Survey of Port Communication Equipment for Safety, Security, and Interoperability

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Abstract:

One of the most difficult problems on port daily operations is the communication. While the development of radios and modern electronics improved and simplified that effort on one level, they also severely complicated it on yet another – interoperability between past and present products. The inability of different brands of radios to work together caused problems not only among port officials and port operators, but also among the various elements of the shipping companies itself. The interoperability problem is even getting worse when there is an emergency or crisis. To solve this problem, we need a fundamental understanding on the existing communication equipment employed at the Port LA and Long Beach. This paper reports the study results on identifying the communication needs, specifically, in the areas of interoperability.

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Introduction

Adaptable and smooth communication among all elements in the ports, including truck drivers for containers, shipping companies, port officials, is vital for safe, accurate, and efficient transportation of goods. Efficient communication is critical to all public safety agencies, including security, police officers, and fire fighters. Consequently, there is an immediate need to improve the efficient and quality of the communication between the users and the dispatcher in metropolitan areas for public safety and related events. As we have witnessed from the various disasters which have struck the United States recently, the lack of an efficient communication between the different public safety agencies caused delays in rescue and recovery efforts.

The methodology applied in the study on the port communication equipment is the following:

Step 1. Data collection. A survey was conducted to know what equipments are employed in the daily working environment and identified the current and future needs.

Step 2. Analysis. To understand the complexity of the communication structure at the port area, we analyze the working equipments based on the data collected in terms of transmission data rate, communication type (analog or digital), modulation schemes, reliability on the covered areas, and interoperability.

Step 3. Recommendation. Based on the analysis, a recommendation is made. It will serve as the fundamental reference for research, development, and demonstration of emerging technology solution for interoperable voice/data communications for use by public safety agencies around Long Beach Port Community.

This paper is organized as follows. Section I is an introduction to the communication systems, including the definition of interoperability, security, and safety. The communication devices employed today are also discussed. Section II presents the users' survey. It summarizes data collected by a survey of users within the California State University of Long Beach (CSULB) Police Department; the Port of Los Angeles Police Department (LAPD), Fire Department (LAFD), and security office; and the Port of Long Beach Police Department, Fire Department, security office, and Long Beach City (LBC). 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. In this survey, the communication equipment used by the agencies and their properties are listed. Section III presents a technical survey on the communication equipments. Properties range from physical characteristics such as dimensions and weight to operating properties such as frequency bands, analog capabilities, and digital capabilities. Additionally, it presents collected 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 used to explain interoperability problems. Conclusions and recommendations are given in Section IV.

I: Fundamentals of Communication Systems at Port

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.

1.1 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 in contiguous frequency bands for public safety.

1.2 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 cipher text, 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 cipher text. 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.

1.3 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.

1.4 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 it is called a mobile or cellular telephone. It is completely compatible with regular wireline phones and wireless phones on other networks.

1.5 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.

1.6 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.

1.7 Spectrum and Public Safety Bands

The radio communications spectrum is a limited resource and ranges from 30 kHz to 300 GHz. The 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 separated into channels with defined central frequencies and permitted bandwidth. Figure 1 depicts the spectrum location for public safety agencies. Note that 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.

