to have their batteries periodically recharged or replaced. Portable radios have unobstructed line-of-sight coverage between three and five miles. They may be combined in a wireless radio communication system with other portable, mobile, and base station radios. There are also extremely low-powered portables, which link to portable repeaters for interoperability and access to radio systems.

Characteristics

Approximate Size	7"H x 2.5"W x 2"D
Weight	18-27 ounces
Range	3-5 miles
Power Output	3-5 watts

Figure 7.1 Portable Radio - Motorola XTS 5000

X - capable • - enabled LAFD ■ LAPP ■ LBC ■ CSULB □	LAFD	LAPP	LBC	CSULB	UHF	VHF	800 MHz	ANALOG WIDEBAND	ANALOG NARROWBAND	DIGITAL CONVENTIONAL	DIGITAL TRUNKING	IMBE VOCODER	ENCRYPTION
Astro Saber	•				•			X	X	•		•	X
XTS 3000	•						•	•	•	X		X	X
XTS 5000	•				•			X	X	X	•	•	X
XTS 5000	•					•		X	X	•	X	•	X
XTS 5000	•						•	•	•	X	X	X	X
Astro Saber		•			•			X	X	•		•	X
Astro Saber		•			•			•	•	X		X	X
Saber			•		•			•					
Saber			•			•		•					
HT1000				•	•			•	•				

Table 7-1 Sample of portable radio specifications.

7.1.2 Mobile Radios

Mobile radios are larger than portable radios with average dimensions of 2"H x 7"W x 12"D, and are designed to be mounted on the dash, trunk, or other fixed location within a vehicle. Like the portable radios, mobile radios contain both a transmitter and a receiver, but tend to have an external antenna mounted on the vehicle. Mobile radios connect to the vehicle's power supply, which enables them to have a higher transmitter output power, typically ranging between five and fifty watts. The microphone is usually handheld, and the speaker is either internal or externally connected. Higher transmitter power and external antenna result in effective communication ranges exceeding those of portable radios, typically five to fifteen miles. Since physical space is not as important as in portable radios, mobile radio receivers tend to be more sensitive. Like portable radios, mobile radios may be combined into radio communication systems with other portable, mobile, and base station radios.

Characteristics

Approximate Size	2"H x 7"W x 12"D
Weight	3-22 pounds
Range	5-15 miles
Power Output	5-50 watts

Figure 7.2 Mobile Radio - Motorola XTL 5000

X - capable • - enabled LAFD ▩ LAPP ▩ LBC ▩ CSULB □	LAFD	LAPP	LBC	CSULB	UHF	VHF	800 MHz	ANALOG WIDEBAND	ANALOG NARROWBAND	DIGITAL CONVENTIONAL	DIGITAL TRUNKING	IMBE VOCODER	ENCRYPTION
Astro Spectra	•				•			•	•	X	X	X	X
XTL 5000	•				•			X	X	X	•	•	X
XTL 5000	•					•		X	X	•	X	•	X
XTL 5000	•						•	X	X	•	X	•	X
TK790/890	•				•	•		•	•				X
XTL 5000		•			•			•	•	•	X	•	X
Spectra		•			•			•					X
IC-M602		•				•		•					X
M7100		•					•	•	•	•	X	•	X
Syntor x9000			•			•		•					X
MaxTrac				•	•			•					
CDM 1250				•	•			•	•				

Table 7-2 Sample of mobile radio specifications.

7.1.3 Repeaters

Measuring about 9"H x 19"W x 17"D, repeaters are much larger than mobile and portable radios. Repeaters are specialized radios, which contain a transmitter and receiver to perform three basic functions. They receive and demodulate incoming signals, regenerate the information, and then modulate and retransmit the information on a different frequency with higher power and greater elevation to increase line-of-sight coverage [4]. Repeaters have a range of twelve to twenty-five miles and are used to increase the effective communications coverage area for portable, mobile, or base station radios that otherwise might not be able to communicate with one another. The repeater's receiver is tuned to the frequency used by a portable, mobile, or base station transmitter for incoming signals, and the repeater's transmitter is tuned to the frequency used by a portable, mobile, or base station receiver for outgoing signals. Repeaters can communicate with each other through an alternate RF frequency, an Internet connection via computer, or telephone connection. The typical output power for repeaters is 20-125 watts. Landline power cables typically supply power to repeaters, and they often have UPS battery backups in the event of power outages.

