

Radio Communications

Cindy M. Cast

State of Florida Domestic Security Vice-Chair Communications Focus Group

Regional Domestic Security Task Force – Region 7 Chair Communications Focus Group

Introduction

- Government agencies rely on Land Mobile Radio (LMR) systems to support voice two-way radio communications for personnel in the field to communicate.
- This presentation will focus on the technical development of radio systems and interoperability between radio systems.
- 23 years of experience in working with radio communications technology

Topics

- Radio Communications History
- Radio System
 - Capacity
 - Frequency
 - Coverage
 - Type
- Interoperability
 - Programming
 - Console Patches
 - Gateways



Radio Communications History



- In the 1930s Land Mobile Radio (LMR) systems began to be developed for use by federal and government agencies to provide voice communications. Since then, basic radio systems to complex radio systems have been deployed.



- Radio communications take place utilizing different types of radio devices. Devices consist of handheld portable radios, mobile radios installed in vehicles, desktop radios in an office environment and/or dispatch consoles.



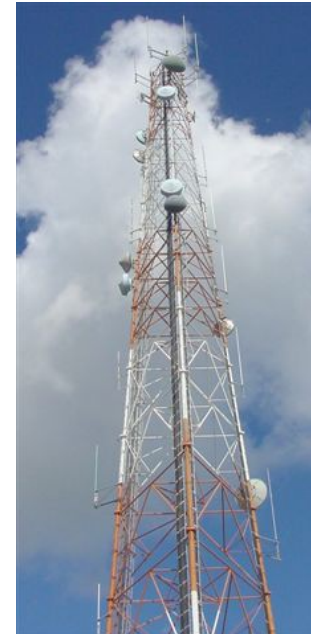
Radio Communications History

- Usage:



Radio System

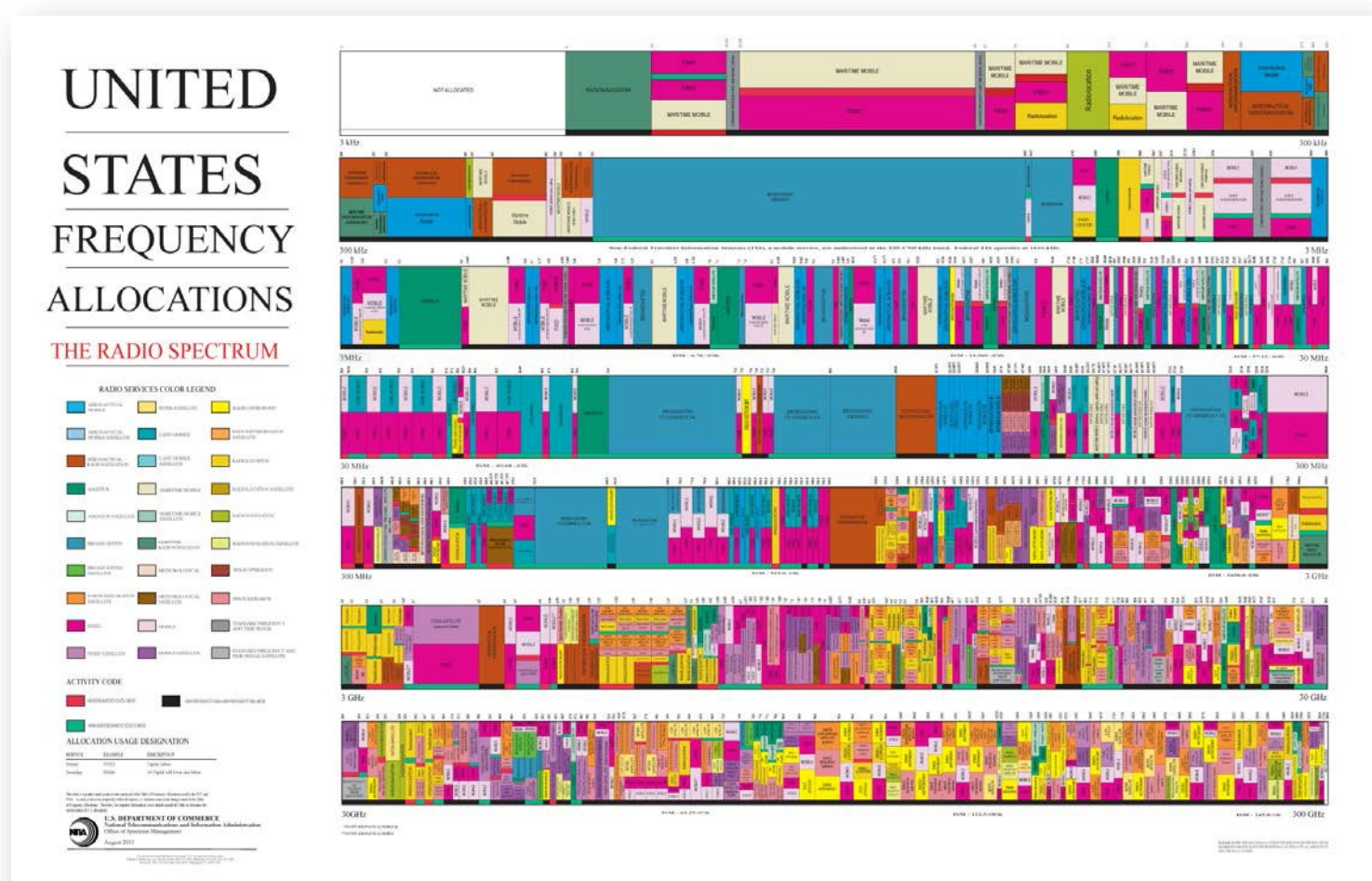
- Radio Systems are complex terrestrially-based, wireless communications systems. Not all radio systems are the same. They are referred to as two-way radio systems because they can transmit and receive a signal. When developing a radio system there are many elements involved. The primary four elements are:
 - Capacity
 - Frequency
 - Coverage
 - Type



