

*Unit 5*

*Frequency Regulations and Usage*

# Unit Terminal Objective

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**At the end of this unit, students will be able to identify methods and standards relating to frequency regulations and use.**

# Terminology and Conventions of Use

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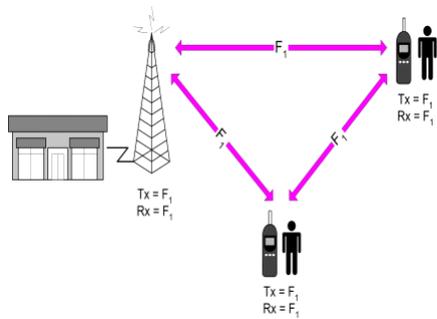
- A *frequency* is a defined unit of electromagnetic spectrum, one of several parameters that define a channel
- A *channel* is a talk path and may utilize one or two frequencies
- A *talkgroup* is a virtual channel within a group of frequencies

# Terminology and Conventions of Use (cont'd)

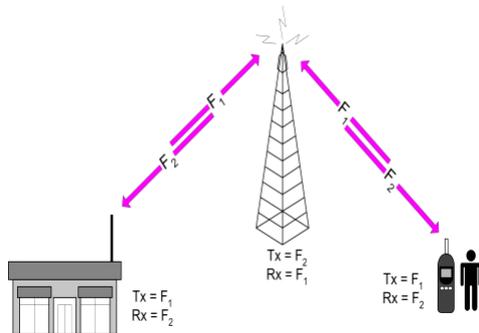
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- Frequencies are written with up to five places past the decimal and should be identified as "wide" (25 kHz spacing) "narrow" (12.5 kHz spacing) or "ultra-narrow" (6.25 kHz spacing)
  - Example: 155.4750 N
  - All frequency references on an ICS Form 205 represent mobile and portable frequencies

