

2. OVERVIEW OF COMMUNICATION SYSTEMS

A communication system is made up of devices that employ one of two communication methods (wireless or wired), different types of equipment (portable radios, mobile radios, base/fixed station radios, and repeaters), and various accessories (examples include speaker microphones, battery eliminators, and carrying cases) and/or enhancements (encryption, digital communications, security measures, and interoperability/networking) to meet the user needs. This section provides the reader with information on the system technologies and the system enhancements. The technologies are discussed in section 2.1, types of equipment are presented in section 2.2, accessories are discussed in section 2.3, and enhancements are discussed in section 2.4.

2.1 Technologies

For practical purposes, a communication system can be considered to be “wired” or “wireless” (e.g., conventional telephone, radio communications, etc.). A wired system is technically known as a hard-line system and can be thought of as a localized, private telephone system that uses wires to operate over a limited area. A wireless system uses radio frequencies to “connect” users and is capable of operating over a much larger geographical area than a hard-line (wired) system. Since the communication equipment available to emergency first responders today does not use optical transmission methods, only radio frequency (RF) equipment will be considered here.

The major advantages of RF communication systems over hard-line communication systems are their ability to provide communications over large distances, through some obstacles (depending on the frequency), and to an almost unlimited number of users. The range of the signal is defined to be the distance between the transmitter and the receiver at which the amplitude of the signal received by the receiver is less than the amplitude of the background noise. For example, a person can experience this noise using low-cost “walkie-talkies.” When the separation between the two walkie-talkies is great enough, the voice signal is lost and all that is heard is the background noise (sometimes called static). The range of the signal in a communication system may also be affected by interference from atmospheric disturbances, such as electrical storms, and high-power RF sources (such as radar equipment and broadcast equipment). Also, RF signals do not pass through water. Radio transmission quality also begins to deteriorate as the edge of the coverage area is approached.

Shared communication systems such as radios, the Internet, and telephone conference calls are subject to saturation by users (the maximum capacity whereby adding users will deteriorate and degrade the amount and quality of information able to be transferred over the system), a problem that compounds exponentially as the number of users increases. Communication system efficiency requires that the users follow published communication system guidelines regarding proper system discipline in order to ensure maximum efficiency of communication traffic.

2.1.1 Radio Frequency

Wireless systems (radios) transmit data and voice information using a specific radio frequency (RF) to other radios tuned to the same frequency. Common radio messages are transmitted over

the RF band between 0.05 MHz and 900 MHz. Most public safety communications radios (portable, mobile, base station, and repeaters) transmit frequencies between 30 MHz and 900 MHz which are dedicated to public service use. Cell phones and systems, such as global positioning receivers, call boxes, electronic signs, irrigation systems, and mobile command units, that transmit information from remote locations, transmit in the microwave band between 1 GHz and 20 GHz. An example of RF technology that transmits only data is the SD-125 RF Link Module, manufactured by Maxon, shown in figure 2-1.



Figure 2-1. SD-125 RF link module, Maxon

2.1.1.1 Conventional Radio System

In conventional RF systems, each user group is assigned a discrete radio channel (or frequency) that is independent of other user group channels (or frequencies). The users within the group transmit and receive only on that channel, on a first come first serve basis. Transmissions may occur with or without the assistance of a repeater (see sec. 2.2.4). Communications without a repeater are considered to be simplex communications (transmit and receive on the same frequency) and are typically used when only a small coverage area is required.

Conventional radio systems provide communication between users within a given geographic coverage area. A major advantage of a conventional radio system is that users equipped with radios from different manufacturers can communicate with one another provided they are programmed to the same frequency, which includes the appropriate CTCSS or DCS programming. (CTCSS and DCS are techniques commonly employed to aid in the rejection of interference from other radio systems). Disadvantages to conventional radio systems include user accessibility delays when a channel is being utilized by other users, and security concerns because of the ease of “eavesdropping” on potentially sensitive communications by the public or

media equipped with scanner radios. Modulation and encryption system compatibility must also be addressed in planning for interoperable communications. Figures 2–2 and 2–3 illustrate a mobile and a portable conventional radio, respectively. The mobile radio is a Kenwood Compact Synthesized FM Mobile Radio, TK-862H, and the portable radio is a Relm GPH21.



