CHAPTER III: FIREFIGHTER COMMUNICATION ISSUES

Communication problems commonly encountered by firefighters (and others) can be broadly divided into two categories. First are mechanical or technical issues related to unsuitable equipment, system design, inadequate system capacity (too much radio traffic), and building construction, among others.

The second category includes human factors such as radio discipline, training, and tactical decisionmaking. These factors, while not technical issues themselves, adversely affect firefighter radio communications, especially when combined with technical and equipment issues.

This chapter presents an overview of these communication issues as well as a review of communications issues that affect fire departments every day.

Technical Issues

Fire departments consistently have problems maintaining effective communications while operating in large structures, such as high-rise office buildings and apartments, and warehouses. Similar issues exist in structures with a large number of windows (or areas of glass) with reflective coatings. Communications from areas below grade (e.g., basements, parking garages, subway systems, tunnels) tend to be uneven. For the typical home, communications are generally not a problem. The technical issues associated with the physical structures themselves (building materials, height, etc.) are discussed further in Chapter IV.

Below is a discussion of the technical issues that are commonly associated with fire department radio communication difficulties.

EQUIPMENT

In general, the most common communication problem encountered by firefighters is the inability to effectively communicate while wearing self-contained breathing apparatus (SCBA). In addition, it is difficult to operate most portable radios while wearing full personal protective gear (PPE). Thick fire suppression gloves make it difficult to turn knobs or push buttons, and low-light and smoke conditions coupled with wearing an SCBA facepiece make it hard to see the LCD display on a radio (if so equipped).

Another common problem is the equipment's tolerance to hazardous environmental conditions, such as high heat, prolonged exposure to water, and rough handling. While radios are water resistant, not all models are waterproof. This is more of a problem with older radios, however, as newer models are more water resistant if not completely waterproof.

Many radio systems are highly dependent on computer technology. In the event such technology fails (e.g., the trunking software becomes inoperable), the entire radio system can be disabled.[2] To prevent complete failure of the radio communication system, most jurisdictions employ backup analog frequencies to maintain critical communications (e.g., dispatch and contact with units). Reliability and sustainability are key components of any sophisticated system.

The usefulness of a portable radio is dependent on the life of its battery. Some older radios require batteries to be "conditioned" or otherwise use special chargers for optimal battery life. This requires users to be especially diligent about maintaining radios and their batteries, which can be challenging for departments already busy with emergency response and apparatus maintenance.

SYSTEM DESIGN

Perhaps one of the most critical technical issues related to radio communications is the design of the system itself. Whether a department uses low band, high band, analog, or digital technology, an adequately funded, carefully thought out, strategically designed system (i.e., the number and placement of tower sites and repeaters) will perform better than one that was not carefully planned.

The lack of frequencies available to public safety agencies has made it difficult for some jurisdictions to modernize their radio communications systems. Public safety departments are limited to VHF low band, VHF high band, UHF 450 MHz, and UHF 800 and 900 MHz. Instead of transitioning to a completely new system, many jurisdictions are exploring the possibility of applying new technology to enhance their existing system's capability with only a modest expenditure of fire department budget.

There are common design problems for most systems. An inadequate number of tower sites and repeaters typically result in "dead spots" – areas where radio communications are difficult or impossible. Buildings and terrain, among other factors, can cause dead spots. Similarly, a system might be designed with too little signal output to reach all areas of the jurisdiction (in some areas, for example, the radio system output is limited due to proximity to an airport or the Canadian or Mexican borders).

As discussed later in this chapter, fire departments cannot always separate dispatch and tactical operations channels. This is a critical function, as the combination of dispatch and incident operations can overwhelm a single radio channel, causing critical messages to go unheard. Some experts also argue that large-scale incidents (e.g., high-rise fires) should

[2] In a trunked radio network or system, a large number of workgroups (or users) share fewer channels because the trunking equipment dynamically allocates an available channel when users key their radio. A computer manages the system. When a user (e.g., firefighter) has a message to transmit, the computer assigns an available trunk. "The advantage of this type of system is that it uses a group of available frequencies more efficiently by utilizing the capabilities of the computer to manage the radio traffic on each frequency. Thus, more radio traffic can be handled on the available frequencies, without causing congestion and interference." [**314**]

use multiple tactical channels to separate key functions, such as fire attack, search, emergency medical services, command, etc.