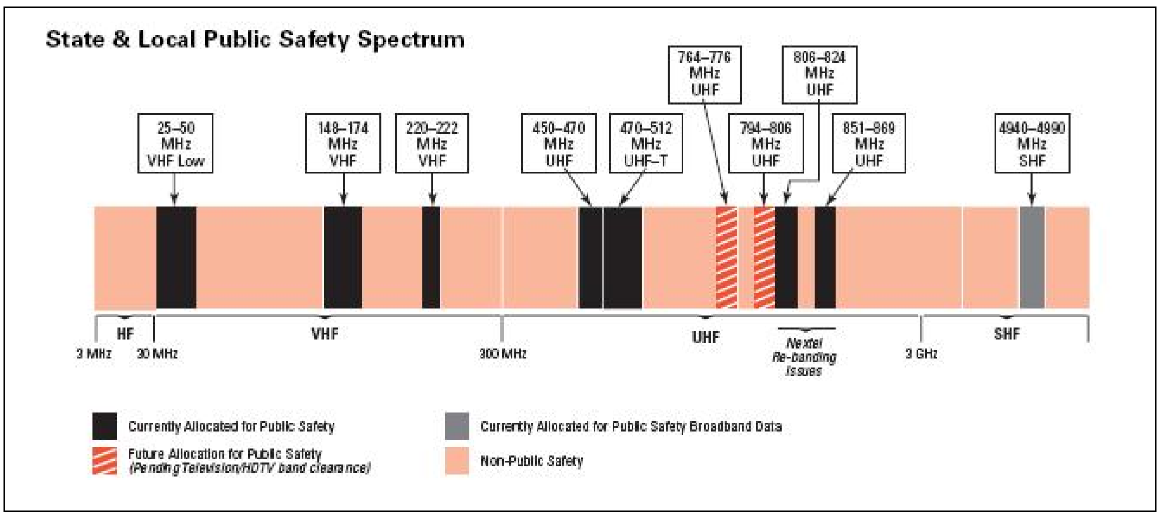

Figure 1. Public Safety Frequency Bands referenced from [2]

1.8 Conventional and Trunked Communication

Currently, digital radio channels use frequency division multiplexing access (FDMA), which previous analog radio systems implemented. These radio 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.

1.9 Land Mobile Radio System

A simple diagram of land mobile radio (LMR) systems is depicted in Figure 2. It illustrates the communication channels among portables, land mobiles, repeaters, and based stations.

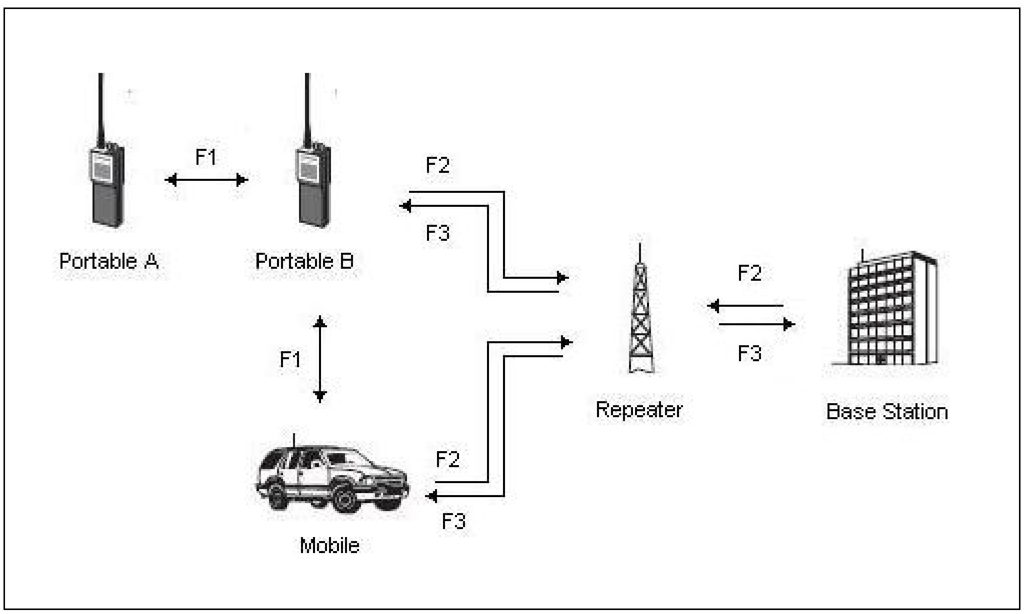

Figure 2 Diagram of LMR system

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) as shown in Figure 2, 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.

The land mobile radio systems used by public safety agencies are half-duplex. This means that the repeaters transmit on different frequencies (F3) as shown in Figure 2 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. Full-duplex radios can transmit and receive signal simultaneously on different frequencies. These are typically found in base stations as shown in Figure 2. They are rarely used elsewhere since they are expensive and consume more power.

II. User Survey on Using Communication Equipments

2.1 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.

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 3 shows the overall effectiveness of communication devices used in port community. The survey data indicates that two-way radios should be the most effective method for future routine and emergency communication. Users indicated that the effectiveness of wireless phones, wireline phones, the Internet, and pager/Short Messaging Systems (SMS) are effective for daily, routine communication. However, the rated effectiveness of these methods falls considerably in emergencies. The ratings for Internet telephones and wireless data remain fairly constant at marginally effective in both daily work and emergency communication.