Characteristics

Approximate Size	9"H x 19"W x 17"D
Range	12-25 miles
Power Output	20-125 watts

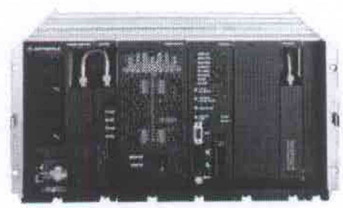

Figure 7.3 Repeater - Motorola Quantar

X - capable • - enabled LAFD ■ LAPP ■ LBC ■ CSULB □	LAFD	LAPP	LBC	CSULB	UHF	VHF	800 MHz	ANALOG WIDEBAND	ANALOG NARROWBAND	DIGITAL CONVENTIONAL	DIGITAL TRUNKING	IMBE VOCODER	ENCRYPTION ENABLED
Quantar	•				•			•	•	X	X	N/A	N/A
Quantar	•						•	•	•	X	X	N/A	N/A
Quantar		•			•			X	X	•	X	N/A	N/A
Quantar		•					•	X	X	•	X	N/A	N/A
Quantar			•		•			•	•	X	X	N/A	N/A
Quantar			•			•		•	•	X	X	N/A	N/A
Quantar			•				•	X	X	•	X	N/A	N/A
MSF 2000				•	•			•				N/A	N/A
Spectra				•	•			•				N/A	N/A
Spectra				•		•		•				N/A	N/A
Radius M1225				•	•			•	•			N/A	N/A

Table 7-3 Sample of repeater specifications.

7.1.4 Mobile Data Terminals

Mobile data terminals were developed to minimize dispatch use over voice channels. Mobile data terminals are customized computers or laptops used to transmit or retrieve data stored on central computers. They are connected to radio modems for use over the same LMR infrastructure used by mobile and portable radios. Some laptop computers have options for built-in wireless connectivity to the radio networks.

Mobile Data Terminal Usage

LAFD	•
LAPP	•
LBC	•
CSULB	•

Figure 7.4 MDT – Panasonic CF29

7.1.5 Wireless Phones

Wireless phones use commercial rather than private networks, and come in cellular or satellite versions. Cellular phones are handheld devices that are much smaller than portable radios. These are limited by the availability of commercial cell sites located in the area of use. Satellite phones can be car-mounted units comparable to mobile radios, or handheld devices like their cellular counterparts. Instead of accessing the phone network through cellular towers, they communicate with satellites in geosynchronous, low earth, or medium earth orbit.

Wireless Phone Usage

LAFD	•
LAPP	•
LBC	•
CSULB	•

7.2 Frequency Range

Table 7.4 shows portable/mobile transmitter frequency and repeater receive frequency (MHz). Table 7.5 shows portable/mobile receive frequency and repeater transmit frequency (MHz).

Table 7-4 Portable/Mobile Transmit Frequency and Repeater Receive Frequency (MHz).

o receive • transmit		LAFD	LAPP	LBC	CSULB	156-157	136-174	380-403	403-470	450-520	700-776	764-776	773-797	794-806	803-806	806-824	851-870
PORTABLES	Astro Saber	•							•								
	Astro Saber	•								•							
	XTS 3000	•													•	•	
	XTS 5000	•					•										
	XTS 5000	•						•	•								
	XTS 5000	•								•							
	XTS 5000	•									•		•		•	•	•
	Astro Saber		•						•								
	Astro Saber		•							•							
	Saber			•			•										
	Saber			•				•	•								
	Saber			•						•							
	HT1000				•				•	•							
MOBILES	Astro Spectra	•							•								
	Astro Spectra	•								•							
	XTL 5000	•					•										
	XTL 5000	•						•	•								
	XTL 5000	•								•							
	XTL 5000	•										•		•		•	•
	TK790/890	•					•			•							
	XTL 5000		•					•	•								
	XTL 5000		•							•							
	Spectra		•						•	•							
	IC-M602		•			•											
	M7100		•													•	•
	Syntor x9000			•			•										
	CDM 1250				•				•	•							
REPEATERS	Quantar	•							o								
	Quantar	•								o							
	Quantar	•														o	
	Quantar		•						o								
	Quantar		•							o							
	Quantar		•													o	
	Quantar			•			o										
	Quantar			•					o								
	Quantar			•						o							
	Quantar			•												o	
	Radius M1225				•					o							

Table 7-5 Portable/Mobile Receive Frequency and Repeater Transmit Frequency (MHz).

o receive • transmit		LAFD	LAPP	LBC	CSULB	156-163	136-174	380-403	403-470	450-520	764-767	773-776	806-824	851-870
PORTABLES	Astro Saber	•							o					
	Astro Saber	•								o				
	XTS 3000	•												o
	XTS 5000	•					o							
	XTS 5000	•						o	o					
	XTS 5000	•								o				
	XTS 5000	•									o	o	o	o
	Astro Saber		•						o					
	Astro Saber		•							o				
	Saber			•			o							
	Saber			•				o	o					
	Saber			•						o				
	HT1000				•				o	o				
MOBILES	Astro Spectra	•							o					
	Astro Spectra	•								o				
	XTL 5000	•					o							
	XTL 5000	•						o	o					
	XTL 5000	•								o				
	XTL 5000	•									o	o		o
	TK790/890	•					o			o				
	XTL 5000		•					o	o					
	XTL 5000		•							o				
	Spectra		•						o	o				
	IC-M602		•			o								
	M7100		•											o
	Syntor x9000			•			o							
	CDM 1250				•				o	o				
REPEATERS	Quantar	•							•					
	Quantar	•								•				
	Quantar	•												•
	Quantar		•						•					
	Quantar		•							•				
	Quantar		•											•
	Quantar			•			•							
	Quantar			•					•					
	Quantar			•						•				
	Quantar			•										•
	Radius M1225				•					•				