Radio System - Capacity

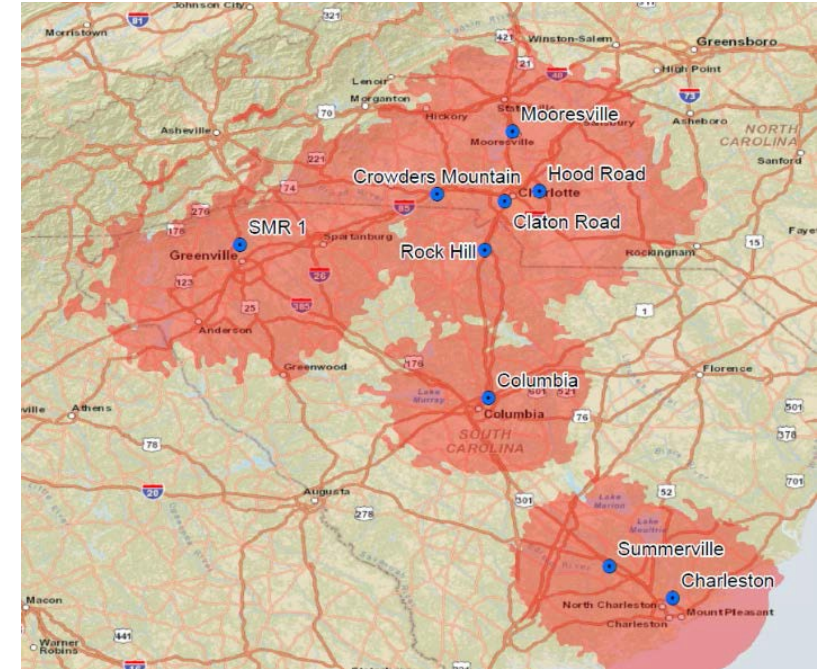
- Capacity relates to the capability of the radio system to sustain a given number of conversations at the same time.
- During the planning stage questions are asked to obtain this information. Some questions are:
 - How many departments or agencies will use the radio system?
 - How many separate talkpaths are needed?
 - A talkpath is a separate conversation between a group of radios based on discipline or mission.
 - How many radio devices will be operational on the radio system?
 - Portable, Mobile, Desktop, and/or Consoles
 - What is the average length of the conversation/transmission?
 - Transmission is when a radio transmits on a talkpath (when a users presses the Push-to-Talk (PTT) button on the radio and talks).
- Capacity has to be revisited regularly as additional radio devices or agencies are added to the system. They may impact the capacity available for existing radio users.