SYSTEM CAPACITY

In general, fire departments throughout the country are responding to a higher number of calls for service than ever before and call volume will continue to rise. The majority of these calls are for EMS, which is a national trend. While EMS calls do not typically require a tactical channel, the associated radio traffic (e.g., dispatch, response, ER consults) may add to the system traffic. A dramatic increase in call volume and increased frequency of use may cause the system to reach capacity. As a result, existing communications may lack the capacity to handle the associated rise in radio traffic.

A large-scale event such as natural or other disaster (i.e., terrorist event) is also likely to dramatically increase system traffic. In such cases, multiple city agencies or departments are likely to be at the scene of the incident, each using its respective communication system, possibly causing the radio system to reach capacity.

Trunked systems provide more capacity than conventional VHF and UHF radio systems because a computer assigns a frequency only while a firefighter is actively transmitting, and then automatically takes it back when the transmission ends so the signal is immediately available for another transmission.

INTERIOR (STRUCTURE) COMMUNICATIONS

It is critical for firefighters to communicate with one another within a structure and with units operating outside the structure, regardless of the building construction. The inability to communicate from buildings, below grade, basements, garages, tunnels, etc., is a persistent problem in the fire service.

The construction of a structure can contribute to communications problems. Residential buildings are typically constructed of wood and other materials easily penetrable by radio waves. Commercial structures, however, are typically built with large amounts of steel and concrete that, to varying degrees, act as barriers to radio frequency waves. In addition, some types of glass and other window materials used in commercial construction inhibit radio frequencies. This topic is discussed in depth in Chapter IV.

High-rise structures, warehouses, and underground structures such as tunnels and basements pose their own challenges to radio communications. In addition to the construction materials used to build them, the height of such structures can interfere with line-of-sight (LOS) access to repeaters and radio towers.

Following the September 11, 2001, terrorist attacks, the Fire Department of New York (FDNY) contracted with McKinsey and Company to review its response and preparedness for future events. Based on interviews with firefighters, McKinsey reported that communication failures occur on a regular basis when transmitting from the inside to outside or vice versa from a high-rise building, tunnel, or subway system. Of the over

2,000 high-rise buildings in New York City, the FDNY feels that only a fraction allow reliable communications. [**51**]

After-incident reviews of the World Trade Center collapse indicate that inadequate communications prevented personnel from receiving critical information about the impending collapse of the Towers. The reason cited was that FDNY portable radios do not work well in high-rise buildings and the signals from the radios were rebroadcast by a repeater system. Therefore, when critical information was relayed, it was sporadic or not fully received.

McKinsey and Company notes that the communication failures can be corrected by deploying repeating infrastructure that "receives, amplifies, and retransmits radio communication signals to improve coverage." The report observed that portable repeaters "may help mitigate in-building communication difficulties, but do not provide full coverage for high-rises," and suggests that stationary repeating infrastructure is preferred, especially if it is "designed, installed and maintained properly." [**51**]

With an estimated cost of $0.30–$0.60 per square foot of high-rise space, McKinsey and Company estimates that FDNY would have to spend upwards of $250 million to install permanent repeater systems to ensure radio communications in the city's high-rise structures. In the case of tunnels, McKinsey recommends that FDNY participate in the Police Radio System, which is funded by the Metropolitan Transportation Authority. The Police Radio System uses UHF radios to maintain two-way voice communication. Particularly with the vulnerability of a limited security subway system to a terrorist attack, FDNY and other fire departments with subway systems in their districts should ensure that communication systems are fully operational in these structures.

POOR RECEPTION

Inadequate radio reception is the result of many factors. Most notable among these factors are low power, interference, and the terrain-and-built environment.

There is a direct relationship between RF power output and transmitting range. The higher the RF output, the greater the transmitting ranges, and vice versa. Portable radios have a low RF output and, therefore, have a short operating range. On average, the RF output of portable radio range from 1 to 7 watts. [**314**] In comparison, mobile radios typically have an RF power output 20–100 watts. [**314**] Because mobile radios are not portable, they cannot provide on-scene communications or be carried into a large structure. As a result, firefighters must carry low-powered portable radios, which may not work very well in large structures.

Atmospheric interference is uncontrollable. This natural occurrence results from solar disturbances on the surface of the Sun. These solar disturbances, also known as "solar flares," emit large volumes of electromagnetic radiation and highly energized particles, which can affect satellite and radio communications on Earth. The highly energized charged particles pass through the ionosphere traveling at the speed of light and can affect radio signals over the entire frequency spectrum.

Electronic interference is also common. Many public safety radio systems often suffer destructive interference from a variety of sources, including commercial 800-MHz trunking antenna sites (Nextel, for example), interference with other public safety radio systems (e.g., neighboring jurisdictions), or other electronic devices.