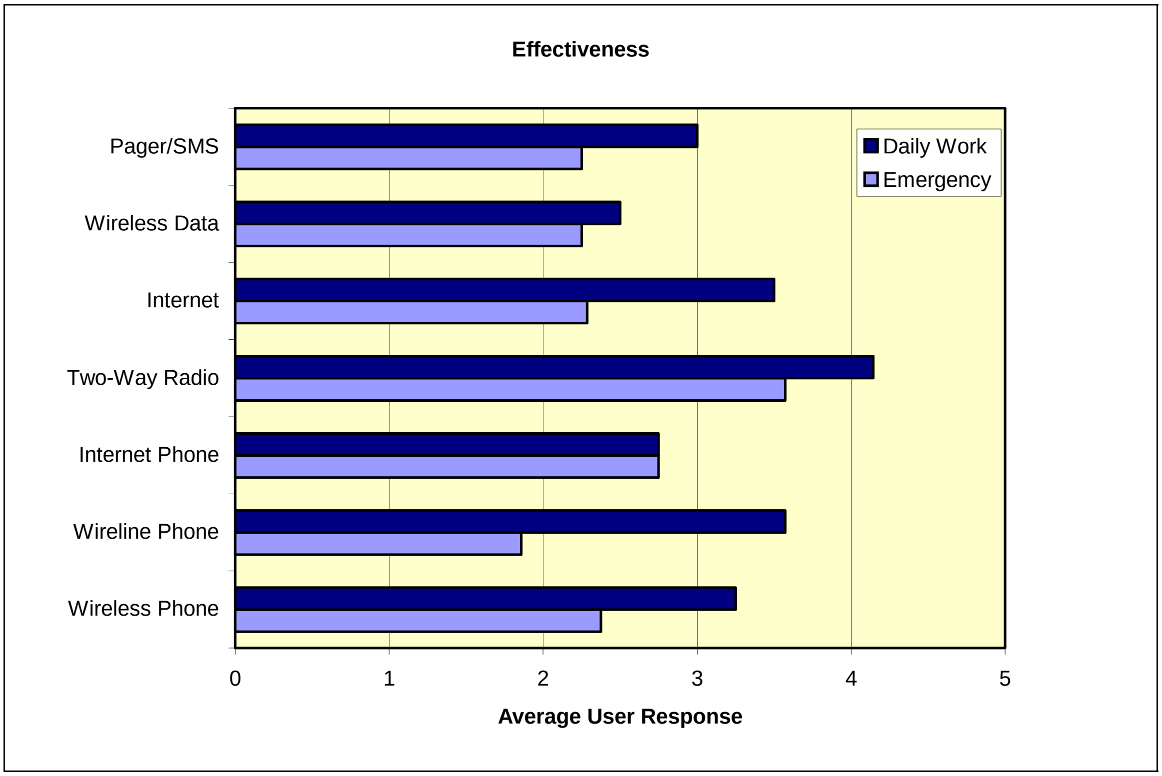

Figure 3 Overall effectiveness of communication devices.

Figure 4 shows the safety of communication devices used in port community. Safety issues are rated relatively highly for all communication devices, regardless of routine or emergency use. Safety is rated important for all methods, and with two-way radios leading all other devices in importance. Figure 5 shows the security of communication devices used in port community. 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. Figure 6 shows the interoperability of communication devices used in port community. 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.

2.2 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.

2.3 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.

