CHAPTER I: INTRODUCTION

One of the most significant problems facing firefighters within a structure on the fireground is the ability to communicate reliably between the firefighters themselves and between the firefighters and the command post or communications center. In an ideal world, firefighters would be able to communicate with one another and the command post at all times, regardless of where they are or what they are doing. However, this is not the case.

Over the past decade, incidents involving firefighter injuries and fatalities have demonstrated that, despite technological advances in two-way radio communications, important information is not always adequately communicated on the fireground or emergency incident scene. Also, the events of September 11, 2001, and other emergency situations in recent years have highlighted the need not only to improve firefighter radio communications, but also the communication systems available to law enforcement personnel, emergency management officials, and other public-safety responders. Equally important is the interoperability of all of these systems.

The continued incidence of firefighter fatalities where communications are cited as a contributing factor as well as the industry-wide lack of consensus on the appropriate frequencies to use in fireground communications have prompted NIOSH to more thoroughly investigate fire department communications and its problems.

Scope of Work

This study seeks to identify and address specific deficiencies in firefighter radio communications by researching the types of radio communication systems currently in use by the fire service and identifying what problems exist with them; identifying current technologies of interest to firefighter communications; identifying knowledge gaps regarding the effectiveness of such technologies; and finally, make recommending future research to improve firefighter radio communication and personnel location. In particular, this study focuses on communications problems caused by inadequate radio frequency (RF) signal propagation within a structure during firefighting operations and to and from the structure to the incident command post (ICP) or dispatch center.

The scope of work is described in more detail in Chapter II, “Methodology.”

Types of Radio Systems

Currently, most fire departments in the United States use conventional analog or digital mobile two-way radio technology operating in the 30–50-MHz band (VHF, low band), 150–160-MHz band (VHF, high band), 450–470-MHz band (UHF), and more recently the 800-MHz band. [**77,314**] Which type of system a fire department uses has both historical and technological reasons. Historically, the communication systems were first available in the lower bands. In terms of technology, communications systems have been chosen according to atmospheric propagation characteristics and to a lesser extent by

structure propagation characteristics. For example, the lower bands propagate further through the air than do the higher. In a rural area, this is a plus as it allows coverage from a base over a much longer range, which keeps costs and complexity down. In an urban area the long range can be a minus as the radio environment has many more users within range and interference is a big problem.

Very high frequency (VHF) is the part of the radio spectrum from 30 to 300 MHz. VHF radio systems, either low band or high band, are simplex systems—messages are sent only one-way at a time. The low band provides relatively long-range coverage from base to mobile units but suffers from skip interference caused by distant low band signal skipping off the ionosphere and interfering with local radio transmissions. The high band also has problems with interference from mobiles up to 50 miles away and can only give reliable hand-held-to-hand-held communications for about ¾ of a mile unless the radio is elevated more than 5 feet above the ground. High-band VHF systems typically need to use repeaters to provide area coverage. Although, VHF has superior structure penetration in comparison to UHF [77], VHF's susceptibility to interference makes it a poor choice for urban use. Many rural systems use VHF radios because of their range, and because their relatively uncrowded RF environment does not cause unacceptable interference.

Ultra high frequency is the part of the spectrum from 300 to 3000 MHz. These ultra high frequency channels do not have the range of the low or high band frequencies of the VHF, and typically require the use of repeaters to have the same coverage as low or high band VHF frequencies [**84**]. Conversely, because of the shorter range and the lack of skip propagation, they do not suffer from the interference problems of the VHF bands.

VHF and UHF, except 800 MHz, are conventional radio systems. In a conventional system, a group of radios share one fixed channel or frequency. If that channel is in use by one user in the workgroup, service is not available to others.

The FCC has designated parts of the 800-MHz to 900-MHz radio frequency (RF) band as public safety radio frequencies for use in public safety trunking radio systems. Trunked systems, which are usually computerized, allow more efficient use of frequencies. In a trunked system a set of radio channels (a trunk) is assigned under computer control. When a firefighter transmits, a computer automatically assigns the firefighter to an open frequency. When the firefighter ends the transmission, the frequency is automatically made available to the next firefighter transmitting [**315**]. The operator does not have to manually select a frequency. Because these systems have multiple frequencies and they are only assigned while a radio is actively transmitting, they provide higher capacity than conventional VHF and UHF radios. This helps prevent radio system congestion. The high capacity of these systems and low interference from other users of the public safety trunking band make these systems appropriate for use in congested areas.

No band of frequencies is perfect; many frequencies work well. The selection of frequency is dependent on a variety of factors, including "frequency availability, area to be covered, type of terrain, number of radio units required, frequencies used by bordering fire [or public safety] districts, mutual-aid agreements, type of operation, and use of emergency medical radios."[**315**]

Communications from Inside a Structure to the Outside or Vice Versa

Fireground communication has significantly changed over the past decade with the proliferation of the portable radio. In the fire departments reviewed, each firefighter team of two will typically carry a small portable radio. In some fire departments each firefighter has their own radio. The increase in number of portable radios coupled with the multitude of communication systems has prompted many fire departments to reexamine their radio procedures, and develop new fireground communication protocols to aid in controlling radio traffic.