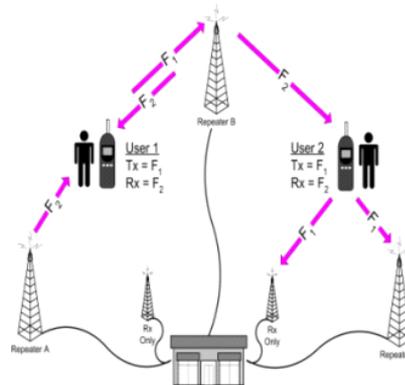
# Conventional Radio Systems - Modes



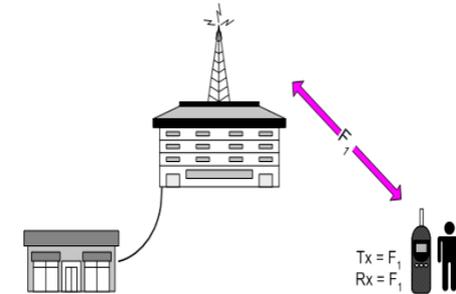
Simplex



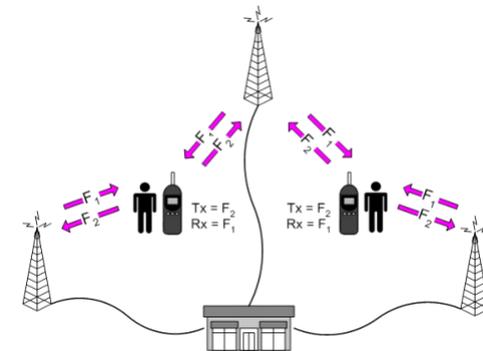
Repeater