- Public Safety radio systems are available for government agencies in specified frequency bands:
 - VHF High Band (VHF); 138 to 174 MHz
 - Ultra High Frequency (UHF); 380 to 512 MHz
 - 700 MHz; 758 to 775 MHz and 788 to 805 MHz (available in 2000s)
 - 800 MHz; 806 to 815 MHz and 851 to 860 MHz (available in 1990s)



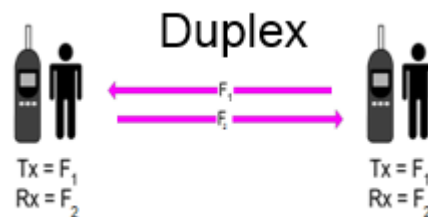
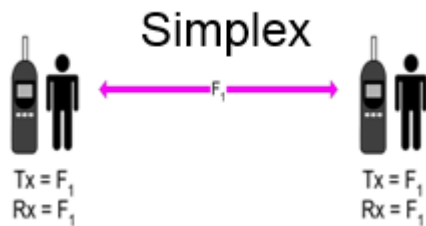
Radio System - Coverage

- Coverage relates to the geographical area that the radio system will operate and function (transmit and receive).
- During the planning stage questions are asked to obtain this information. Some questions are:
 - Provide a map of the area where the radio system will operate.
 - Will the radios be used outside on the street level and/or open fields?
 - Will the radios be used inside of houses?
 - Will the radios be used inside of commercial buildings?
 - How dense of a building is the radio system required to function?
- Coverage has to be revisited regularly as the topology of the area may change from year to year based on new construction and even trees. This may impact the existing coverage that radio users are accustomed to having.



Radio System - Type

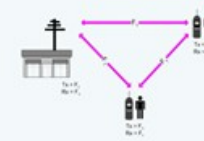
- **Conventional** – radio systems that have dedicated frequencies and channels assigned to individual groups. A simplex configuration utilizes the same frequency to transmit and receive. A duplex configuration utilizes two frequencies; one to transmit and one to receive.



2-5 mile range between portable radios
(at approximately the same elevation)



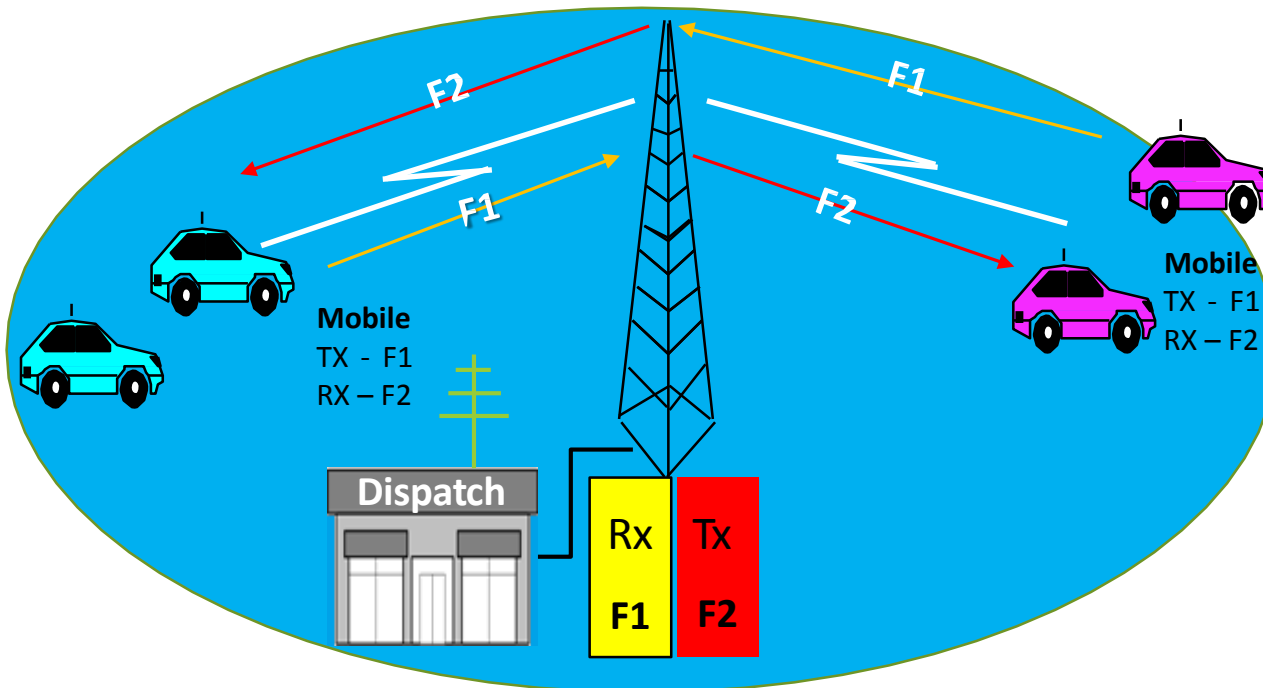
up to 20 miles between mobiles or
mobile to base.