Figure 2–2. TK-862H, compact synthesized FM mobile radio, Kenwood



Figure 2–3. GPH21, portable radio, Relm

2.1.1.2 Trunked Radio Systems

Trunked radio systems typically allocate 20 or more talk groups (logical channels) to a particular radio frequency channel. A radio system’s computer assigns a user and the user group to a frequency when the push-to-talk (PTT) button is pressed. A user is an officer or member assigned to the precinct or fire company, and a user group is a police precinct or fire company. This results in a single conversation occurring over several channels, eliminating the need for the users to manually change frequencies, thus maximizing the system efficiency. In addition, the channel capacity increases because other users can use the time between transmissions for their communications without the need to wait for a “clear channel.” Because the computer selects the channel and monitors the repeater before transmitting, the trunked radio system is more technically complex than the conventional system. Since it appears to be simpler and faster to use, it may be considered more efficient. Another apparent advantage to a trunked system is the increased difficulty in eavesdropping on conversations that may switch channels with every transmission. However, scanners that can follow talk groups on a trunked radio system are widely available to the general public, whereby digital spread spectrum radios may provide user security from such methods of eavesdropping.

The disadvantages of the trunked system are those common to all RF radio systems (i.e., atmospheric interference, unreliability in certain environments, such as underground and confined spaces, and unable to be used in explosive environments, etc.). Additional disadvantages of the trunked system include the increased complexity of the infrastructure with

regards to an increased number of antenna and repeater sites (especially in the case of 800 MHz systems), dependence on the computer system and software that controls the trunked system, and reliance on the equipment of one manufacturer for guaranteed operation. Examples of trunked radios are shown in figures 2–4 and 2–5. Figure 2–4 is a Yaesu/Vertex-Standard GX 4800UT UHF mobile radio, and figure 2–5 is a portable system, the Yaesu/Vertex-Standard HX482UT conventional and trunked system.



Figure 2–4. GX 4800UT UHF trunked system mobile radio, Yaesu/Vertex-Standard



Figure 2–5. HX482UT, conventional and trunked system, Yaesu/Vertex-Standard

2.1.2 Hard-Line Technology

Hard-line communication systems operate by transmitting voice and data through a cable that connects to a telephone-like apparatus. The major advantage of a hard-line system is the ability to communicate from underground, confined spaces, shielded enclosures, collapsed structure void spaces, and similar locations (such as explosive environments) where RF systems are unreliable or unable to be used. An additional advantage of hard-line communication systems is that they are totally secure. Outside eavesdropping is not possible because the transmissions are contained within the wired system. The disadvantages of a hard-line system are the distance and mobility constraints imposed by the cable, the time required to set the system up at an incident site, and the limited number of users that can be supported by a system at a given location.

2.2 Types of Equipment

The RF communication equipment considered in this guide includes portable radios, mobile radios, base/fixed station radios, repeaters, and base station/repeaters. Each type of equipment will be discussed in the following sections.

2.2.1 Portable Radios

Portable radios are small, lightweight, handheld, wireless communication units that contain both a transmitter and a receiver, a self-contained microphone and speaker, an attached power supply (typically a rechargeable battery), and antenna. Portable transceivers (such as a walkie-talkie) have relatively low-powered transmitters (1 W to 5 W), need to have their batteries periodically recharged or replaced, and may be combined in a wireless radio communication system with other portable, mobile, and base station radios. There are also very low-powered transceivers, available with power outputs of 0.1 W, which are generally linked to portable repeaters for extended range and interoperability with higher-powered radio systems.

2.2.2 Mobile Radios

Mobile radios are larger than portable radios and are designed to be mounted in a fixed location inside a vehicle (police cruiser, fire truck, etc.). Like the portable radios, mobile radios contain both a transmitter and a receiver and may contain an internal speaker. However, mobile radios connect to the vehicle's power supply, which enables them to have a higher transmitter output power (typically 5 W to 50 W) and an external antenna. The microphone is usually handheld, and the speaker may be externally located to the radio. Because of the higher transmitter power and external antenna, the effective communication range is greater than that of a portable radio, especially if a repeater is not used. The receivers in mobile radios are generally more sensitive than the receivers found in portable radios, as physical space for components in mobile radios is not as critical as in portable radios. Personnel who do not need to communicate with others when away from the vehicle typically use mobile radios. As with portable radios, mobile radios may be combined into a radio communication system with other portable, mobile, and base station radios.

2.2.3 Base/Fixed Station Radios

A base (or fixed) station radio also contains a transmitter and a receiver. The radio is powered by an external electrical system (typically 110 V ac) and is connected to an antenna located tens to hundreds of feet away, typically on top of a building or on a tower. Because the base station radio uses an external electrical system (i.e., commercial power mains), compared with portable and mobile radios, they have the most powerful transmitters (5 W to hundreds of watts) and the most sensitive receivers. Microphones can either be handheld or desktop models, and the speaker can either be external or internal to the radio.

