

Push-to-Talk Land Mobile Radio

ISICS Radio Basics Whitepaper

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Contents

Abstract	2
Introduction.....	3
Radio Hardware	3
Antennas	3
Batteries	4
Accessories	4
Radio Operations	5
Channels, Frequencies, and Talkgroups	5
Digital Audio.....	5
Conventional Operation	5
Trunking Basics.....	6
Trunking Operations and Scanning	7
Encryption.....	7
Conclusion.....	8

Abstract

This whitepaper explores the intricacies and advancements in Push-to-Talk (PTT) land mobile radio (LMR) technology. This paper seeks to shed light on key hardware components, such as antennas, batteries, and accessories, as well as maintenance of radios and accessories. Operational concepts of PTT LMR radios, with particular emphasis on radios used on digital trunking systems, will also be explored.



Introduction

Push-to-talk (PTT) is a communication method commonly used in land mobile radio (LMR) systems, which are essential for public safety and public service. PTT allows users to initiate communication by pressing a button, typically located on the handset or a microphone. Push-to-talk systems enable users to transmit voice messages over a radio network. PTT offers efficient communication, as users only transmit when necessary, reducing channel congestion. Additionally, it provides a level of security, as conversations are typically confined to the closed radio network, minimizing the risk of interception by unauthorized parties. PTT functionality is often integrated into modern communication devices, including handheld radios, vehicle-mounted radios, smartphones, and specialized communication consoles. This integration allows for seamless communication across various platforms and devices. Overall, PTT functionality in land mobile radio systems provides reliable, efficient, and secure communication for users where instant and coordinated communication is critical.

Radio Hardware

Antennas

The radio antenna is an important piece of the radio. Its purpose is to convert the electric voltage of the radio transmitter into radio waves, and in return, receive the radio signals over the air and convert them back into electric voltage for the radio receiver to receive and demodulate voice and data packets.

Most two-way radio manufacturers offer different styles and sizes of portable and mobile two-way radios. Some portable radios offer the “stubby” antenna for a less intrusive approach, and “low profile” styles for a covert, more discreet look when being used. Keep in mind however, the stubby antennas and the low-profile antennas may reduce the performance quality.

When installing the radios’ antenna, be sure to be VERY CAREFUL. Always be sure that the antenna is not loose and is firmly tightened into the connector but do not over-tighten as damage to the connector may happen rendering the radio inoperable.

Your radio antenna requires limited maintenance, however, make sure the antenna is free from cracks, frays, or other damage. Also, over time the antenna may loosen from the connector and requires the antenna to be hand tightened. Never hold a radio from the antenna as this causes stress and strain on the connector and can snap off, rendering the radio inoperable.

Batteries

The battery provides the radio with the power needed to operate effectively and efficiently. There are many different battery options for portable radio equipment, such as battery capacity and battery chemistry. These options vary to the needs of the user. All batteries are not universal and are typically dependent the manufacturer and model of the radio.

There are many different battery sizes (capacity) and battery types (chemistry) of batteries. Typically, the needs of the user will be the deciding factor on what the best option for them. Today, Lithium-Ion battery is one of the most common types of battery due to the high-capacity density along with the lightweight characteristics. Most manufacturers also produce non-rechargeable, one-time use batteries along with AA alkaline battery packs typically for use during emergencies.

It is very important to know how to care for the battery as this will assure your radio works in times of need. Make sure to inspect your radio's battery often. Look for any cracks and notice if the battery becomes swollen. A swollen battery must be replaced immediately even if it still works. A swollen battery is a fire hazard. Make sure the battery contacts are clean to ensure good contact with the radio. It is good practice to fully discharge a battery before recharging to maximize the life of the battery. Newer batteries often require battery conditioning, which most new chargers are capable of. An overheating battery can be a sign of an incorrect installation on a charger or of a failing battery. If you notice the battery is no longer holding a charge it is a good idea to replace the battery. When storing batteries, make sure they are kept away from moisture in a dry and climate-controlled room. Extreme temperature can affect the life of the battery. Stored batteries naturally lose capacity even when they are not being used. It is good practice to cycle stored batteries and keep them charged in case they are needed in an emergency.

Accessories

There are many accessories available for two-way radios. It is very important to understand the types of accessories available for use with your two-way radios, how they work, and how to handle them along with good maintenance routines. What accessories you use depends on the needs of your agency. Users may utilize radio speaker microphones (RSM), in the ear surveillance headset, and/or Bluetooth radio speaker mics (on the shoulder or used with firefighting equipment).

Always refer to the manufacturer's manual for best practices on caring for the device. Make sure the microphones are not blocked with any debris and the cables are not frayed or exposed. It is always recommended to put the devices out of service if any cables are exposed.

Radio Operations

Channels, Frequencies, and Talkgroups

Before discussing radio operation, it is important to understand the difference between a *channel*, *frequency*, and *talkgroup*. These terms are often used interchangeably, but there are some nuances to be aware of. A **channel** is an agreed-upon frequency or talkgroup where specific communications will take place. “Fire 1”, “Law Ops”, and “Tac 5” are examples of channels. A **frequency** is the number of times a radio wave cycles in a second. In public safety, frequencies are most commonly expressed in MHz (megahertz), which is millions of cycles per second. In a conventional radio system, a channel is represented by a dedicated frequency. In a trunked radio system, a group of frequencies are digitally assigned by a control channel for more efficient use of the radio spectrum. A **talkgroup** is a number that represents a group of radio users in a trunked radio system.