Repeater System with Remote Receivers

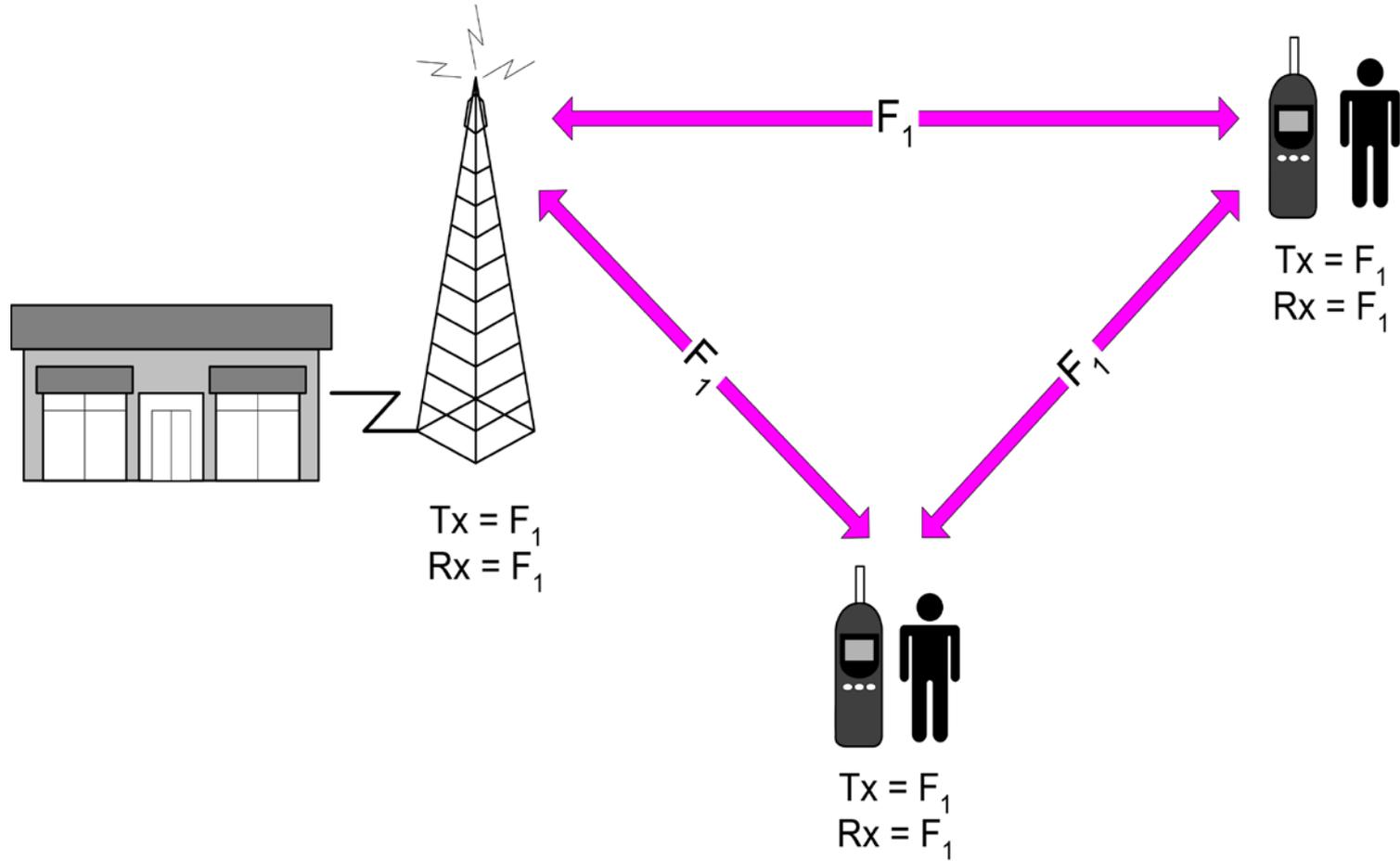


Remote Radio



Simulcast

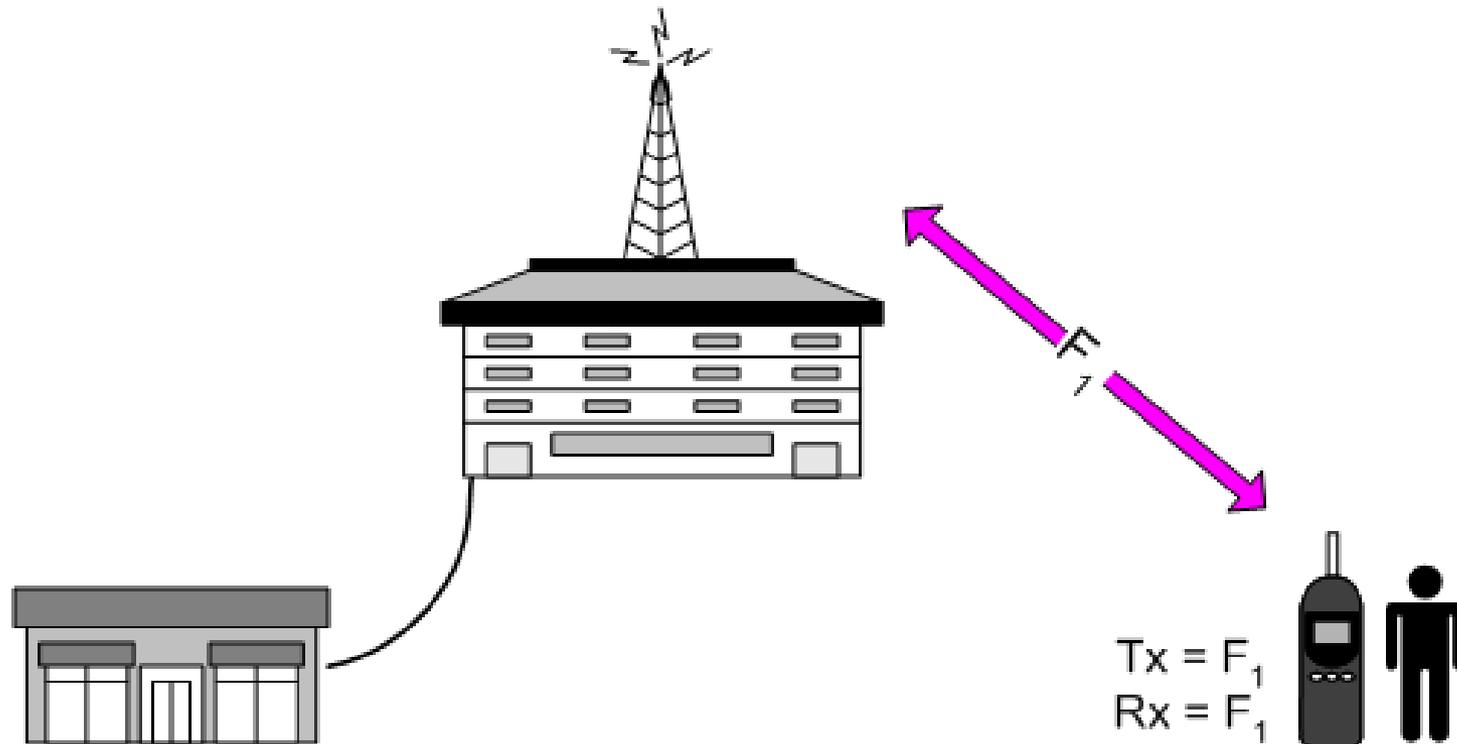
# Simplex Radio System



# Remote Base System