7.3 Technology Survey Results

7.3.1 Interoperability

LAFD

The Los Angeles Fire Department has portables and mobiles operating in all three frequency bands. However, their repeaters are only setup for UHF and 800 MHz. The Quantar repeaters have the ability to operate in analog mode only or detect analog/digital and repeat in the appropriate mode. However, this dual mode does not allow communication between analog and digital devices. The survey data indicates that the repeaters operate in analog-only mode so only a few of their devices are compatible. Models not compatible with these repeaters include portables and mobiles operating in VHF, digital conventional. Other incompatible models are UHF portables on digital conventional and digital trunking. Incompatible mobiles operate in UHF digital trunking and 800 MHz digital conventional. Additionally, there is a different model for the two UHF bands. This means that different ranges of frequencies are available, so UHF radios may not be compatible with UHF radios from other agencies or possibly even within the same agency.

LAPP

The Los Angeles Port Police (LAPP) repeaters operate on digital conventional channels in UHF and 800 MHz. Since there is no digital-only mode on the repeater, this operates on analog and digital modes. All of their portables and mobiles have the capability of operating in analog and digital modes. The survey data indicates that they have models operating on both, so analog models would not be able to communicate with digital models. They also have a marine radio, IC-M602, with a limited frequency range in the VHF band. This radio is not operable with their listed repeaters, since their repeaters operate on the UHF and 800 MHz bands.

LBC

The City of Long Beach has repeaters operating in analog mode for VHF and UHF bands, while the 800 MHz band operates in digital/analog mode. The few mobiles and portables models listed in the survey operate in either VHF or UHF analog. Therefore, they provide communications for others in their region on the 800 MHz band.

CSULB

All equipment used by the CSULB police operates on the UHF band in analog mode. The only exception is a repeater on the VHF band.

Interagency

The diversity in bands, frequency channels, analog/digital modes, and trunking/conventional modes for the equipment listed in this survey indicate there is very little equipment interoperability between agencies. However, some agencies have repeaters operating on bands other than the bands of their mobiles and portables, which could accommodate other agencies since operating parameters can be changed remotely on the Quantars. Also, some agencies have not listed repeaters that operate on the same bands as some of their radios. Therefore, these may be stockpiled radios for use in specific interagency operations. Aside from the LMR equipment, all agencies use cellular phones, which is a stopgap method for attaining interoperability. It is a temporary solution, since commercial systems become congested during major disasters.

7.3.2 Security

All digital radios and some analog radios listed in this survey are capable of some form of encryption. However, most radios have this as an optional feature, which requires the addition of a hardware module or reprogramming by an authorized person. Every agency involved with this survey does not use encryption.

7.3.3 Safety

This survey on specific equipment features does not address safety issues. However, that does not mean that some equipment features are not relevant to safety issues. For example, dead spots in the LMR system are addressed with strategic positioning of repeaters to ensure the best possible coverage. Certain factors such as distance from the repeater, urban density, and structural density have a large effect on communication abilities. Distance has the greatest effect on analog radios, since signal quality diminishes with increased distance. Digital radios are less affected, but they do have a cutoff point where signal quality degrades dramatically. Additionally, since repeaters have relatively high output power compared to portables, at long ranges it is possible for a user to hear incoming signals from the repeater without having the ability to talk back since portable output powers are much lower. Use in urban environments with many large buildings, or within a building, will decrease the strength of the signal reaching the repeater. Other methods used by the agencies to combat dead spots and/or improve communication include the use of mobile command centers and satellite phones.

Part IV: Conclusions and Recommendations

8. Conclusions

8.1 Conclusion on User Survey

The data demonstrates that two-way radios should be the most effective method of communication in both routine and emergency situations. Other effective communication methods during routine situations include the Internet, wireline, wireless phones, and paging systems. Therefore, two-way radio voice communication should be the primary focus of future studies.

Priorities vary depending on the situation analyzed. If priority is placed on routine communication, interoperability between the systems is important to streamline communication. Therefore, interfaces between two-way radios on other communication systems are important. If emergency situations are stressed, then priority lies with improving the effectiveness of two-way radio communication systems.

Users stressed safety as the number one issue concerning all communication systems. Again for purposes here, safety is defined as promoting a safe environment for the user of the communication device. Typically, this involves the ability to communicate with team members at all times, whether the reason is for backup or additional information. There are also interoperability implications in cases that involve communication with users from other regions. Interoperability of two-way radio systems is clearly a critical factor for safety. Additionally, ensuring good coverage, so radio communication is readily available throughout a jurisdiction, is another method to ensure user safety.

Security appears to be the least important category according to the data in both surveys. It is rated lower than any other category, and it is not enabled in any of the communication devices used by any agency. However, if it is needed, parts can be installed or other radios can be reprogrammed.

8.2 Conclusion on Technology Survey

The technical data includes information on the radio networks used by local public safety agencies. It clearly demonstrates that interoperability issues are present, not only between agencies but within agencies. For example, on scene radio communication using portable simplex communication would not be possible between users with radios on the UHF and VHF bands. The repeater network used by the LAFD and LAPP operate on the UHF and 800 MHz bands, which do not support the VHF radios used by the city of Long Beach. Users commented on this issue with the desire to see a common spectrum for interoperability.