2.2.4 Repeaters

A repeater is a specialized radio that contains both a receiver and a transmitter. Repeaters 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. The incoming signal is rebroadcast back to the radio network on

a different frequency, usually with higher power and from a better location (tall buildings, mountaintops, and/or towers). Figure 2–6 shows a Vertex VXR-5000 repeater.



Figure 2–6. VXR-5000 repeater, Vertex

2.2.5 Base Station/Repeaters

Several manufacturers offer base station/repeater radios. These radios cannot operate as both a base station and a repeater simultaneously, but when installed for use, they are configured to operate as either a base station or as a repeater.

2.3 Accessories

Most accessories are for portable radios and are designed to allow for maximum user flexibility. There are optional trunking accessory boards available for many conventional radio systems, and optional encryption modules available for some radios to allow for secure communications.

2.3.1 Accessories for Portable Radios

Additional accessories for portable radios include optional batteries for extended operating time, speaker-microphones, carrying cases, battery eliminators, and vehicular adapters. Multiple carrying case options are available: those that allow for optional batteries; those that have specialized operations mounting requirements, such as the strap-on chest case for instances when a radio cannot be worn on or near the waist; or those that are water resistant for operations that may occur in extremely wet environments.

Several optional speaker-microphones attach to portable radios through the remote speaker/microphone jack. These include boom microphones (attenuates background noise and works best when the user's voice is not obstructed), ear microphones (worn in the ear and transmits ear canal vibrations into microphone signals), bone microphones (worn on the top of

the head or behind the ear and transmits vibration signals), and throat microphones (worn on the throat and transmits vibration signals). Voice operated switch (VOX) activated accessories have the same function as the PTT button but allow hands-free use of the radio. Alternately, full duplex operation of radios (able to transmit and receive on different frequencies simultaneously) provides hands-free and simultaneous, bi-directional communications.

Battery eliminators are specialized accessories that are attached to the radio in place of the battery. They allow portable radios to operate from a power source such as the electrical system of the vehicle rather than the radio's own battery, thus extending the useable life of the radio's battery before it needs to be recharged. Battery eliminators are most often used with portable radios that have no external power (e.g., 12 V dc) jack. Battery eliminators can be obtained from radio manufacturers or specialized third party aftermarket vendors.

Vehicular adapters are also specialized adapters for portable radios that allow portable radios to operate as a mobile radio. When the portable radio is placed into a vehicular adapter, the radio operates off the electrical system of the vehicle, is connected to an antenna mounted on the vehicle, and in some instances, is connected to an amplifier in order to increase the output power of the transmitter (for example, 5 W to 50 W for increased range). While the portable radio is in the vehicular adapter, the radio's battery is recharged.

2.3.2 Accessories for Mobile Radios and Base Station/Repeater Radios

There are fewer accessories available for mobile and base station radios. They are generally chosen when the radio is initially purchased because they are often dependent upon installation requirements and restrictions.

Accessories for mobile and base station radios typically include these devices: transmitter power amplifiers, specialized modules that allow the radio to be connected to computers or other data terminals, remote mounting systems to minimize theft, external speakers that can be mounted for operator convenience, and specialized microphones that may allow for the user to change channels or transmitter output power.

2.4 Enhancements

Enhancements are those items or applications available to the customer for modification of the communication system for a specific purpose. Enhancements discussed in this section include the following items: encryption, digital communications, security measures, and interoperability/networking.

2.4.1 Encryption

Both conventional and trunked RF radios may allow for the encryption of sensitive communications for security purposes if the system is equipped with the appropriate encryption electronics. Some radios may require the installation of an optional encryption module for secure communications. Voice and data transmissions may be encrypted by simple inversion, rolling code, or by digital encryption. Protection from scanner monitoring and even more

sophisticated monitoring devices can also be accomplished with spread spectrum radios operating in the ISM bands; however, because of the low power utilized in the ISM bands, reliable communications may not be possible.

2.4.2 Digital Communications

Digital communications is a technique whereby voice (sound waves) and data information present in the radio signals is converted into binary code represented using electronic or electromagnetic signals. The binary code is then converted by mathematical algorithms that need to be decoded by mathematical algorithms in the receiving radio in order for the user to understand the information. It offers users enhanced signaling and control options, more consistent audio quality, greater radio spectrum efficiency, and a broader range of encryption capabilities. Communications between users is less likely to be interrupted in terms of signals being dropped. At the edges of a coverage area, digital technology improves the signal integrity to maximize communications.