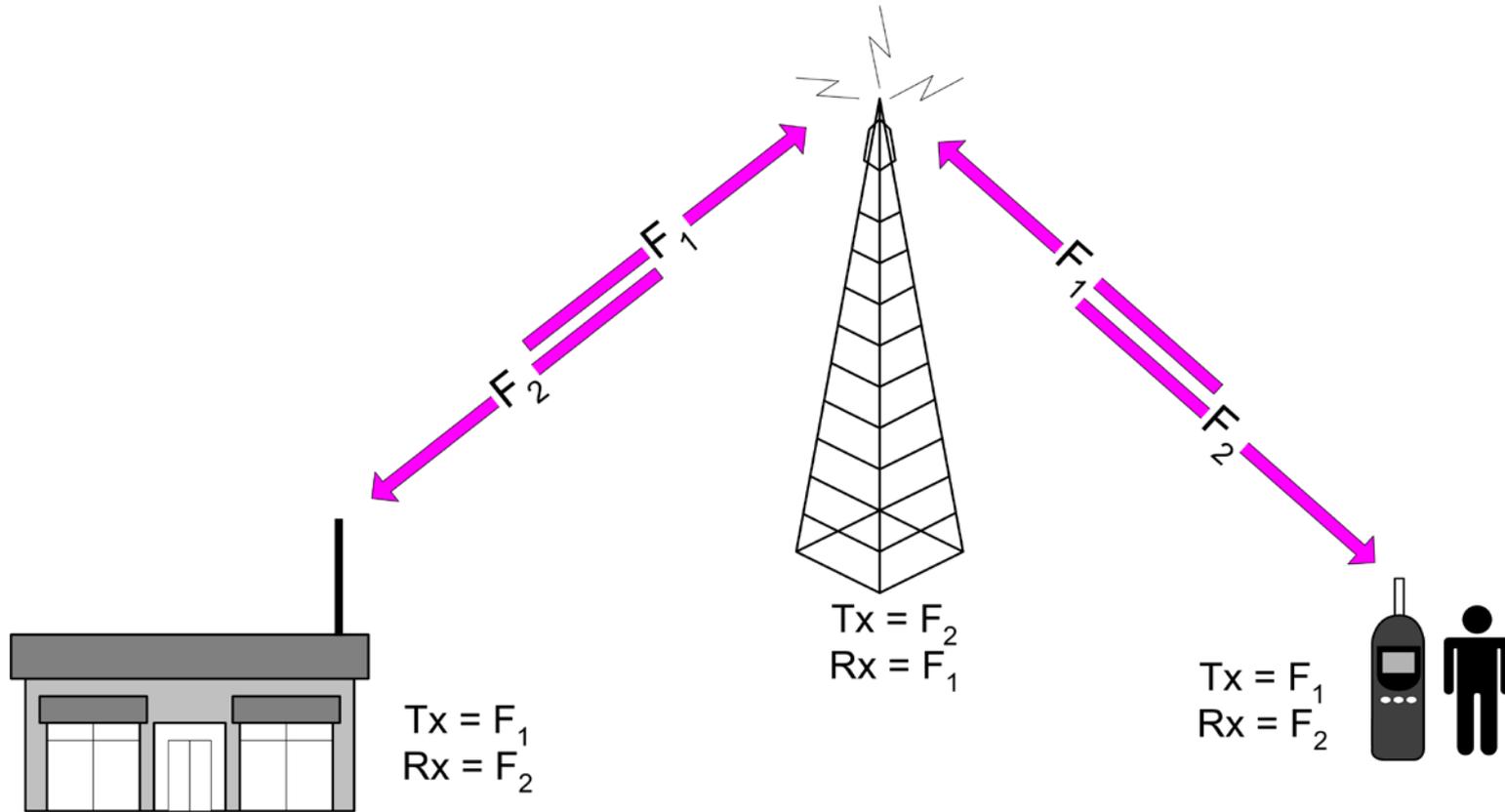
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This is the same as simplex, except the base station transmitter is on a hilltop or other high object