The range of a system is primarily determined by the power of its transmitter, as well as the placement, height and gain of the antenna

Radio System - Type

- **Conventional** – repeaters can be added to the radio system design to increase the area where the radio will work. The repeater rebroadcasts the information.



800 MHz Mutual Aid Conventional Channels – are configured for both a conventional duplex repeater radio system with simplex channels. This system is comprised of one calling channel and 4 tactical channels repeated and 4 simplex channels. In Florida, the majority of public safety agencies have these channels in their radios and dispatch centers.

Non-Federal 800 MHz National Mutual Aid Repeater Channels			
Description	Ch. Name	Mobile RX (MHz)*	Mobile TX (MHz)*
Calling	8CALL90	8	8
Calling – Direct	8CALL90D	8	8
Tactical	8TAC91	8	8
Tactical – Direct	8TAC91D	8	8
Tactical	8TAC92	8	8
Tactical – Direct	8TAC92D	8	8
Tactical	8TAC93	8	8
Tactical – Direct	8TAC93D	8	8
Tactical	8TAC94	8	8
Tactical – Direct	8TAC94D	8	8

Default operation should be carrier squelch enable/disable CTCSS without reprogram be programmed for receive, and the user *The frequency in parenthesis, which is 1 channel names were ICALL, ITAC1 - ITAC

National Interoperability Field Operations Guide

U.S. Department of Homeland Security
Office of Emergency Communications
Version 1.6.1