The environment – both topographic factors and the built-in environment (e.g., high-rise buildings) – is yet another cause of poor reception and solutions exist to help correct these reception problems. In some areas, additional antenna sites have reduced (or eliminated) interference caused by environmental factors.

INTEROPERABILITY

Radio communications interoperability allows various departments (e.g., fire, police, public works) to communicate with each other or another neighboring jurisdiction. The objective is for these departments to exchange information when necessary (e.g., mutual-aid call, mass casualty incident, special event).

Throughout the country, adjacent jurisdictions or even agencies in the same jurisdiction use different radio communication systems. For example, while one county may use high-band frequencies (154.115–159.21 MHz), its neighboring jurisdictions might use an 800-MHz trunked system. Or, a city's police department could use an 800-MHz trunked system while the fire department uses a high-band system.

Interoperability is not only critical in the case of a major emergency incident or disaster, but also important for the everyday types of calls where two or more departments are involved.

While a significant problem in fire service communications, interoperability is outside the scope of this report and is not addressed in detail.

DIGITAL VS. ANALOG

Modern communication systems are evolving from analog to digital technologies. Digital systems offer better performance over a broader range of conditions, much greater flexibility, and more efficiency than analog at a lower cost. As with most alternatives, tradeoffs must be considered. Rarely does one find that all the pluses are on one side and that is the case with analog and digital communications.

Performance

The human ear corrects errors in analog communications systems. It can decode a wide range of hissing, crackling, volume changes, and other variations. As the signal to noise ratio (SNR) degrades, there comes a point where the transmission cannot be understood. But with digital communications, other error-correcting methods must be used. Digital communications allows for error-correcting codes that provide clear transmission over a much wider range of SNR than analog. However, at some point as the SNR drops, it falls so low that the digital system can no longer correct errors. When this happens, the signal quality varies from perfect to gone. So, while digital schemes are capable of error-free transmission while analog ones are not, it is not uncommon to find radio users who prefer to let their ear decide when the transmission is indecipherable rather than have the signal just go away.

Flexibility

Digital communication systems can transmit analog signals obtained by analog-to-digital conversion, plus information such as computer data. Any signal that can be sent by analog means can be sent digitally. But an analog system cannot send everything that a digital system can. Video can be sent by analog means (standard television), but better performance is obtained using digital (HDTV). In addition to the ability to transmit a wider variety of signals than analog systems, digital communications can be organized into area-wide communications systems such as computer networks. These digital networks can be local, wide area, or even global and provide efficient and flexible data transmission not remotely feasible using analog means.

Security

Digital communications can be encrypted to provide robust security while analog cannot be protected nearly as well.

Efficiency

With digital communications, signal structure can achieve a much more efficient communication system via digital compression techniques. Digital communications are efficient enough to send more information per user to allow more users to occupy a given number of radio spectrum or channels. In analog communication, the only parameters of interest are message bandwidth and amplitude.

Consequently, with the increased speed of digital computers, the development of increasingly efficient digital communications algorithms, and the ability to interconnect computers to form a communications network, digital communication is now the choice for many situations.

Human Factors

Even with the most technologically advanced radio communication system, the success and failure of radio communications depend on the person who transmits the radio message as well as the one to whom the message is transmitted. For example, location of the microphone in relation to the mouth and SCBA when transmitting can be important with some radio systems. The clarity with which the transmitting person speaks, coupled with the volume of the transmission, will drive the audibility of the message at the receiving end. It is also incumbent on firefighters to know when to transmit over the radio and when not to transmit a message.

MESSAGE TRANSMISSION

Well thought-out, clear, and concise messages are important characteristics for firefighters to employ during their radio transmissions. On the fire scene, when firefighters are excited or are panicked, radio transmissions can be loud and uncontrolled. Messages of this nature are difficult to understand. Discipline requires firefighters to exercise discretion in messages transmitted over the radio. Noncritical messages increase the radio traffic and may prevent emergency messages, such as a Mayday event or impending building collapse, from being transmitted.

Over the years, radio codes and other phonetic techniques have been developed to make communications understandable, both for the sake of clarity and to compensate for poor radio links. These include the widely known phonetic alphabet (Alpha, Bravo, …, Yankee, Zulu). Such alphabets, used for spelling things out over voice links, are variously known as phonetic radio spelling telephone alphabets and analogy alphabets. In addition, codes are commonly used by police and other agencies to provide succinct communication. These may be “10:4” or other numeric based messages that in some cases describe a response or situation. In spite of these techniques, clear and understandable radio communication is still a common problem. Firefighters must learn any terminology used in their jurisdiction.