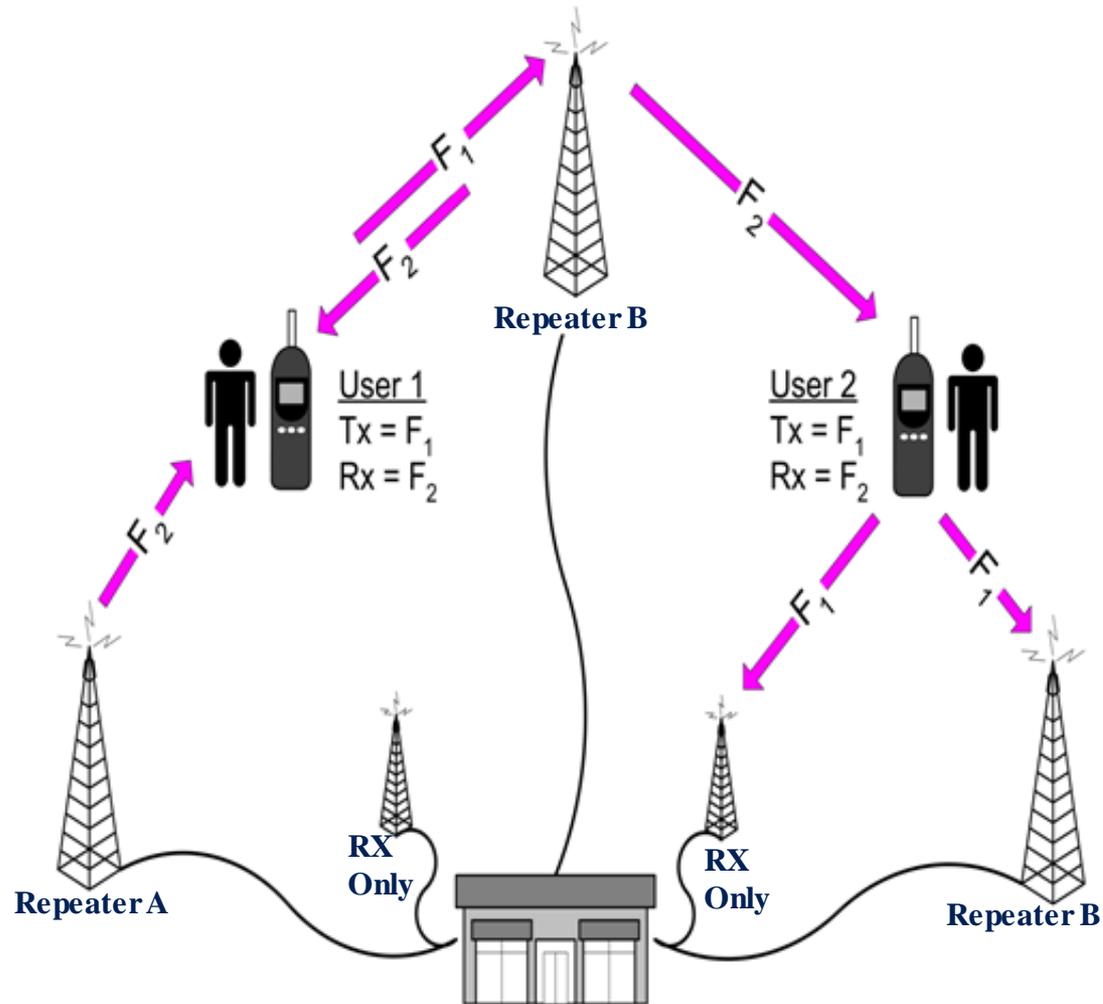


# Repeater System

Transmit and Receive on different frequencies.