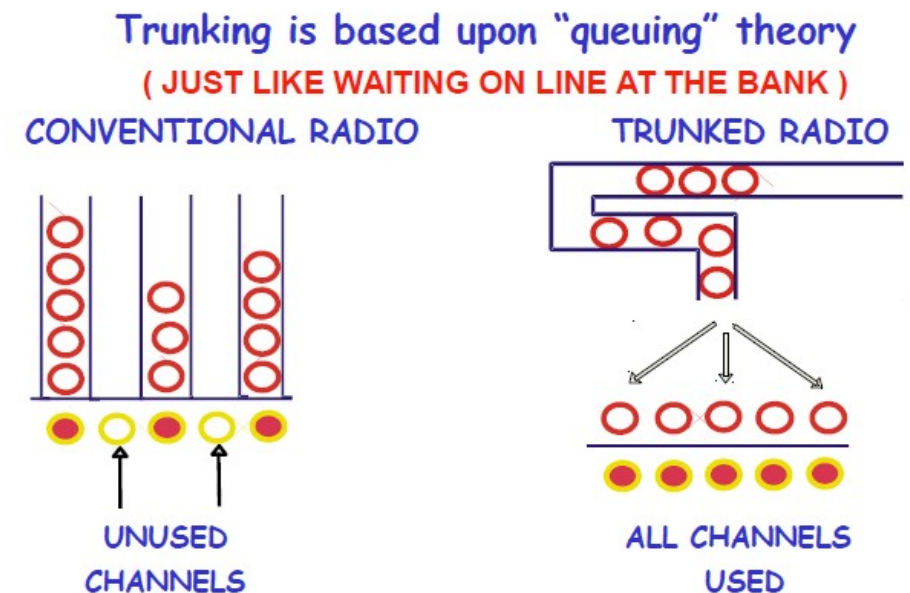


Homeland Security

June 2016

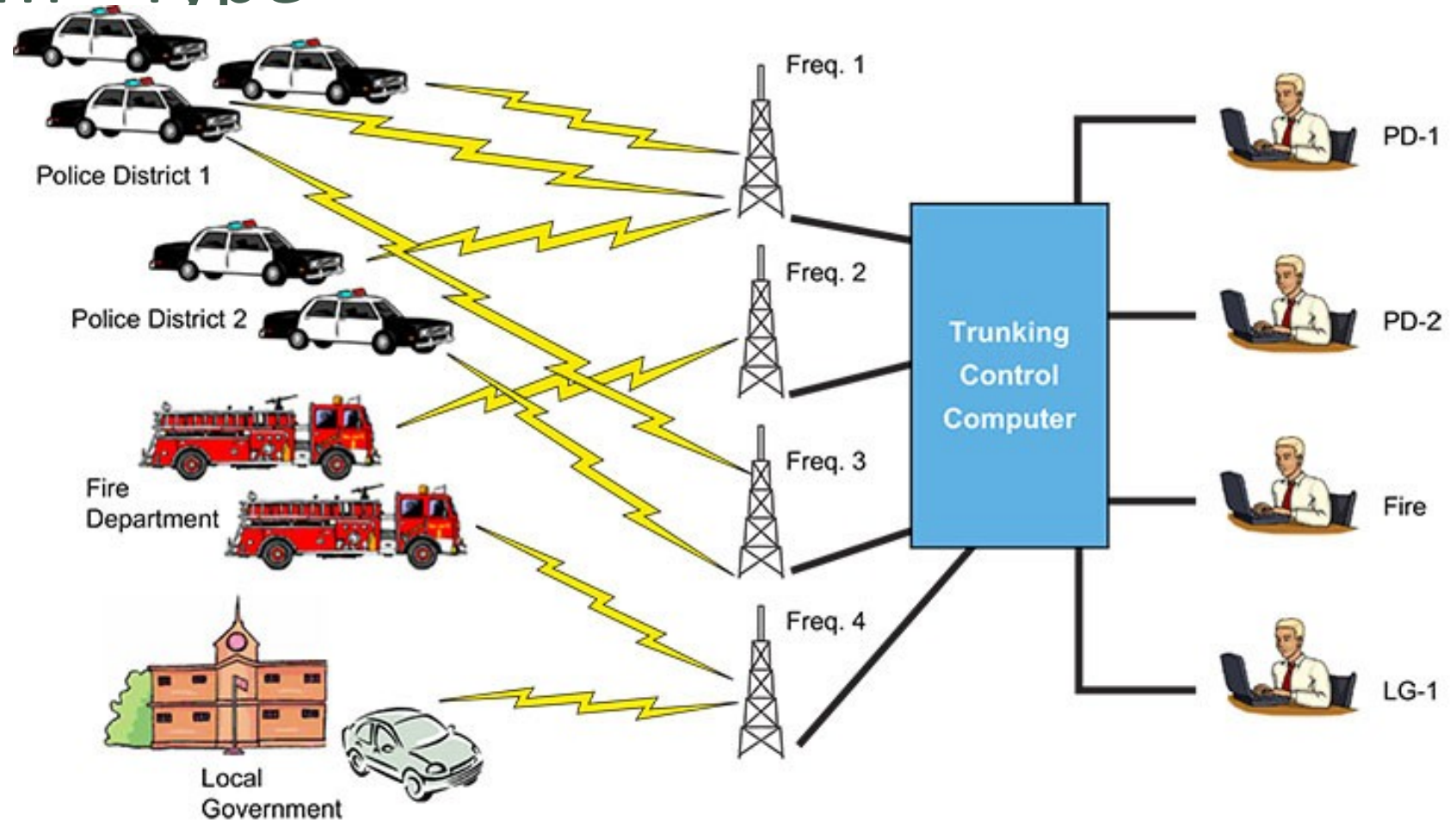
Radio System - Type

- **Trunked/Trunking** (developed in the 1990s) – radio systems which are more complex because they have an automated computer control which provides less user intervention to operate. All frequencies are grouped in a pool and utilized as needed. This provides greater spectral efficiency when there is a large numbers of users. Instead of assigning, for example, a radio channel to one particular agency at a time, users are instead assigned to a logical grouping known as a talkgroup. These talkgroups may have as many conversations simultaneously based on the amount of frequency pairs in the radio system.
- Trunked radio systems take advantage of the probability that with any given number of users, not everyone will need to use the system at the same time. Therefore with a given number of users, fewer discrete radio channels are required.



Radio System - Type

- Trunked/Trunking



Radio System - Type

- **Trunked/Trunking - Access to the System**

- When the radio is turned on and every time it changes talkgroups, the radio sends a data message to the radio system (control channel)
 - System ID number, Radio ID number & Talkgroup ID number
- Radio system (control channel) verifies the ID is valid and the ID has rights to the talkgroup, then sends a data message to the radio granting access. The radio continues to monitor the control channel for messages.