To counter problems with distortion and inaudible radio communications while wearing SCBA, some equipment manufacturers have designed integrated microphone and speaker systems into SCBA. Depending on the manufacturer, some of these systems use a bone microphone worn by the firefighter or a microphone integrated into the SCBA facepiece. Speakers are often a modified headset that fits in the firefighter’s ear, under their SCBA face piece and other protective gear. Most include a large, easy to operate push-to-talk button for use while wearing firefighting gloves. These systems increase the clarity of radio transmissions, reduce the amount of feedback from radios being too close to one another, and increase the likelihood that the transmission will be heard and understood.

DIFFICULTY OPERATING RADIOS

As mentioned previously, the use of full PPE and SCBA makes it difficult to use a portable radio effectively. While the push-to-talk button is generally easy to use with gloves, the knobs and other buttons can be much more difficult. To overcome this, some departments are programming their radios so that the first and last position on the channel selector will automatically direct the firefighter to a channel monitored by the dispatch center. In the event of an emergency, the firefighter can turn the dial all the way in either direction and reach someone to alert them of the emergency.

INADEQUATE TRAINING

Though firefighters receive hundreds of hours of training on emergency response, radio communications do not typically receive the same amount of attention. As such, firefighters may not be aware of proper radio usage. Examples include how to use the radio in general, how to use the radio while wearing SCBA, and how radio communications are affected by a Mayday event.

FIRE SERVICE CULTURE

Firefighters are, by their nature, problem solvers and independent. It is difficult to convince firefighters that they need to call for help quickly in the event that they become lost, trapped, or incapacitated. Waiting to call for help delays rescue efforts. And when a firefighter's Mayday calls are not initially heard, rescue efforts can be delayed even longer.

Applicable Standards and Regulations

Standards have been developed to address communications systems, but, by and large, such standards are mute on identifying the best system for fire service communications. Thus each jurisdiction has the challenge of designing and building a radio communication system that meets its current and anticipated future needs.

NFPA

The National Fire Protection Association (NFPA) is a national nonprofit organization that develops consensus based codes and standards for the fire service. The NFPA has developed NFPA Standard 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*, 2002 Edition. This standard does not make specific recommendations on the types of radio system or frequency ranges that should be used by fire departments for emergency incident communications. Rather, it addresses construction, layout, staffing, and emergency backup components of the communication center.

The nineteenth edition of the NFPA's *Fire Protection Handbook* references radio frequency selection, but only shows that fire departments use VHF low band, VHF high band, UHF 450 MHz, and UHF 800 MHz and 900 MHz. It does state that, "each band of frequencies has its advantages and disadvantages, and the selection of a particular band will depend on factors such as frequency availability, area to be covered, type of terrain, number of radio units required, frequencies used by bordering fire districts, mutual aid agreements, type of operation, and use of emergency medical radios."[**314**] The handbook also describes Simplex, Two-Frequency Half Duplex, Two-Frequency Full Duplex, Two-Frequency Repeater Systems, Trunked Systems, Tone-Coded Squelch, and Radio Paging Systems, but does not take a stance or recommend one type of system or frequency over another.

FCC

The Federal Communications Commission (FCC) is an independent United States government agency, directly responsible to Congress. The FCC was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite and cable. The FCC's jurisdiction covers the 50 states, the District of Columbia, and U.S. possessions.

Recent FCC activity of interest to the firefighting community includes:

- Permitted use of UWB devices in restricted bands and restricted transmit power.
- Removal of 50 MHz of government frequency allocation from 4840–4990 GHz with reallocation to public safety use. This band permits broadband services in support of public safety.
- Allocation of 764–776 MHz and 794–806 MHz for public safety use.
- Development and promotion of broadband services to compete with local broadband service from cable and telephone companies. As part of this effort, the FCC strongly supports development of Access PLC, which uses the medium voltage power grid to deliver broadband service to homes and offices.

PSWAC

Congress empowered the Public Safety Wireless Advisory Committee (PSWAC) in June 1995 to address issues relating to spectrum needs and uses for the public safety community. The PSWAC identified an immediate need for 2.5 MHz more of spectrum, and a longer term need for an additional 25 MHz of spectrum for public safety use. PSWAC found that 70 MHz more of spectrum must be allocated if the public safety agencies and emergency responders were to use modern technologies, many of which require additional spectrum.