Specific equipment used by these agencies exhibit limited compatibility, primarily since all agencies have repeaters and radios operating on the UHF band. However, it is unclear as to whether they are tuned to compatible frequency channels in order to communicate if needed. Additionally, with the exception of the City of Long Beach, most radios are capable of the older analog modes. All radios used by all agencies are still capable of transmitting on analog wideband, which is the older standard. A more accurate estimation of interoperability can be developed with more specific information on the model numbers of radios still in use, as well as the approximate number of units involved.

9. Recommendations

Project 25 (P25) is the standard for interoperable two-way digital wireless communication systems and is based on the frequency division multiple access (FDMA) of its analog predecessors. The objectives of P25 are to provide intra-agency and inter-agency interoperability, improved spectrum efficiency, and increased functionality.

The P25 standard supports the following open source architectures to provide communication with multiple forms of communication. These are the common air interface (CAI), RF sub-system, inter-system interface, telephone interconnect interface, network management interface, and the host and network data interfaces.

P25 defines the common air interface (CAI), which allows any mobile radio to work within the radio system. The CAI specifies narrowband channel bandwidths at 12.5 kHz, talk-around, and protection from proprietary technology (migrations, upgrades, alternate vendors). It specifies conventional and trunking capabilities, encryption standards, over-the-air rekeying, and the vocoder standard IMBE. It supports many encryption algorithms including DES, triple-DES, and AES. It states that channels must transmit data at 9600 bps, with voice data at 4400 bps.

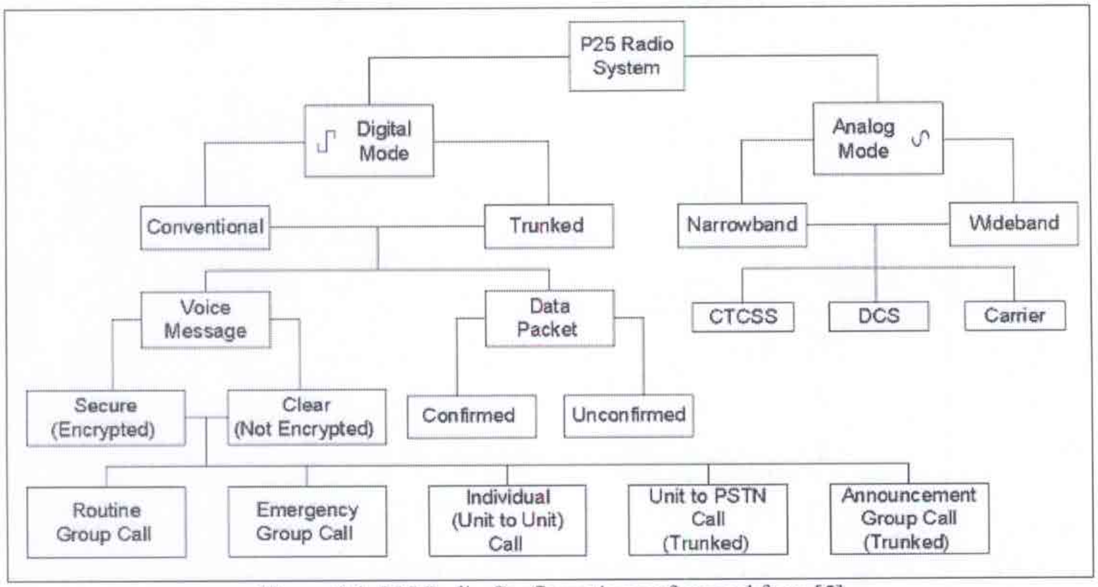

Figure 8.1 P25 Radio Configurations referenced from [5]

Backwards compatibility comes from the ability of P25 compliant radios to operate in digital or analog modes. Under the P25 standard, any P25 compliant radio can communicate with another P25 compliant radio in digital conventional, digital trunking, wideband analog, or narrowband analog modes. This includes portables, mobiles, and repeaters.

Vendor incompatibility occurs because of fundamental design differences in the communication system as well as proprietary technology. These are overcome by defining standards for the blocks of the communication system diagrammed in figure 5.1, and covered in the CAI. The introduction of digital communication systems increases the possibilities of incompatibilities in features such as encryption and vocoder algorithms. Defining of standards helps to overcome this obstacle. Older radios that use proprietary technology not defined by P25 standards will not work with P25 systems. For example, older Motorola Astro radios have a digital format using an alternate vocoding algorithm, which is incompatible with the IMBE standard defined by P25.

Another incompatibility issue involves the channels used within the radio frequency bands. For interoperability within an agency, the system of repeaters must receive any and all channel frequencies used by radios within the system. Additionally, this requirement holds for any other agency that may need to operate on the system.

Many agencies are migrating to equipment using P25 standards. This should ensure compatibility between future and legacy systems, compatibility between different vendors, and a course for future changes. Despite the use of P25 equipment, interoperability issues still exist, so it does not guarantee full compatibility. Further research into the standards set forth by P25 would give more insight into possible changes to the two-way radio infrastructure and feature set to enable safer, more secure communication, and greater interoperability with other agencies and wireless systems.