The focal point of all fireground communications is the command post. Typically, the command post will be positioned as close to the incident as safely possible to facilitate the communication process. The type of fire and the type of structure involved dictates the location of the command post. Structures such as high-rise buildings, tunnels, and sub-basements may disturb the effectiveness of portable radios and communications. In these situations, some fire departments may position the command post inside the structure to compensate for the portable radios' weak RF output. For example, on fires located on the upper levels of a high-rise structure the command post may be established several floors below the fire (as opposed to the street level) to help improve communication.

In the fire departments reviewed, each department had more than one tactical radio channel for fire operations. Typically, once the command post has been established, fire ground units are switched off of the main dispatch channel to a tactical fire ground channel. These channels usually have a restricted range that permits fire ground units to communicate independently of the main dispatch channel, and also prevent the bleedover of other radio traffic from other fire units operating in the vicinity.

Firefighters operate as a team consisting of two or more personnel. Each interior team can have one or more portable radios. To help control traffic, all radio communications with command post is normally made by the unit officer or the senior team leader. However, if fire conditions restrict visibility, team members may have to communicate with each other by radio, which can substantially increase radio traffic. Some departments restrict the use of individual portable radios to only emergency situations where firefighter may become separated or trapped.

The operation modes commonly used in fire department communication systems include simplex, duplex, and trunked.

The simplex mode requires both a transmitter and receiver at each end of the communications path. In simplex mode, only one end (i.e., the transmitter or the receiver) may operate at a time. It requires only one frequency. Only one firefighter may transmit a message on a portable radio while using a simplex channel, all others must receive.

During interior fire department operations, firefighters may switch to a simplex channel because their low-powered radios cannot transmit outside the building. Simplex channels

do not require the use of repeaters or towers. Rather, the portable radios themselves act as the transmitter and receiver sites.

Duplex mode uses two frequencies that allow both ends to communicate simultaneously. Thus, one user may interrupt another to facilitate discussion. Repeaters may be used in a duplex system. Repeaters, typically located in a high place such as a mountaintop or tall building, receive a transmission from a radio (in the system) on one frequency and retransmits (or "repeats") on another. Repeaters can also be located in fire apparatus and command vehicles for use on particular incidents where communications are problematic. All radios with proximate distance will receive the transmission from the receiver. Repeaters are used to augment the range of the radio system.

Repeaters also allow a low-power portable radio to hear other radio messages (to, from, and within a structure) when obstructions may normally hinder communications. Sometimes, even in the presence of a repeater, obstructions are too great and will prevent a radio signal from being transmitted.

A trunked system, which may include a single user or different workgroups, uses a group of radio frequencies (a trunk). The system is dynamically controlled by a computer, which directs a transmission to an available channel or frequency.

Firefighter Radio Communications Problems

Communication problems encountered by firefighters (and others) can be broadly divided into two categories. First are mechanical or technical issues related to unsuitable equipment, radio malfunction, system design, inadequate system capacity (too much radio traffic), and failure due to extreme environmental conditions (e.g., fire, heat). Poor and mottled radio communications in large structures have also been a persistent problem. Another technical issue is interoperability, or the ability for various departments (e.g., fire, police, public works) to communicate with each other or another neighboring jurisdiction. The second category of problems relates to human factors.

In many instances, a variety of mechanical and technical issues such as RF attenuation, fading, and building construction can prevent the system from maintaining sufficient link quality for reliable communications. In large multistory structures, for example, the frequency may bounce of the walls and windows with reflective coverings, or simply be absorbed from the construction of the building. Some of these cases involve situations where a firefighter is in danger and most in need of communications. As a result, this lack of reliable communication could severely compromise the effectiveness, the safety, and even the life of the first responder.

Human factor include radio discipline, training, tactical decisionmaking as well as others. These factors combine with technical and equipment issues to adversely affect firefighter radio communications. As such, these factors are considered as a component of the overall analysis.

One of the most interesting comments about radio communications noted during this research is: "Our [the fire service] radio systems aren't failing, but rather we can't get the signal throughout buildings with 100 percent accuracy . . . this is affected by building construction, windows, elevator shafts, the output strength of the system, and the [strategic design and implementation of infrastructure such as the] presence of repeaters."[1]

Organization for the Report

The remainder of this report is divided into five major sections, each addressing one aspect of the study. The first section, Chapter II, reviews the study research methodology. The second section, Chapter III, discusses the overall firefighter communication problems, both technical issues and human factors. It also presents an overview of these communication issues as well as a review of communications issues that affect fire departments everyday. The third section, Chapter IV, examines the communication problems inherent in structures, and the risk to firefighters. The fourth section, Chapter V, discusses the results of the research and includes descriptions of available technologies of interest, their current applications, potential applications, limitations, and areas needing further investigation.

The report has two appendices. Appendix A is a tabulation of prioritized project issues, and Appendix B details the communications problems of 24 jurisdictions, both large and small. A Glossary of Terms and Abbreviation follows the appendices. The report concludes with a Master Reference List containing more than 350 citations used in the preparation of this report.

[1] Telephone conversation with Deputy Chief Jeff Coffman, Fairfax (VA) County Fire and Rescue Department.