Digital Audio

Digital audio technology has significantly enhanced the clarity and reliability of communications in LMR systems. When using digital audio, the radio user's voice is first encoded into a series of 1's and 0's, and then transmitted over the air. The receiving radio decodes these 1's and 0's back into a representation of the user's voice. The signal is also usually processed by a Digital Signal Processor (DSP), which filters out sounds at frequencies outside the normal range of human voice, decreasing the effect of loud background noise.

A significant challenge when transitioning from an analog to a digital radio system is the change in user experience. Digital audio sounds very different from analog audio, and it may take end users a few weeks to get accustomed to how voices sound on the new system. It is very important that end users understand this fact, as often end users initially report a worse user experience, but then start to realize the benefits of digital radio after they become used to the way it sounds.

Conventional Operation

Traditionally, radios operate in conventional mode. Conventional mode can either be simplex, or duplex. Simplex means that one frequency is assigned to a channel, and it is used for both transmitting and receiving. Duplex means that

two frequencies are used, one for receiving and one for transmitting. Duplex channels are most commonly used for repeaters, where one frequency is used for radio-to-repeater communication, and the other for repeater-to-radio communication. Conventional channels can be either analog or digital.

Repeaters are used to boost the signal of a channel across a large geographical area. Typically, repeaters are assigned a frequency pair - one frequency for input and one frequency for output. Portable and mobile radios will transmit on a repeater's input frequency at a low power (5-50 watts), and the repeater will repeat this transmission on its output frequency at a much higher power (100+ watts). This higher power, coupled with the fact that repeater antennas are usually located high up on a tower or building, allows radio users to communicate over a much greater distance than directly from radio to radio.

Trunking Basics

Although conventional operation is simple, it can be extremely inefficient. Each Channel requires at least one - and often two - dedicated frequencies, which sit dormant when the channel is not being used.

As the radio spectrum becomes more crowded, this has started to present a larger issue in resource allocation. Trunking radio systems seek to mitigate this problem by assigning each transmission a frequency pair from a pool as the transmission occurs. After the transmission is over, the assigned frequency pair gets returned to the pool, ready to be assigned to another transmission. This allows many channels to share a small number of frequency pairs, significantly increasing the efficiency of the radio system.

A trunking system's frequency pool is comprised of two types of frequency pairs: control channels, and voice channels. When a user presses the PTT button on their trunking radio, the radio transmits a sequence of data packets on the control channel's input frequency requesting a channel grant for the talkgroup it is selected on. The radio system checks for a free voice frequency pair, and then announces the call on the control channel's output frequency. This announcement includes the talkgroup, voice frequency pair, and the ID of the transmitting radio. The transmitting radio then tunes to the input frequency of the voice frequency pair and plays a tone advising the user that it is clear to begin speaking (talk permit tone). Receiving radios that are selected on that talkgroup tune into the receive frequency of the voice frequency pair and play the audio received.

Trunking Operations and Scanning

One of the greatest challenges when transitioning to a trunking radio system is getting end users used to the talk permit tone. New users of trunking systems are often unaccustomed to having to wait a moment between keying up and speaking and will often inadvertently end up cutting off the beginning of their transmission. End users may also be unaccustomed to “busy” tones, which occur when the system does not have an available frequency pair, or the radio is out of range of the system. This is colloquially known as the “bonk”, due to the sound that radios make as a busy tone.

Radio affiliation is the process of the radios being connected and interacting to a radio tower site. When the radio is turned on or off, or when the channel is changed, data is being sent back and forth from tower site to radio. All trunking two-way transceivers are in constant communication with the nearest radio tower. Affiliation is very important, this allows the radio tower (site controller) to see the radio is active on the system and allows the radio system to send voice and data information to the radio.

Scanning works differently on a trunked system compared to scanning on a conventional system. The trunked system is constantly trying to be efficient with all system resources. Therefore, talk group audio is only sent to sites where a radio is registered and transmitting on a talk group affiliated to that site.

Encryption

As discussed before, digital audio converts the voice of the radio user into a series of 1's and 0's. Another significant advantage of this is that it allows the information to be easily encrypted. Encryption is the process of changing data for the purpose of obscuring its contents, in a way that the intended recipient can recover the original data. Encrypted radio traffic is not able to be deciphered by bad actors with a radio scanner, allowing agencies to maintain operational security. However, encryption also poses its own set of issues, namely making interoperability more of a challenge. Agencies that wish to have interoperability while remaining encrypted need to ensure that their radios have the correct ciphers and key capabilities and need to share keys with each other.

A cipher is an algorithm used to encrypt and decrypt data. Many different ciphers exist and are not interoperable, meaning radio traffic encrypted with a certain cipher must also be decrypted by the same cipher. Some common ciphers include ARC4, DES-OFB, and AES256. At this time, the only recommended cipher for use in operational environments is AES256, because of the level of security it provides.

Many radio vendors include single key encryption being a more expensive upgrade. When configuring radios for encryption, it is important to consider current and future needs. If single key encryption is selected, only one encryption key will be able to be loaded into the radio. In the future, if it is needed to load another agency's encryption key in order to interop with them, it will not be possible without an expensive upgrade.

When designing a radio system and implementing radio operation policies that include encryption, it is important to balance the need for security with interoperability capabilities. An agency that requires all traffic to remain encrypted by policy may not be interoperable with surrounding agencies that do not use encryption. Some agencies encrypt most of their traffic but allow it to be broadcast in the clear when working with other agencies, and other agencies keep most of their traffic in the clear, while having a few encrypted channels available for sensitive or tactical situations.

Conclusion

In conclusion, mastering the use of land mobile radio systems involves a comprehensive grasp of both the hardware and operational aspects. By adhering to best practices, maintaining equipment diligently, and balancing security with interoperability, agencies can ensure that their communication systems are robust, efficient, and capable of meeting the demands of public safety and service.