- **Trunked/Trunking - Call Process**

- When a user presses the Push-To-Talk (PTT) button on a radio, the radio sends a data message to the radio system (control channel)
 - System ID number, Radio ID number & Talkgroup ID number
- Radio system (control channel) verifies the ID is valid and the ID has approval/rights to the talkgroup, then sends a data message to the radio granting access and provides the details on which frequency pair/channel to utilize for the transmission. The system then sends a data message to all radios that have that talkgroup selected with the frequency pair/channel information the radio automatically moves to that channel to listen to the message. Once the message is finished, the radios move back to the control channel and monitor it for additional messages.

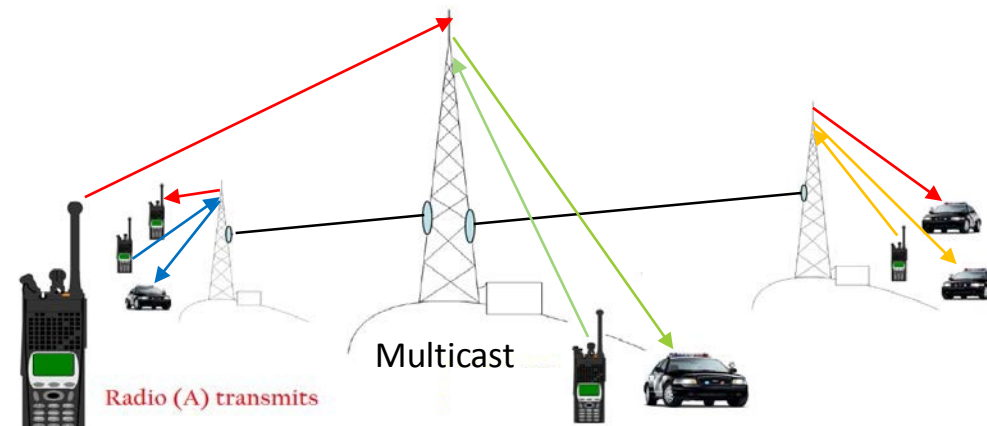
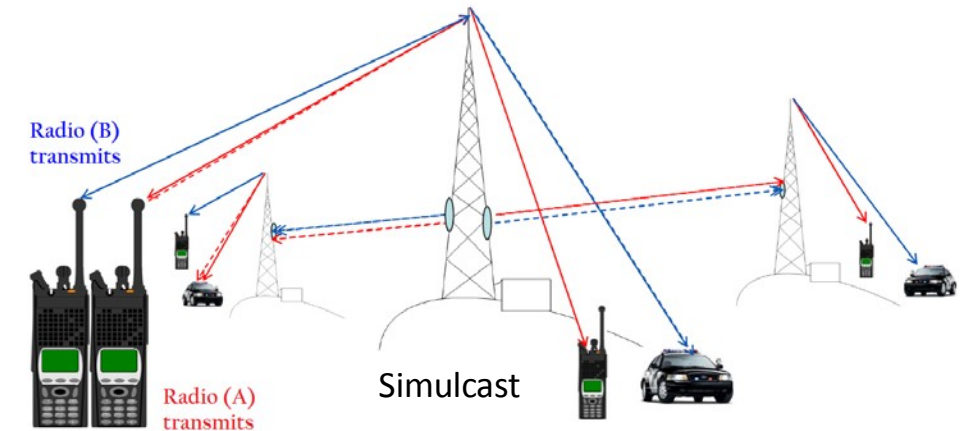
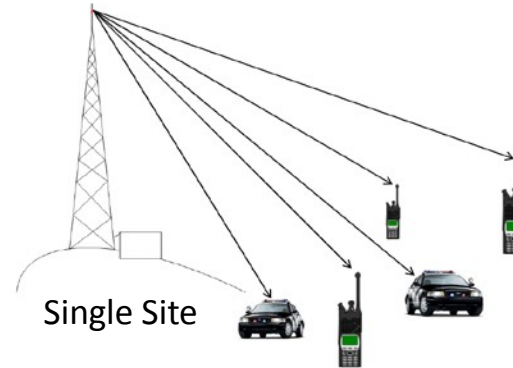