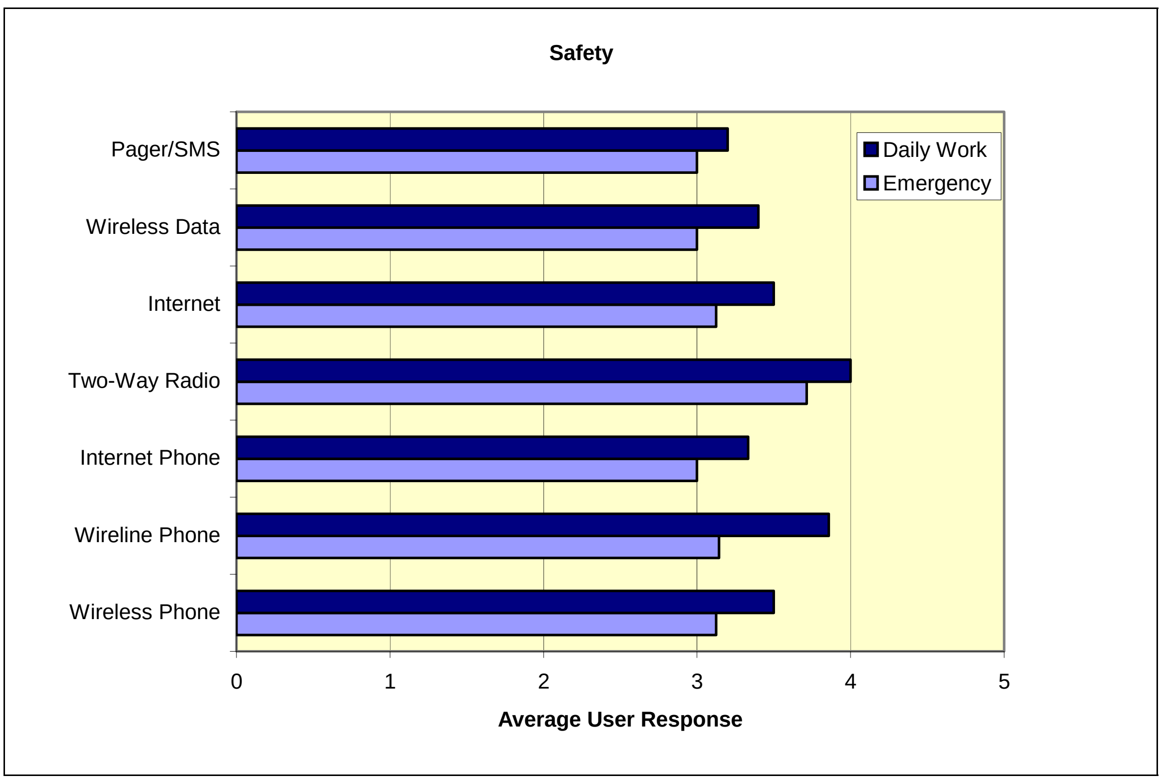

Figure 4 Safety level desired in communication devices.

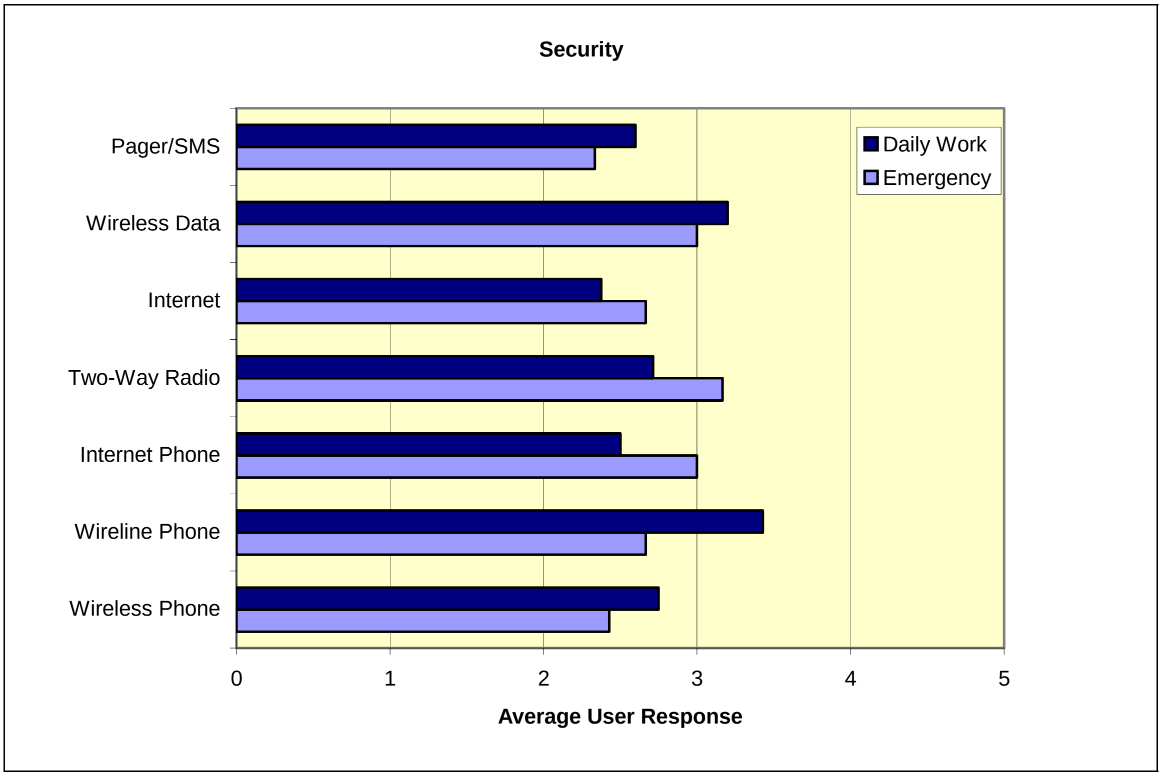

Figure 5 Security level desired in communication devices.