Experiences From the Field

This section summarizes the communications problems — mechanical and technical issues, as well as human factors — that are commonly encountered by jurisdictions throughout the country and the solutions implemented to mitigate them. Below are highlights of the actual communications problems experienced by these jurisdictions; a more comprehensive writeup is found in Appendix B.

The departments reviewed were mostly all-career fire departments, large and small, in mostly urban or suburban areas as the information on these departments was more readily available. A small group of volunteer departments and jurisdictions in rural areas was also reviewed. In some instances, urban fire departments also provide fire or EMS services to rural areas.

In all, information from 24 fire departments is included in this report. Of these, 18 are all-career fire departments, 5 are combination, and 1 is an all-volunteer fire department. Table 4 summarizes the departments reviewed.

The jurisdictions ranged in population from a high of 3.7 million in Los Angeles to a low of 3,700 in Gettysburg, OH. The service land areas also varied widely (as does the physical characteristics — terrain and topography — of each area). Land area protected, as measured in square miles, ranged from 15 square miles in Springfield, NJ to 8,000 square miles in Clark County, NV.

Communication and radio system priorities differed somewhat in urban and rural departments. In urban settings, fire departments contended with a larger variety of structures such as high-rise buildings, multilevel residential structures, basements, tunnels, and underground transportation systems (e.g., subways). The rural areas, typically residential in nature, had fewer large buildings and generally no underground transportation systems.

TABLE 4: SUMMARY OF FIRE DEPARTMENTS REVIEWED

Jurisdiction	Resident Population[3]	Land Coverage area (square miles)	Land Area	Fire Department Type
Austin, TX	656,562	252	Urban	Career
Bellingham, WA	67,171	32	Urban/Suburban	Career
Boston, MA	589,141	48	Urban	Career
Boulder, CO Rural Fire Department	18,000	25	Suburban/Rural	Combination
Brighton, CO	20,905	17	Suburban/Rural	Combination
Charlotte, NC	540,828	242	Urban	Career
Chicago, IL	2,896,016	227	Urban	Career
Clark County, NV	1,375,675	8,000	Urban/Rural	Combination
Dallas, TX	1,188,580	385	Urban	Career
Detroit, MI	951,270	139	Urban	Career
Everett, WA	91,488	48	Urban/Suburban	Career
Fairfax County, VA	969,749	395	Urban/Suburban	Combination
Gettysburg, OH	3,700	60	Rural	Volunteer
Los Angeles, CA	3,694,820	469	Urban	Career
Milwaukee, WI	596,974	96	Urban	Career
Phoenix, AZ	1,321,045	475	Urban	Career
Pittsburgh, PA	334,563	56	Urban	Career
Portland, OR	529,121	134	Urban	Career
San Antonio, TX	1,144,646	412	Urban	Career
San Diego, CA	1,223,400	324	Urban	Career
San Francisco, CA	776,773	49	Urban	Career
Schaumburg, IL	75,386	19	Suburban	Career
Springfield, NJ	14,429	15	Suburban	Combination
Wichita, KS	344,284	136	Urban	Career

In addition, urban systems experienced higher service volumes and increased radio traffic. Urban areas had a higher propensity for radio congestion. Fire departments in urban areas were mostly career, sometimes supplemented with volunteers, whereas rural systems have more volunteer providers.

[3] Data from U.S. Census 2000 is used for consistency and comparison. Data may not agree with that reported by the jurisdiction.

Topography and terrain in both urban and rural areas varied widely. Typically, rural systems covered larger land areas that are more spread out and not as densely populated. Natural elements such as mountains, hills, and other potential interfering terrain were present in both urban and rural systems, depending on the area.

More often than not, the urban departments have the resources to provide a communications system with the necessary hardware that meets the needs of the area. The urban areas had a greater population and tax base. In many departments, the fire department operating budget comes directly from property taxes. Properties in urban areas generally have a higher assessed valuation than an equal property in a rural area, and therefore will raise more tax dollars.

Table 5 summarizes radio communications issues commonly experienced by the fire departments reviewed for this study.

TABLE 5: SUMMARY OF FIRE DEPARTMENT RADIO COMMUNICATION ISSUES

Topic	Area	Issue
Poor Reception	Physical environment	• Canadian & Mexican borders • Topography and terrain
	Interference	• Neighboring jurisdictions • Wireless communications
Interior Communications	High-rise and other structures	• Poor communications
	Tunnels and underground structures	• Poor communications
Unsuitable Equipment	Hazardous conditions	• Water exposure • Visibility
	Personal protective equipment	• Self-Contained Breathing Apparatus
System Design	Inadequate infrastructure	• Lack of repeaters and tower sites • Lack of channels and frequencies
System Capacity	System capacity	• Inadequate capacity
Interoperability	Mutual aid	• Cannot communicate
	Other city departments	• Cannot communicate

POOR RECEPTION

International Border

- **Problems –** Departments located on or near the Canadian and Mexican borders of the United States often experience problems with signal strength and interference. Along the Canadian border, some localities have limited frequency space because Canada is reclaiming some of the VHF frequencies and essentially narrowing the available bandwidth. Localities located on the Mexican border are often plagued with interference from sources across the border.