Radio System - Type

- Trunked/Trunking
- Trunking refers to the ability of transmissions to be served by free/unused frequency pairs/channels whose availability is determined by algorithmic protocols.
 - Vendors have proprietary trunked protocols that require a radio to be of the same manufacturer as the radio infrastructure
 - P25 trunked protocol allows radios to be of different manufacturers than the radio infrastructure.
- When a trunked radio system control channel gets too many messages at the same time, it may not have the capacity to keep up with the amount of messages coming in.
- Trunked radio systems rely on a centralized computer controller to make channel assignments and grant radios access. Trunked systems may be impacted if malfunctions of the controller occur. Problems with the controller could affect all of the radio users in large systems.
- If too many users try to access the radio system at the same time and there are no available channels, queueing occurs. The radio receives a beep and waits for the channel assignment. If a user tries to talk on a talkgroup that already has someone talking, the user will hear a busy signal or beep.
- The system may go into “throttling” mode, which is a safety mechanism used by some manufacturers that prevents the system from shutting down from increased radio activity to the control channel. Throttling gives users a busy signal or error message when someone attempts to use the radio system.

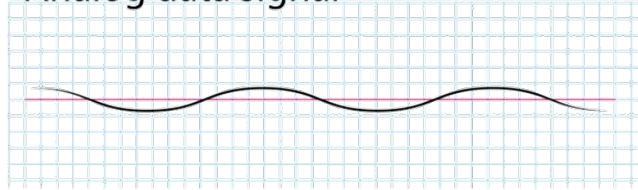
Radio System - Type

- **Single Site** – system utilizes only one tower as part of the infrastructure
- **Multi-Site** - systems can be implemented as:
 - **Simulcast** - uses one channel at each of the simulcasting sites to transmit the same signal simultaneously at the **same** frequency
 - **Multicast** - uses one channel at each of the participating sites to transmit the same signal simultaneously at a **different** frequency (generally trunked systems)
 - **Mixed** – a combination where both simulcast and multicast sites are utilized.

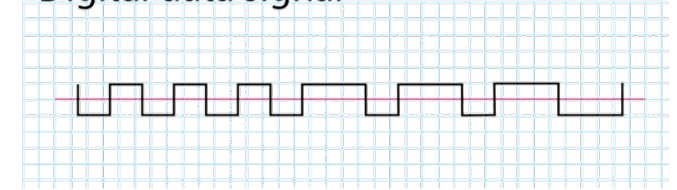


Radio System - Type

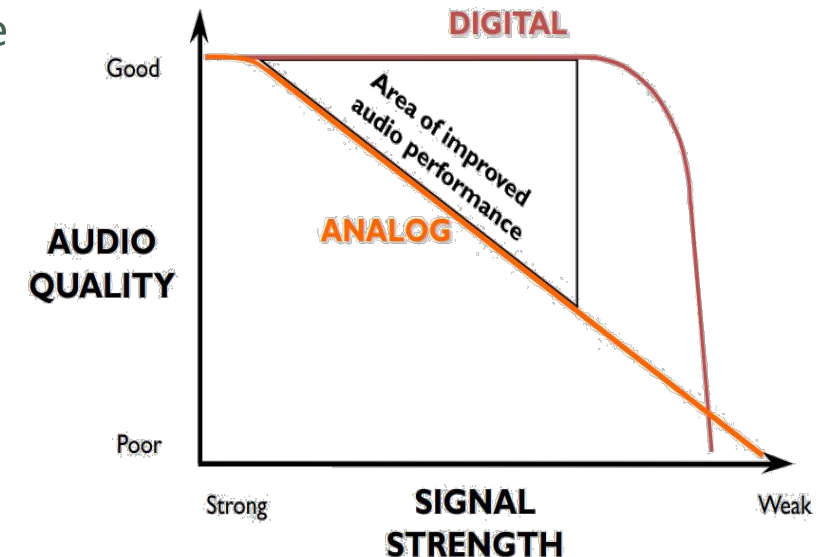
Analog data signal



Digital data signal



- **Analog** - Public Safety analog systems use Frequency Modulation (FM), similar to regular FM broadcast radio. Simultaneous user transmissions will result in a “squeal” or muffled sound. There is a gradual increase in noise level and loss of audio clarity as the signal strength decreases. In a high-noise environment, the background sounds will be transmitted along with the voice message.
- **Digital** - Digital systems use a voice encoder/decoder (VOCODER) to convert human voice into 1's & 0's. Digital systems are designed to provide clearer audio by digitally correcting errors in low signal levels. As the RF signal level decreases, bit errors are digitally corrected so that the received voice quality degrades very little (P25 systems use digital audio). Users may be unaware when they are out of coverage since there is no increase in noise. In a high-noise environment (where the ambient noise level exceeds the RF signal level), bit errors will occur and, the encoder's attempts at error correction generally provides a clear message but it can result in unintelligible electronic sounds or silence.