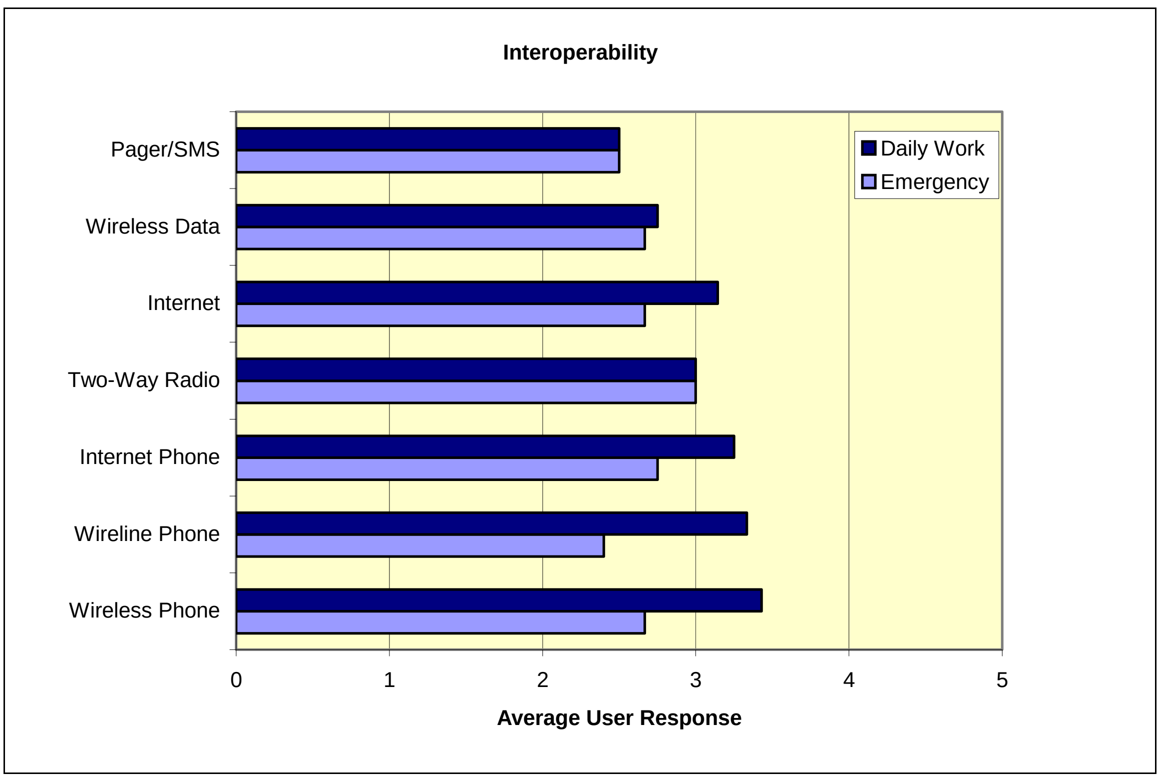

Figure 6 Interoperability level desired in communication devices.

2.4 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.

2.5 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.

III. Technology Survey on Communication Equipments

In this technical survey, the communication equipment (portable radios, mobile radios, repeaters, mobile data terminals, and wireless phones) 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 three Tables, 1-3, 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
o – enabled
N/A – not applicable

The last tables in this section, Tables 4 and 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.

rx – receive
T – transmit

3.1 Portable Radios

Portable radios as shown in Fig. 7, 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 Portable Radio - Motorola XTS 5000

Table 1 Sample of portable radio specifications.