- **Solutions** –The cities of Bellingham and Everett, WA, which experience radio communications difficulties because of their proximity to the Canadian border, are upgrading to an 800-MHz radio system. San Diego, CA, which experienced interference because of its location on the Mexican border, upgraded to an 800-MHz radio system in the early 1990s.

Topography and Terrain

- **Problems** – Hills, canyons, mountains, and forests can often cause interference and dead spots, and the shadowing from mountains also poses similar signal disturbances.

- **Solutions –** The City of Los Angeles encompasses 470 square miles that include hills, canyons, and mountains. Its fire department often experiences coverage issues because of this diverse topography. To overcome these challenges, Los Angeles has worked carefully on the strategic design and placement of radio system infrastructure (such as towers and repeaters). The Boulder Rural Fire Department even uses "human repeaters" when necessary. The City of Portland, OR, located behind the West Hills and close to volcanoes Mount Hood and Mount Saint Helens, experiences similar dead spots and communications difficulties. To combat these obstacles, Portland constructed a large antenna above the West Hills.

Neighboring Jurisdictions

- **Problems** – The radio systems of neighboring jurisdictions sometimes cause interference for fire departments. This occurs when adjacent towns operate on similar frequencies, and can sometimes prevent one department from sending or receiving messages. One jurisdiction may be at a higher elevation than the other and have higher towers.

- **Solutions –** The Springfield, NJ Fire Department has taken steps to solve their interference problems with local jurisdictions and discussions are underway to investigate the feasibility of trunking the current radio system. This may prove an effective alternative to upgrading; in Springfield, there are not enough frequencies available for the department to transition to an 800- or 900-MHz system. Gettysburg, a rural city in Ohio, would like to upgrade it current radio system too, but does not have the funds to do so.

Wireless Communications

- **Problems –** Many jurisdictions experience problems with the Nextel cellular phone system. The Nextel system, which operates on the 800-MHz band, seems to be incompatible with the pre-existing radio communication systems also in the 800-MHz band.

- **Solutions –** Fairfax County, VA's public safety system is experiencing system coverage degradation from Nextel (interference), and has proposed moving Nextel out of the 800-MHz band. The county has developed this plan as a means of avoiding reorganization or restructuring of its public safety radio system.

  Portland, OR, which experiences similar problems, had Nextel and the fire department swap frequencies to solve the problem. The fire department gave up a channel on the end of their radio spectrum for Nextel's channel in the middle of the city's band.

  Clark County, NV is awaiting final approval between the FCC and Nextel on a plan that addresses interference to public safety communications in the 800-MHz band. This plan is known as the Joint Commentor's Consensus Plan.

INTERIOR COMMUNICATIONS – LARGE STRUCTURES

High-Rise and Other Structures

- **Problems –** One of the most significant problems facing firefighters inside a high-rise structure is the ability to communicate reliably among firefighters and with the command post. Portable radios often do not have the RF power output necessary to communicate through the barriers inside the structure and reach the outside. Many of the cities reviewed have problems communicating during high-rise operations.

- **Solutions –** Jurisdictions have managed this problem in different ways, depending on the specific nature of the communication challenge. Pittsburgh, which uses a centralized UHF communications system for all city services, encounters most of its problems in large and high-rise structures, especially sub-ground or tunnel areas. The city solves communications problems with a talk-around system that uses two-way radios for a ½-mile communications radius.

  Dallas, TX and San Diego, CA solve their high-rise and structural communication problems by relaying messages via "runners" through egress stairwells. For special events, such as the 2003 Super Bowl and events at the San Diego Convention Center, the San Diego Fire Department uses a Mobile COW (Cellular on Wheels), which acts as a mobile antenna to repeat communications outside a building.

In Charlotte, NC the fire department is testing a mobile repeater and has reported some success in overcoming communications difficulties during interior operations, where the department uses simplex mode—radio to radio—to communicate. A mobile repeater adds signal strength to the interior of the structure, allowing firefighters to better communicate.