To help understand digital communications technology, it is important to understand analog communications technology. Analog communications is the transmission of information using a continuously variable electromagnetic signal. The information usually transmitted by analog systems is from sound, such as that contained in conversation and music. Prior to transmission of the sound information, it must be converted into an electrical form (as is done with a microphone). For several technical reasons, the electrical information is typically transformed into higher frequencies by modulating a continuous wave radio signal. Examples of this type of transformation and modulation are the FM and AM signals on your radio. Analog communications is the basis for most current cell phones and communication systems. Perhaps the best and simplest example of analog radio communications is the Citizens Band (CB) radio service.

2.4.3 Security Measures

Communications security is becoming increasingly important. Presently, the general public can purchase any one of several different radio receivers that will allow them to monitor virtually any and all public safety communications. As a result, secure communications may be difficult to achieve unless measures are incorporated into the planning of a communication system.

Security measures that can be incorporated into a communication system include, but are not limited to, digital encryption of radio signals, voice inversion, digitizing of voice and data as in a digital system, and use of digital cellular or PCS telephone circuits. Security may also be improved by the use of spread spectrum techniques. No single security measure is appropriate for every situation, nor is it necessarily true that all security technologies will work with, or are appropriate for, all communication systems. Encryption systems may require extensive planning and coordination to ensure compatibility and interoperability. It is best to consult with the radio manufacturer's sales and technical personnel for the most reliable and accurate information regarding current encryption technologies and their uses.

2.4.4 Interoperability and Networking

Interoperability is the process of connecting different groups using different radio systems and communication technologies (telephones, radios, cellular communications, and satellite communications) so that they can communicate directly with one another without having to go through multiple dispatchers or relay personnel. In the context of communications, interoperability describes the situation where different communication systems that are otherwise incompatible with one another work together without relying on the addition of considerably more manpower. An example of interoperability would be where a police radio system can “directly” exchange information (voice or data) with the National Guard radio system or the FEMA radio system; or a municipality’s public works department using a Motorola Type I Trunked System can “directly” exchange information (voice or data) with the adjacent jurisdiction’s fire department which uses a Com-Net Ericsson EDACS Trunked System. Some trunked radio systems may allow for interoperability between different talk groups and may allow the connection of third party dispatch systems. Integration with other communication systems may also be permitted. These systems may include private automatic branch exchange (PABX) systems, data networks, cordless extensions, and paging systems. Examples of data networks that a radio system may be interoperable with are automatic vehicle location and Geographic Positioning Satellite systems. Another example is a telephone interconnect system where telephone calls are patched through the radio system.

Simply stated, a communications interconnect system allows telephones, cell phones, radios on different frequencies, proprietary formats, trunked talk groups, and conventional radio networks to communicate with each other using interface modules. The interconnect system can allow for several two-way and conference calls to occur simultaneously. There is no need for a dispatcher to connect one system to another system as the cross-connection operations are unmanned. This can result in a much greater interoperability between equipment and organizations. Figure 2–7 is the JPS TRP-1000 Transportable Radio Interconnect System, and Figure 2–8 shows the Communications Applied Technology (C-AT) ICRI battery powered, man-carry radio interconnect “switch.”

2.4.5 Incident Management and Assessment Tools

In developing the Chemical-Biological defense equipment guides, a number of incident management and assessment tools were identified that are available to the emergency first responder community. Several of these tools, as well as their internet addresses, are listed in the following paragraphs.



Figure 2-7. TRP-1000 transportable radio interconnect system, JPS



Figure 2-8. ICIR man-carry radio interconnect switch, C-AT

Consequence Assessment Tool (CATS) is a disaster analysis system for Natural and Technological Hazards that was developed for the Defense Threat Reduction Agency (DTRA) and the Federal Emergency Management Agency (FEMA). It is supplied with over 150 databases and map layers to help the emergency response organizations before (for training and planning), during (to assess quickly and accurately), and after (to obtain information and support) a disaster. It can be customized per user requirements. The internet address for CATS is <http://cats.saic.com/main.html>.

Chemical Biological Response Aide (COBRA) is an internet site that offers a family of products and services for the emergency first responder. The COBRA Guide 2000 is an interactive, electronic version of the Department of Transportation's (DOT) 2000 Emergency Response Guide book. The web site is www.defensegp.com/cobraproducts.cfm.

E Team is an internet-based workflow management application designed for emergency responders. This software is Incident Command System (ICS) compliant, allowing communication and data sharing between all command posts and operations centers. It is designed for incident reporting, resource request tracking, and infrastructure status reporting. The web site for E Team is <http://www.eteam.com>.

Each of the listed web sites has additional links to supplemental information for the emergency first responder.