Appendix A: List of Acronyms

2G	Second Generation GPRS
3G	Third Generation GPRS
ADP	Advanced Digital Privacy
AES	Advanced Encryption Standard
AMBE	Phase II Vocoder
APCO	Assocation of Public Safety Communications Officials International
C4FM	Continuous Four Level Frequency Modulation – type of DQPSK
CAI	Common Air Interface
CDPD	Cellular Digital Packet Data
CQPSK	Simultaneous Phase and Carrier Modulation to minimize spectrum width
CTCSS	Continuous Tone-Coded Squelch System
DCS	Digital-coded Squelch
DES	Data Encryption Standard
ESMR	Extended Specialized Mobile Radio
GPRS	General Packet Radio Service
GSM	Global Service for Mobile Communication
HF	High Frequency
IMBE	Improved Multiband-Excitation
LOS	Line-of-sight
LMR	Land Mobile Radio
MDT	Mobile Data Terminal
MTSO	Mobile-telephone switching office
OTAR	Over-the-air Rekeying – updates encryption keys over the radio network
P25	Project 25
PSTN	Public Switch Telephone Network
PSWN	Public Safety Wireless Network
RD-LAP	Radio Data Link Access Protocol
RF	Radio Frequency
RFSS	Radio Frequency Subsystem
SHF	Super High Frequency
SMR	Specialized Mobile Radio
SMS	Short Messaging Systems
SU	Subscriber Unit
TIA	Telecommunications Industry Association
UHF	Ultra High Frequency (403-470 MHz)
UPS	Uninterruptible Power Supply
VHF	Very High Frequency (136-174 MHz)
VoIP	Voice Over Internet Protocol
VRM	Vehicle Radio Modem

Appendix B: References

[1] National Institue of Justice, "When They Can't Talk, Lives Are Lost," National Task Force on Interoperability Brochure, February 2003, Available at http://www.ojp.usdoj.gov/nij/pubs-sum/211512.htm

[2] National Institue of Justice, "Radio Spectrum," NIJ InShort, February 2006. Available at http://www.ojp.usdoj.gov/nij/pubs-sum/212975.htm

[3] D. Veeneman, "Understanding Trunking," Monitoring Times, Apr., pp X-X, 2005. Available online at http://www.signalharbor.com/sr/05apr/index.html

[4] M. Tarplee, "Fundamentals of Repeaters," [Online Document] Available at http://www.ycars.org/presentations/ Fundamentals%20of%20Repeaters.ppt

[5] Daniels Electronics Ltd, "P25 Radio Systems Training Guide," [Online Document], [2006 June 6] Available at http://www.danelec.com/pdfs/P25%20Training%20Guide.pdf

Interoperability Resources

[6] M. J. Taylor, R.C. Epper, and T.K. Tolman. "Wireless Communications and Interoperability Among State and Local Law Enforcement Agencies," National Institute of Justice Report, January 1998.

[7] K. Imel and J. Hart, "Understanding Wireless Communications in Public Safety A Guidebook to Technology, Issues, Planning, and Management," NLECTC Report, January 2003.

[8] National Institue of Justice, "Communications Interoperability: Basics for Practitioners," NIJ InShort, April 2006. Available at http://nij.ncjrs.org/publications/pubs_db.asp

P25 Resources

[9] www.project25.org

[10] http://www.apcointl.org/frequency/project25

[11] www.tiaonline.org/standards/project_25

Specification Sheets

[12] www.motorola.com

[13] www.icomamerica.com

[14] www.kenwoodusa.com

[15] www.macom.com

Appendix C: Data Sheets

Los Angeles Fire Department

Mobile Radios					
Make	Motorola	Motorola	Motorola	Motorola	Motorola
Model	ASTROSpectra	XTL 5000	XTL 5000	XTL 5000	XTL 5000
Band	800 MHz	800 MHz	VHF	UHF R1	UHF R2
Bandsplits	806-824 MHz 851-870 MHz	764-776 MHz 794-806 MHz 806-825 MHz 851-870 MHz	136-174 MHz	350-470 MHz	450-520 MHz
Power	35 W	10-35 W	10-50 W	10-40 W	10-45 W
Weight	6.1 lbs	6.1 lbs	6.1 lbs	6.1 lbs	6.1 lbs
Size	2.0H x 7.1W x 8.6D	2.0H x 7.1W x 9.1D	2.0H x 7.1W x 9.1D	2.0H x 7.1W x 9.1D	2.0H x 7.1W x 9.1D
Date	2000	2005-2006	2005-2006	2005-2006	2005-2006
Mode	Analog/Digital	Analog/Digital	Analog/Digital	Analog/Digital	Analog/Digital
	Conventional	Conventional Trunked	Conventional Trunked	Conventional Trunked	Conventional Trunked
Encryption	Optional	Capable	Capable	Capable	Capable

AstroSpectra: unclear as to whether encryption is optional feature require additional hardware, or its an option to implement it on a transmission. Capable of analog and digital modes.