# Voting/Remote Receivers



# Voting/Remote Receivers (cont'd)

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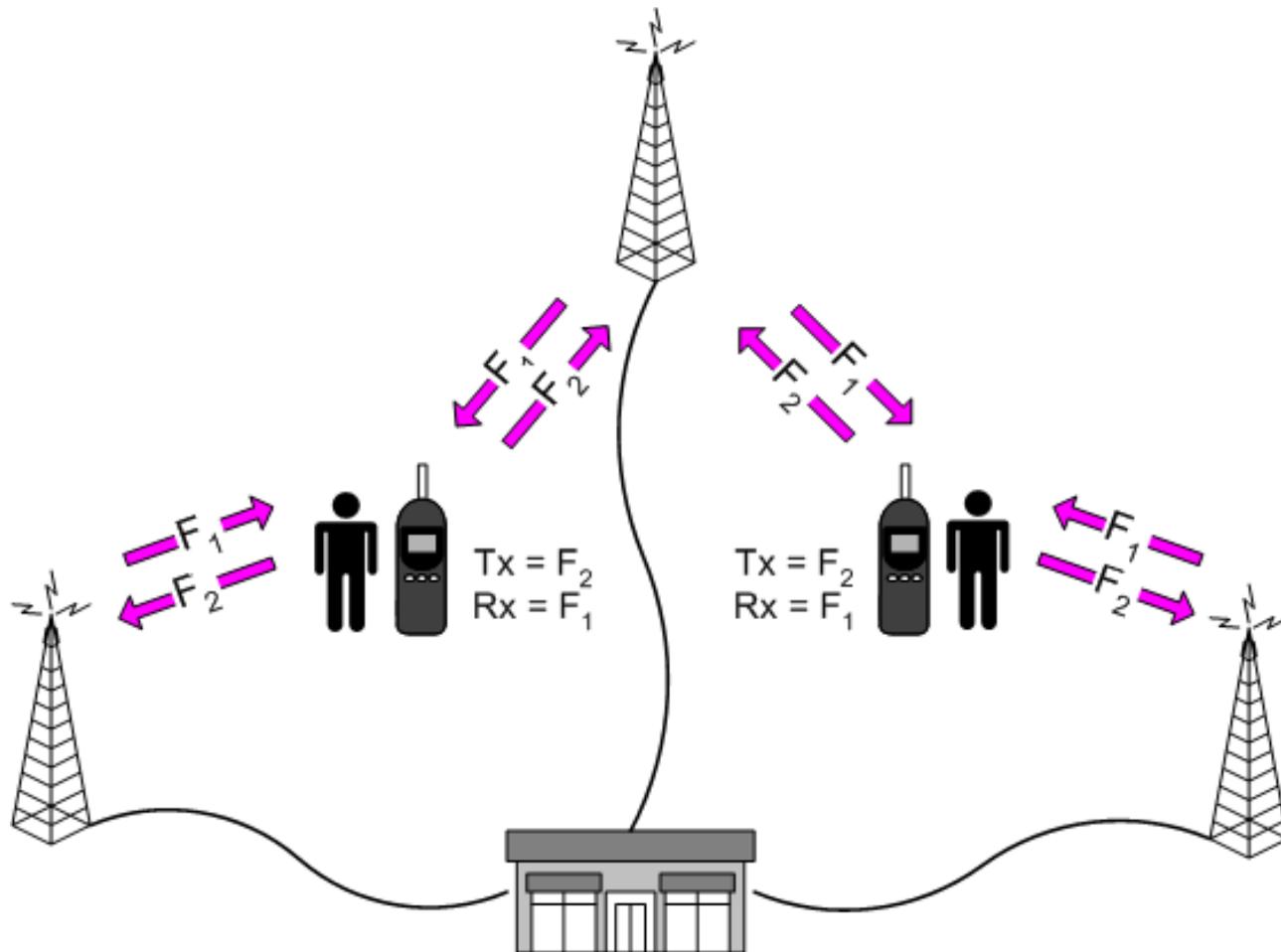
- Remote or satellite receivers are used in addition to regular repeater base station or trunk receivers to pick up relatively weak portable and mobile signals
- Audio from these receivers is routed to a central voting comparator or voter where the best received audio is selected
- The strongest signal is not always selected; that with the highest signal-to-noise ratio is typically best

# Voting/Remote Receivers (cont'd)

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- Selected audio may come from multiple receivers during a single transmission
- Some systems are configured to lock onto a single receiver, once chosen, for a transmission
- Selected audio is routed to the ultimate receiving locations, such as consoles or repeaters for retransmission