Schaumburg, IL has a new 800-MHz system with four antenna sites. Fire department officials have reported dramatically improved communications during structural firefighting events. Before the new system, the fire department experienced dead spots throughout the village and problems in high-rise structures, typically constructed of concrete and Lexan glass. Additionally, new building codes required installation of signal boosters during construction for certain types of buildings.

Phoenix, AZ uses a conventional direct radio communication system in VHF. Two tower sites and diversity receivers comprise the primary infrastructure. The receivers allow the department to communicate without talk-around channels or runners. The diversity receiver operates like small radio towers and accepts the emitted radio signal on several antennas with a radius of 2 square miles. The department operates 24 VHF channels, and there are 36 diversity receivers per channel. This system works well in high-rise and other large structures. However, it does have its drawbacks. The two most common challenges are fade and feedback.

Many new buildings in Boston, MA, Clark County, NV, and Fairfax County, VA are installing bi-directional amplifiers. Bi-directional amplifiers, commonly known as BDAs, are used for improving/correcting portable radio communications to, from, and within large structures. These BDAs let fire departments operate their fire department channels within a building.

Tunnels and Underground Structures

- **Problems –** Road tunnels, often constructed with massive amounts of concrete and steel, create a manmade barrier to radio communications and pose a serious threat to firefighters. Other underground structures yield similar problems.

- **Solutions –** The City of Boston is attempting to preempt communications difficulties while it constructs a major underground expressway. The city reported success with using a "leaky cable" device in its Ted Williams Tunnel, and plans to install the same device in the new expressway. This leaky cable is a "byproduct of conventional coaxial cable with small slits cut through its layers that allow RF signal to seep out in amounts strong enough to cover small areas of square footage." [**296**]

UNSUITABLE EQUIPMENT

Water Exposure

- **Problems** – Prolonged exposure to water can decrease the effectiveness of portable radios. If a radio system is antiquated, water exposure can cause serious equipment damage and endanger firefighters.

- **Solutions** – The straightforward solution to water exposure problems is to purchase new, waterproof equipment. The Milwaukee, WI Fire Department has reported no problems with its new portable radios; they are specially designed to be submerged in water without damage.

Self-Contained Breathing Apparatus

- **Problems** – Many firefighters struggle with the portable radio and the ease of using it in a zero-visibility environment while wearing bulky fire department gloves.

- **Solutions** – The Schaumburg, IL Fire Department alleviates this problem by programming the extremes of the channel selector on the portable radio (selector turned all the way left or right) to the same, recognizable channel (usually dispatch) regardless of zone selection. So, if the firefighters operating in a zero-visibility environment accidentally change the radio from the tactical operations channel and cannot find it again, they can turn the selector all the way in either direction and still talk to a dispatcher in the event they need help.

SYSTEM DESIGN

Lack of Repeaters and Tower Sites

- **Problems** – Some of the fire departments reviewed experienced problems with radio communications due to a lack of essential infrastructure, such as repeaters and towers. In most cases, system infrastructures were insufficient. In other cases, poor system design and placement of infrastructure were the problem.

- **Solutions** – San Francisco alleviated problems by switching from a 400-MHz radio system to an 800-MHz radio system 8 years ago. The newer system accommodates more working channels (16, with three controlled for dispatch and one for each of the 10 battalions) and interoperability. The department has also added more towers and repeaters and is currently upgrading the system with portable repeaters, as well as moving repeaters to higher elevations to prevent interference from high-rise buildings.

Similarly, the Wichita, KS Fire Department solved communication difficulties by switching to an 800-MHz trunked system 10 years ago. Each company officer has a portable radio.

Chicago has solved communication problems by deploying a diverse multi-simulcast radio system and 10 transmitter sites (per channel). The system has up to 32 receivers within any area it serves (12 square miles). Because of this, communications with dispatch via portable radios have highly improved.

Los Angeles's problems from the city' size and diverse terrain and topography have been alleviated by incorporating backup repeater sites in these areas. The city has solved communication problems in subways and tunnels by wiring them with underground cables, which carry a signal for four or five of the fire department channels.

Lack of Frequencies or Channels

- **Problems** – Some fire departments have a limited number of tactical channels on their radio systems. These departments are vulnerable to communications problems when multiple incidents occur at the same time.

- **Solutions –** Everett, WA accesses a single dispatch channel and a single tactical channel, which can complicate communications during fire incidents. To alleviate concerns, the department is upgrading to an 800-MHz system.