XTL 5000: dimensions indicate W4, W5, or W7 dash mounts

XTL 5000: ASTRO 25 Digital Trunking, ASTRO analog and digital trunking, analog and digital conventional

XTL 5000: Encryption type III and type IV including: DES, DES-XL, DES-OFB, DVI-XL, DVP-XL, and AES algorithms. Supports ADP

Mobile Radios					
Make	Kenwood	Kenwood	Kenwood	Kenwood	
Model	TK790(H)	TK790	TK890(H)	TK890	
Band	VHF	VHF	UHF	UHF	
Bandsplits	148-174 MHz	148-174 MHz 136-156 MHz	450-480 MHz	450-490 MHz 480-512 MHz 403-430 MHz	
Power	45-110 W	5-45 W	40-100 W	5-40 W	
Weight	7.9 lbs	5.0 lbs	7.9 lbs	5.0 lbs	
Size	2.25H x 7.0W x 12.75D	2.25H x 7.0W x 9.0D	2.25H x 7.0W x 12.75D	2.25H x 7.0W x 9.0D	
Date	1995-2000	1995-2000	1995-2000	1995-2000	
Mode	Analog	Analog	Analog	Analog	
	Conventional	Conventional	Conventional	Conventional	
Encryption	Optional	Optional	Optional	Optional	

Encryption is available as optional scrambler modules.

Los Angeles Fire Department

Portable Radios					
Make	Motorola	Motorola	Motorola	Motorola	Motorola
Model	ASTRO Saber	XTS 3000	XTS 5000	XTS 5000	XTS 5000
Band	UHF	800 MHz	700/800 MHz	VHF	UHF
Bandsplits	403-470 MHz 450-520 MHz	806-824 MHz 851-870 MHz	700-776 MHz 773-797 MHz 803-806 MHz 806-824 MHz 851-870 MHz	136-174 MHz	380-470 MHz 450-520 MHz
Power	1-4 W	3 W	3	6	5
Weight	1.7 lbs	1.55 lbs	~1.5 lbs	~1.5 lbs	~1.5 lbs
Size	9H x 2.9W x 1.2D	6.58H x 2.44W x 1.65D	6.58H x 2.44W x 1.83D	6.58H x 2.44W x 1.83D	6.58H x 2.44W x 1.83D
Date	1999	2001-2006	2001-2006	2005-2006	2005-2006
Mode	Analog/Digital	Analog/Digital	Digital	Digital	Digital
	Conventional	Conventional	Conventional Trunked	Conventional Trunked	Conventional Trunked
Encryption	Capable	Capable	Capable	Capable	Capable

XTS 3000: analog only mode is optional

XTS 5000: Encryption optional, algorithms include AES, DES-XL, DES-OFB, DVP-XL, and DVI-XL

Repeaters/Base Stations					
Make	Motorola	Motorola			
Model	Quantar	Quantar			
Band	800 MHz	UHF			
Power	20-100 W	25-110 W			
ERP	--	--			
Weight	55 lbs	55 lbs			
Size	8.75x19x17	8.75x19x17			
Date	2005-2006	2005-2006			
Mode	Analog/Digital	Analog/Digital			
	Conventional Trunked	Conventional Trunked			
Encryption	Capable	Capable			
Digital R_d					

All models support Astro Digital, SECURENET, and analog operations.

Configurations include analog only, analog/SECURENET, and analog/Astro.

Trunk and encryption capable.

Los Angeles Fire Department

Wireless Phones					
Make	Mitsubishi	Various	Various	Various	
Model	ST-211				
Service	MSV	Sprint	Verizon	Nextel	
Type	Satellite	Cellular	Cellular	Cellular	
Band	1626.5-1660.5 MHz				
EIRP	12.5-16.5 dBW				
Weight					
Size					
Date	2004	2005-2006	2001-2006	2005-2006	
Data/Email	No				

Wireless Data Terminals/Computers					
Make	Panasonic				
Model	CF-29				
Service	Motorola				
Weight	7.94 lbs				
Size	2.3H x 11.8W x 9.5D				
Date	2005-2006				
Data Rate	19.2				

Integrated Wireless Options

- CDPD
- GSM/GPRS
- 1xRTT/CDMA 2000

Los Angeles Port Police

Mobile Radios					
Make	Motorola	Motorola	Motorola	Motorola	
Model	Spectra	Spectra	XTL 5000	XTL 5000	
Band	UHF	UHF	UHF R1	UHF R2	
Range	403-433MHz 450-482MHz 482-512MHz	450-482MHz	350-470 MHz	450-520 MHz	
Power	20-40 W	50-110 W	10-40 W	10-45 W	
Weight	5.5 lbs	10.5 lbs	6.1 lbs	6.1 lbs	
Size	2.0H x 7.0W x 8.6D	2.0H x 9.25W x 12.9D	2H x 7.1W x 9.1D	2H x 7.1W x 9.1D	
Date	1999	1999	2005	2005	
Mode	Analog	Analog	Analog/Digital	Analog/Digital	
	Conventional	Conventional	Conventional Trunked	Conventional Trunked	
Encryption	No	No	Capable	Capable	

Spectra: possible that this was mislabeled away from the digital ASTRO spectra. This is because the spectra was released in 1991, the astro spectra in 1996, and acquisition was in 1999.