Radio System - Type

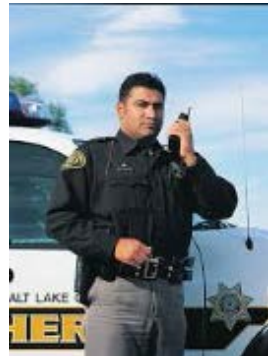


- **Encrypted** - public safety user community has continued to recognize the importance of protecting sensitive information, encrypting audio is a way to achieve this. When radio audio is encrypted, an encryption key is required on the radio in order to unencrypt and listen to the audio message. Once the encryption key is loaded on the radio the radio does this process automatically.
- **Programming** - radios are able to switch between multiple channels or talkgroups, depending on the way a radio is programmed. Each radio must be programmed appropriately to support user access. Radio programming is a very complex process. Generally, agencies have internal staff or contracted staff to program radios. Some critical decisions are required for programming and knowledge of operational procedures is necessary. Specialized software and hardware are required along with authorization from the radio system administrator.



Radio System

- Radio Systems are complex terrestrially-based, wireless communications systems. Not all radio systems are the same. The configuration of the radio system makes it unique. When developing a radio system there are many elements involved which we did not cover. However, the primary four elements are:
 - **Capacity** - # of talkpaths, # of devices, avg. length of conversation
 - **Frequency** – VHF, UHF, 800 MHz, 700 MHz
 - **Coverage** – street level, inside of buildings (density level)
 - **Type** – Conventional, trunked, single site, multi-site, analog, digital, encryption, programming



Interoperability

- Communications Interoperability is defined as, “the ability of Public Safety responders to share information via voice and data communications systems on demand, in real time, when needed, and as authorized.”
- In landmark events such as the 9/11, Hurricane Katrina and others, communications interoperability between emergency responder agencies has been identified as a critical component of incident response.
- DHS in 2005 with the SAFECOM program developed and released the *DHS Interoperability Continuum* framework for assessing and augmenting communications interoperability capability.

Interoperability							
Governance	Limited Leadership, Planning, and Collaboration Among Areas with Minimal Investment in the Sustainability of Systems and Documentation	Individual Agencies Working Independently		Informal Coordination Between Agencies	Key Multi-Discipline Staff Collaboration on a Regular Basis	Regional Committee Working within a Statewide Communications Interoperability Plan Framework	
Standard Operating Procedures		Individual Agency SOPs		Joint SOPs for Planned Events	Joint SOPs for Emergencies	Regional Set of Communications SOPs	National Incident Management System Integrated SOPs
Technology		DATA ELEMENTS	Swap Files	Common Applications	Custom-Interfaced Applications	One-Way Standards-Based Sharing	Two-Way Standards-Based Sharing
		VOICE ELEMENTS	Swap Radios	Gateway	Shared Channels	Proprietary Shared System	Standards-Based Shared System
Training & Exercises		General Orientation on Equipment and Applications		Single Agency Tabletop Exercises for Key Field and Support Staff	Multi-Agency Tabletop Exercises for Key Field and Support Staff	Multi-Agency Full Functional Exercises Involving All Staff	Regular Comprehensive Regionwide Training and Exercises
Usage	Planned Events		Localized Emergency Incidents	Regional Incident Management		Daily Use Throughout Region	
High Degree of Leadership, Planning, and Collaboration Among Areas with Commitment to and Investment in Sustainability of Systems and Documentation							

Interoperability



- If an agency which operates on a separate radio system wants to be interoperable, there are different methods to accomplish this task. Some are:
 - **Programming** – the other radio system in the radio. The radio is required to be able to operate on the frequency, and have the features to function (i.e. trunked protocol). The radio system will only work if the user moves to that channel or talkgroup on their radio and they are within the coverage area of the system.
 - **Console Patches** – a radio or the audio of the radio system is connected in a fixed link to the hardware of another radio system. Then a dispatcher at a console can create a patch which temporarily creates a bridge from one system to the other.
 - **Gateways** – is a hardware device that can connect two or more radios together, which can be mobile or fixed, and provides the ability to connect dissimilar radios onto a single talkpath (a console is not required).

Summary

- Radio Communications History
- Radio System
 - Capacity
 - Frequency
 - Coverage
 - Type
- Interoperability
 - Programming
 - Console Patches
 - Gateways