X - capable o - enabled LAFD (orange) LAPP (teal) LBC (gray) CSULB (white)	LAFD	LAPP	LBC	CSULB	UHF	VHF	800 MHz	ANALOG WIDEBAND	ANALOG NARROWBAND	DIGITAL CONVENTIONAL	DIGITAL TRUNKING	IMBE VOCODER	ENCRYPTION
Astro Saber	o				o			X	X	o		o	X
XTS 3000	o						o	o	o	X		X	X
XTS 5000	o				o			X	X	X	o	o	X
XTS 5000	o					o		X	X	o	X	o	X
XTS 5000	o						o	o	o	X	X	X	X
Astro Saber		o			o			X	X	o		o	X
Astro Saber		o			o			o	o	X		X	X
Saber			o		o			o					
Saber			o			o		o					
HT1000				o	o			o	o				

3.2 Mobile Radios

Mobile radios as shown in Fig. 8, 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 8. Mobile Radio - Motorola XTL 5000

Table 2 Sample of mobile radio specifications.

X - capable o - enabled LAFD (orange) LAPP (teal) LBC (grey) CSULB (white)	LAFD	LAPP	LBC	CSULB	UHF	VHF	800 MHz	ANALOG WIDEBAND	ANALOG NARROWBAND	DIGITAL CONVENTIONAL	DIGITAL TRUNKING	IMBE VOCODER	ENCRYPTION
Astro Spectra	o				o			o	o	X	X	X	X
XTL 5000	o				o			X	X	X	o	o	X
XTL 5000	o					o		X	X	o	X	o	X
XTL 5000	o						o	X	X	o	X	o	X
TK790/890	o				o	o		o	o				X
XTL 5000		o			o			o	o	o	X	o	X
Spectra		o			o			o					X
IC-M602		o				o		o					X
M7100		o					o	o	o	o	X	o	X
Syntor x9000			o			o		o					X
MaxTrac				o	o			o					
CDM 1250				o	o			o	o				

3.3 Repeaters

Measuring about 9"H x 19"W x 17"D, repeaters as shown in Fig. 9, 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 9 Repeater - Motorola Quantar

Table 3 Sample of repeater specifications.

X - capable o - enabled LAFD (orange) LAPP (teal) LBC (grey) CSULB (white)	LAFD	LAPP	LBC	CSULB	UHF	VHF	800 MHz	ANALOG WIDEBAND	ANALOG NARROWBAND	DIGITAL CONVENTIONAL	DIGITAL TRUNKING	IMBE VOCODER	ENCRYPTION ENABLED
Quantar	o				o			o	o	X	X	N/A	N/A
Quantar	o						o	o	o	X	X	N/A	N/A
Quantar		o			o			X	X	o	X	N/A	N/A
Quantar		o					o	X	X	o	X	N/A	N/A
Quantar			o		o			o	o	X	X	N/A	N/A
Quantar			o			o		o	o	X	X	N/A	N/A
Quantar			o				o	X	X	o	X	N/A	N/A
MSF 2000				o	o			o				N/A	N/A
Spectra				o	o			o				N/A	N/A
Spectra				o		o		o				N/A	N/A
Radius M1225				o	o			o	o			N/A	N/A

3.4 Mobile Data Terminals

Mobile data terminals as shown in Fig. 10, 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	o
LAPP	o
LBC	o
CSULB	o

Figure 10 MDT – Panasonic CF29

3.5 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 counter part. Instead of accessing the phone network through cellular towers, they communicate with satellites in geosynchronous, low earth, or medium earth orbit. All public agencies use wireless phones.

3.6 Frequency Range

Table 4 shows portable/mobile transmitter frequency and repeater receive frequency (MHz).
Table 5 shows portable/mobile receive frequency and repeater transmit frequency (MHz).

3.7 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.

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.

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

rx - receive T - 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	o							T								
	Astro Saber	o								T							
	XTS 3000	o													T	T	
	XTS 5000	o					T										
	XTS 5000	o						T	T								
	XTS 5000	o								T							
	XTS 5000	o									T		T		T	T	T
	Astro Saber		o						T								
	Astro Saber		o							T							
	Saber			o			T										
	Saber			o				T	T								
	Saber			o						T							
	HT1000				o				T	T							
MOBILES	Astro Spectra	o							T								
	Astro Spectra	o								T							
	XTL 5000	o					T										
	XTL 5000	o						T	T								
	XTL 5000	o								T							
	XTL 5000	o										T		T		T	T
	TK790/890	o					T			T							
	XTL 5000		o					T	T								
	XTL 5000		o							T							
	Spectra		o						T	T							
	IC-M602		o			T											
	M7100		o													T	T
	Syntor x9000			o			T										
	CDM 1250				o				T	T							
REPEATERS	Quantar	o							rx								
	Quantar	o								rx							
	Quantar	o														rx	
	Quantar		o						rx								
	Quantar		o							rx							
	Quantar		o													rx	
	Quantar			o			rx										
	Quantar			o					rx								
	Quantar			o						rx							
	Quantar			o												rx	
	Radius M1225				o					rx							