XTL 5000: dimensions indicate W4, W5, or W7 dash mounts

XTL 5000: ASTRO 25 Digital Trunking, ASTRO analog and digital trunking, analog and digital conventional

XTL 5000: Encryption type III and type IV including: DES, DES-XL, DES-OFB, DVI-XL, DVP-XL, and AES algorithms. Supports ADP

Mobile Radios					
Make	Icom	M/ACom	Motorola	Motorola	Motorola
Model	IC-M602	M7100	ASTROSpectra	ASTROSpectra	ASTROSpectra
Band	VHF	800 MHz	UHF	UHF	UHF
Range	156.050-157.425 MHz	806-825 MHz 851-870 MHz	438-470 MHz	403-433 MHz 450-482 MHz 482-512 MHz	403-433 MHz 450-482 MHz 482-512 MHz
Power	25	10-35 W 30 W	10-25 W	20-40 W	50-100 W
Weight	3 lbs	6 lbs	6.1 lbs	6.1 lbs	11.2 lbs
Size	4.3H x 8.6W x 4.3D	2.0H x 6.9W x 9.3D	2.0H x 7.1W x 8.6D	2.0H x 7.1W x 8.6D	2.0H x 7.1W x 8.6D
Date	Various	2005	1999	1999	1999
Mode	Analog	Analog/Digital	Analog/Digital	Analog/Digital	Analog/Digital
	Conventional	Conventional Trunked	Conventional	Conventional	Conventional
Encryption	No	Capable	Optional	Optional	Optional

ICOM: has voice scrambling UT-112 and has class D, DSC

Los Angeles Port Police

Portable Radios					
Make	Motorola	Motorola			
Model	ASTRO Saber	ASTRO Saber			
Band	UHF	UHF			
Bandsplits	403-470 MHz	450-520 MHz			
Power	1-4 W	1-4 W			
Weight	1.7 lbs	1.7 lbs			
Size	9H x 2.9W x 1.2D	9H x 2.9W x 1.2D			
Date	1999	1999			
Mode	Analog/Digital	Analog/Digital			
	Conventional	Conventional			
Encryption	Capable	Capable			

Two encryption algorithms, unsure if these are astro and securenet.

Repeaters/Base Stations					
Make	Motorola	Motorola			
Model	Quantar	Quantar			
Band	UHF	800 MHz			
Power	25-110 W	20-100 W			
ERP	--	--			
Weight	55 lbs	55 lbs			
Size	8.75x19x17	8.75x19x17			
Date	2005-2006	2005-2006			
Mode	Analog/Digital	Analog/Digital			
	Conventional Trunked	Conventional Trunked			
Encryption	No	No			
Data Rate					

All models support Astro Digital, SECURENET, and analog operations.
Configurations include analog only, analog/SECURENET, and analog/Astro.
Trunk and encryption capable.

Wireless Phones					
Make	Motorola	Nokia	Rimm	Palm	
Model	Various	Various	Various	Various	
Service	Various	Various	Various	Various	
Type	Cellular	Cellular	Cellular	Cellular	
Weight					
Size					
Date	Continous	Continous	Continous	Continous	
Data/Email	No	No	Yes	Yes	

Los Angeles Port Police

Wireless Data Terminals/Computers					
Make	Motorola				
Model	ML850				
Service	Motorola				
Weight	7.0 lbs				
Size	1.7x10.8x9.4				
Date	2000				
Data/Email	19.2				

Integrated Wireless

LAN 802.11b

WAN (GSM/GPRS, Private DataTAC, iDEN, CDMA) (optional)

Long Beach City

Mobile Radios					
Make	Motorola	Motorola			
Model	Syntor X 9000	Syntor X 9000			
Series	T73KEJ7J04AK	T43KEJ7J04AK			
Band	VHF	VHF			
Range	150-174MHz	136-154.4MHz 150.8-174MHz			
Power	55-100W	20-40W			
Size	2.5H x 11.5W x 16.0D	2.5H x 11.5W x 16.0D			
Weight	22.5 lbs	22.5 lbs			
Mode	Analog Conventional	Analog Conventional			
Encryption	No	No			

Mobile Radios					
Make	Motorola	Motorola	Motorola	Motorola	
Model	Syntor X 9000	Syntor X 9000	Syntor X 9000	Syntor X 9000	
Series	T74KEJ7J04AK	T74KEJ7J04AK	T64KEJ7J04AK	T34KEJ7J04AK	
Band	UHF	UHF	UHF	UHF	
Range	406-420 MHz	450-470 MHz	470-488 MHz 482-500 MHz 494-512 MHz	470-488 MHz 482-500 MHz 494-512 MHz	
Power	100W	50-100W	39-78W	15-30W	
Size	2.5H x 11.5W x 16.0D	2.5H x 11.5W x 16.0D	2.5H x 11.5W x 16.0D	2.5H x 11.5W x 16.0D	
Weight	22.5 lbs	22.5 lbs	22.5 lbs	22.5 lbs	
Mode	Analog Conventional	Analog Conventional	Analog Conventional	Analog Conventional	
Encryption	No	No	No	No	

Long Beach City

Mobile Radios					
Make	Motorola				
Model	VRM 600				
Band	800 MHz				
Range					
Power	15				
Size	small				
Weight	5 lbs				
Control D	N/A				
Weight	N/A				
Mode	Digital Conventional				
Encryption	No				

No spec sheets available for this product.