SYSTEM CAPACITY

Many cities reported no concerns with system capacity, including Austin and San Antonio, Phoenix, Charlotte, Los Angeles, and Portland. These departments have standard operating procedures designed to shut down various parts of the system (e.g., the private line function and interconnect system of an 800-MHz radio system) to ensure no overcapacity.

INTEROPERABILITY

- **Problems –** Often departments do not have the capabilities to communicate with other emergency departments (e.g., fire, police, public works) or with another neighboring jurisdiction using their own communications system. This is essential for exchanging information in mutual-aid calls, mass casualty incidents, or special events.

- **Solutions –** Many departments are currently in the process of upgrading its communication systems to 800-MHz, specifically for interoperability purposes. Others have used alternate technologies or methods to improve or create interoperability. Following are a few examples.

A Boston Fire Department chief, acting as the incident commander, is collocated with an incident commander from another department.

In Charlotte, NC all mutual-aid partners and chief-level officers in other departments are provided with radios. Similarly, departments in Dallas and San Antonio communicate with the police department through a "patch" system. Dispatch will patch police and fire together, and they can talk directly to one another.

Chicago is developing a permanent solution to its interoperability problems, which include an inability to talk directly with law enforcement and EMS, as those departments operate on a different radio system. Because the fire department and EMS respond together on most incidents, the fire department has access to the EMS radio system (VHF) and the police and EMS radio system (UHF). Additionally, the department deploys a command vehicle, outfitted with a suite of radios that allow communication with all departments, to every major incident.

In San Diego, the fire department uses a Motorola 800-MHz system, which has been in place for 11 years. The operations units also carry VHF portables because neighboring departments (recipients of mutual aid) use this system (e.g., California Department of Forestry).

Communications Problems in Firefighter Fatalities

Fire department communications have been cited as a contributing factor to the death or serious injury of numerous firefighters. The deaths have not been directly attributed to failures in radio communications. Rather when communications issues are cited, they are frequently problems in transmissions, standard operating procedures, or unsuitable equipment. Even when such issues strand a firefighter, casualties are generally associated with the fire, and few records are kept on the issues with portable radios. But review of the various departments and of fire literature revealed some instances where failed radio communications were at issue.

In Syracuse, NY, four firefighters perished in 1978 while fighting a fire in a three-story, wood-frame apartment building. Reports attributed the deaths to failed radio communications. While failed radio transmissions contributed to past casualties, Syracuse was of particular note due to the number of staff who died.

The trapped firefighters, confined on the third floor by a rapidly spreading fire, made several calls for help which went unheeded by dispatch, but which were heard by an observer who immediately reported the transmission to a fire officer on the scene. Thirty-seven minutes into the incident, the first of the fatalities was found. [**123**]

Five firefighters were killed at a fire in Hackensack, NJ when the bowstring roof of a car dealership collapsed. Due to changing fire conditions, a battalion chief ordered all personnel to evacuate the structure. This order was never acknowledged nor repeated by the dispatch center. The roof fell before the personnel could exit the structure**. [335]** Hackensack had only one radio channel for both dispatch and tactical operations. Heavy traffic overwhelmed the inadequate tactical channel, and the firefighters' transmissions for help were overridden by transmissions from dispatchers.

A similar situation occurred in Brackenridge, PA after the floor of a commercial structure collapsed. Heavy radio traffic led the crew to switch from the primary incident channel to an alternate tactical channel — effectively cutting them off from the incident commander and the rest of the crews on the scene. The Brackenridge casualties resulted from radio operational issues; with only one channel for dispatch and tactical operations, the system was overloaded and dispatchers overrode transmissions from the fire ground**. [339]**

Unsuitable equipment and product design resulted in the deaths of two firefighters and the injury of a third at the Indianapolis Athletic Club during 1992. The injured firefighter, a captain, reportedly activated the emergency button on his portable radio and made several unsuccessful attempts to radio for help. While the push-to-talk button on the radio was easy to engage with a gloved hand, he had to remove his glove to use the emergency button, and seriously burned his hand**. [337]** Insufficient training might have played a role in the casualties. The department had switched to an 800-MHz system two weeks before the fire. This switch could have been responsible for the delay in acknowledging and processing a request for a second alarm.

Two firefighters were killed and two more injured while fighting a townhouse fire in Washington, DC in 1999. The firefighters were caught in a flashover while attempting to suppress a basement fire. Department personnel were using frequencies that were 15 kHz apart, as recommended by NFPA. But in the past they had experienced problems with interference or bleed over between channels. This interference may have affected the ability of personnel operating on the scene to hear messages from the incident commander. **[338]**