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

rx - receive T - 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							rx					
	Astro Saber	o								rx				
	XTS 3000	o												rx
	XTS 5000	o					rx							
	XTS 5000	o						rx	rx					
	XTS 5000	o								rx				
	XTS 5000	o									rx	rx	rx	rx
	Astro Saber		o						rx					
	Astro Saber		o							rx				
	Saber			o			rx							
	Saber			o				rx	rx					
	Saber			o						rx				
	HT1000				o				rx	rx				
MOBILES	Astro Spectra	o							rx					
	Astro Spectra	o								rx				
	XTL 5000	o					rx							
	XTL 5000	o						rx	rx					
	XTL 5000	o								rx				
	XTL 5000	o									rx	rx		rx
	TK790/890	o					rx			rx				
	XTL 5000		o					rx	rx					
	XTL 5000		o							rx				
	Spectra		o						rx	rx				
	IC-M602		o			rx								
	M7100		o											rx
	Syntor x9000			o			rx							
	CDM 1250				o				rx	rx				
REPEATERS	Quantar	o							T					
	Quantar	o								T				
	Quantar	o												T
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	Radius M1225				o					T				

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.

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.

3.8 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.

3.9 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.

IV. Conclusions and Recommendations

4.1 Conclusions

The survey 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. 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, Sections can be installed or other radios can be reprogrammed.

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. Additionally, 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.

4.2 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. Figure 11 shows P25 Radio configurations [5]. 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.

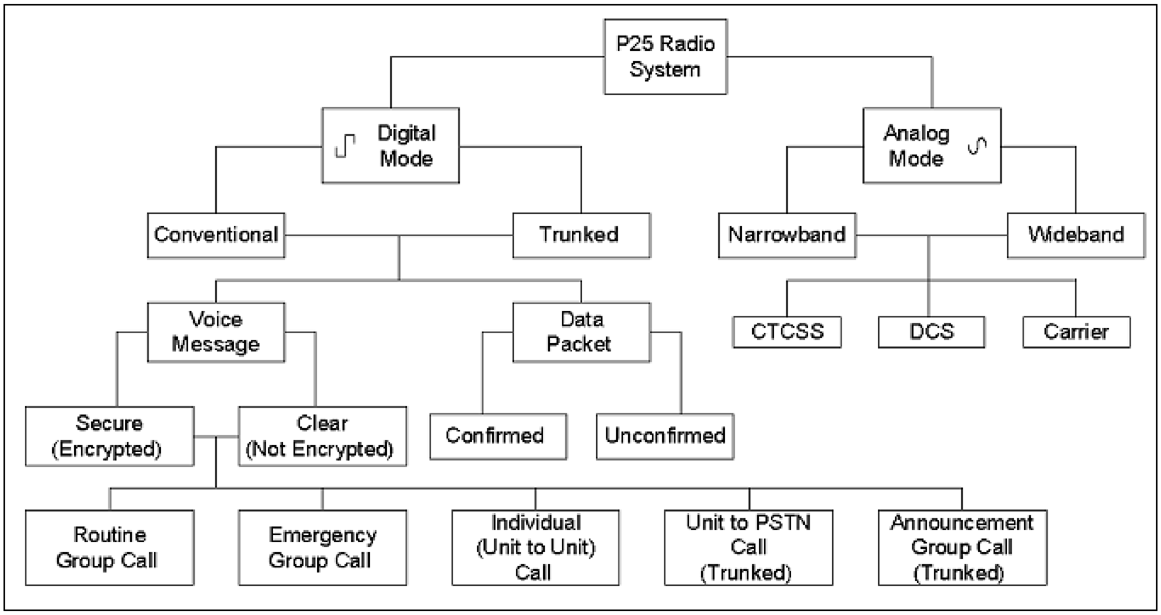

Figure 11 P25 Radio Configurations referenced from [5] .

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. 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.

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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