Portable Radios					
Make	Motorola	Motorola			
Model	Saber	Saber			
Band	VHF	UHF			
Splitbands	136-150.8MHz 146-162 MHz 146-174 MHz 148-174MHz 157-174MHz	403-433 MHz 440-470 MHz 458-490 MHz 482-512 MHz			
Power	N/A	N/A			
Weight	N/A	N/A			
Size	N/A	N/A			
Date	1982	1982			
Mode	Analog	Analog			
	Conventional	Conventional			
Encryption	See Notes	See Notes			

Sabers came in secure-capable and non-secure versions
Earliest Saber introduced in 1986

Long Beach City

Repeaters/Base Stations					
Make	Motorola	Motorola	Motorola		
Model	Quantar	Quantar	Quantar		
Band	VHF	UHF	800 MHz		
Power	25-125 W	25-110 W	20-100 W		
ERP	150	200	500		
Weight	55 lbs	55 lbs	55 lbs		
Size	8.75H x 19W x 17D	8.75H x 19W x 17D	8.75H x 19W x 17D		
Date	2000	2000	2000		
Mode	Analog/Digital	Analog/Digital	Analog/Digital		
	Conventional Trunked	Conventional Trunked	Conventional Trunked		
Encryption	No	No	No		
Digital R_d			19.2		

All models support Astro Digital, SECURENET, and analog operations.
Configurations include analog only, analog/SECURENET, and analog/Astro.
Trunk and encryption capable.

Wireless Phones					
Make	NONE				
Model					
Service					
Type					
Weight					
Size					
Date					
Data/Email					

Wireless Data Terminals/Computers					
Make	Motorola				
Model	MDT 9100				
Service	N/A				
Weight	20 lbs				
Size	large				
Date	1985				
Data/Email	19.6 kbps				

Very little information available for the Motorola MDTs in general.

CSULB Police

Mobile Radios					
Make	Motorola	Motorola	Motorola		
Model	Maxtrack	CDM 1250	CDM 1250		
Band	UHF	UHF (403-470)	UHF (450-512)		
Channels		64	64		
Power	15	1-25	1-25		
Weight		3.15 lbs	3.15 lbs		
Size (HxWxD)	2"x 7"x7"	2"x 7"x7"	2"x 7"x7"		
Date	>10 years	2005	2005		
Mode	Analog	Analog	Analog		
	Conventional	Conventional Wideband Narrowband	Conventional Wideband Narrowband		
Encryption	No	No	No		

Quik call II and MDC 1200 signaling (analog)

Portable Radios				
Make	Motorola	Motorola	Motorola	Motorola
Model	HT1000	HT1000	HT1000	HT1000
Band	UHF (403-470)	UHF (403-470)	UHF (450-520)	UHF (450-520)
Channels	2	16	2	16
Power	1-4 W	1-4 W	1-4 W	1-4 W
Weight				
Size	6.3"x2.3"x1.5"	6.3"x2.3"x1.5"	6.3"x2.3"x1.5"	6.3"x2.3"x1.5"
Date	>10 years	>10 years	>10 years	>10 years
Mode	Analog	Analog	Analog	Analog
	Conventional Wideband Narrowband	Conventional Wideband Narrowband	Conventional Wideband Narrowband	Conventional Wideband Narrowband
Encryption	No	No	No	No

CSULB Police

Repeaters/Base Stations					
Make	Motorola	Motorola	Motorola	Motorola	Motorola
Model	Spectra	Spectra	Radius M1225	Radius M1225	MSF 2000
Band	VHF	UHF	UHF	UHF	UHF
Power	30	20	15	15	25
ERP	30	20	15	15	90
Weight					
Size	19"x4"x16"	19"x4"x16"	6"x6"x2"	6"x6"x2"	19"x36"x15"
Date	>10 years	> 10 years	2000	2000	~ 5 years
Mode	Analog	Analog	Analog	Analog	Analog
	Conventional	Conventional	Conventional	Conventional	Conventional
Encryption	No	No	No	No	No
Digital R_d	-	-	-	-	-

Wireless Phones					
Make	Motorola	Motorola	Motorola	RIM/Blackberry	
Model	I830	I836	I860	7520	
Service	Nextel	Nextel	Nextel	Nextel	
Type	Cellular	Cellular	Cellular	Cellular	
Weight					
Size					
Date	< 2 years	2004-2005	2005	2005	
Data/Email	Yes	Yes	Yes	Yes	

Wireless Data Terminals/Computers					
Make	Sierra Wireless				
Model	MP 750				
Service	Cingular				
Weight					
Size	8"x6"x3"				
Date	2005				
Data/Email	GPRS				

This is a radio modem.