# Simulcast Radio System



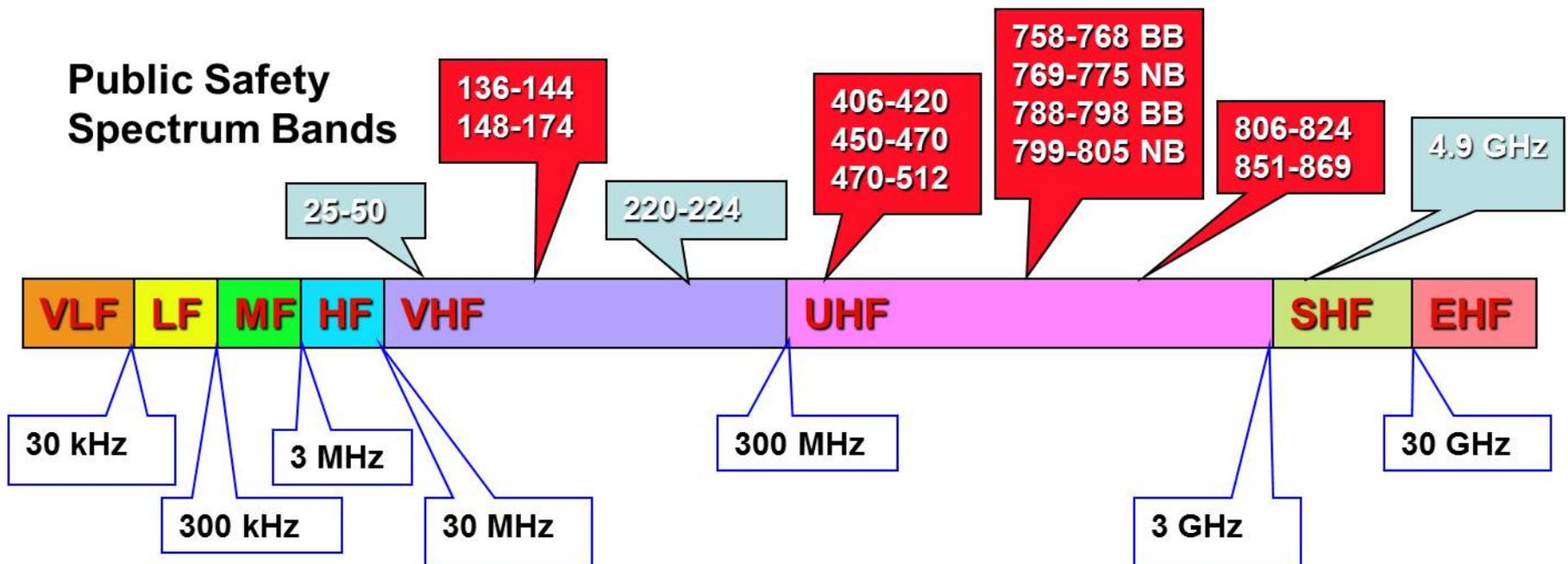
# The Radio Spectrum

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- Radio frequencies are the products of resonance or vibration
- These vibrations can be used for effective communication at a number of frequencies
- As the speed of the resonance increases, physical properties change
- Frequencies range from the audible to the production of light
- As frequencies pass above the audio range, the waves begin to travel through air and become radio frequencies

# Public Safety Spectrum Bands

- The FCC and NTIA have assigned spectrum for use by Land Mobile Radios
- Federal Communications Commission and National Telecommunications and Information Administration



# VHF Low Band

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- **Lowest effective frequency used by Public Safety**
- **30 MHz to 50 MHz**
- **Performs very well in mountainous terrain, primarily because the radio waves conform to the terrain**
- **Longer ground wave than higher bands; more range**
- **Susceptible to long distance “skip”, solar interference, and “industrial generated” noise**

# VHF High Band

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- **Widely mixed use – most commonly used public safety band**
  - **108-137 MHz – Exclusive to aviation (AM modulation)**
  - **138-144 MHz – Exclusive to Federal (primarily military)**
  - **144-148 MHz – Amateur radio**
  - **148-150 MHz – Shared mobile and satellite**
  - **150-162 MHz – State & local public and private**
  - **156-157, 161-162 MHz – Marine band**
  - **162-174 MHz – Primarily Federal**
- **Non-Federal LMR Frequency pairings are random**
- **Extensive Federal use**
- **Good medium-range propagation**

# VHF Usage

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- VHF FCC Part 90 LMR has no designated pairs
  - Inconsistent use (high side/low side) e.g.
    - 153.9275/155.0475 ; 155.0475/159.3075
  - Inconsistent TX/RX splits
    - 153.9275/154.4375; 153.7475/159.4575
  - 175 kHz minimum; the further apart the better
  - Can cause interference to other repeaters:
    - Repeater output to repeater input on same or close frequencies
  - Adjacent frequencies overlap each other

# VHF Usage (cont'd)

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- Usage
  - Analog or digital
  - Conventional or trunked
  - Repeater, base, mobile

# UHF Band

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- **Duplex use**
  - **406-420 MHz – Federal Use**
  - **420-450 MHz – Amateur radio and Federal radio-location**
  - **450-470 MHz – Non-Federal public and industrial/business**
  - **470-512 MHz – Non-Federal public safety and industrial/business - also UHF TV channels 14-20**
  - **Standard frequency pairings**

# UHF Paired Frequencies

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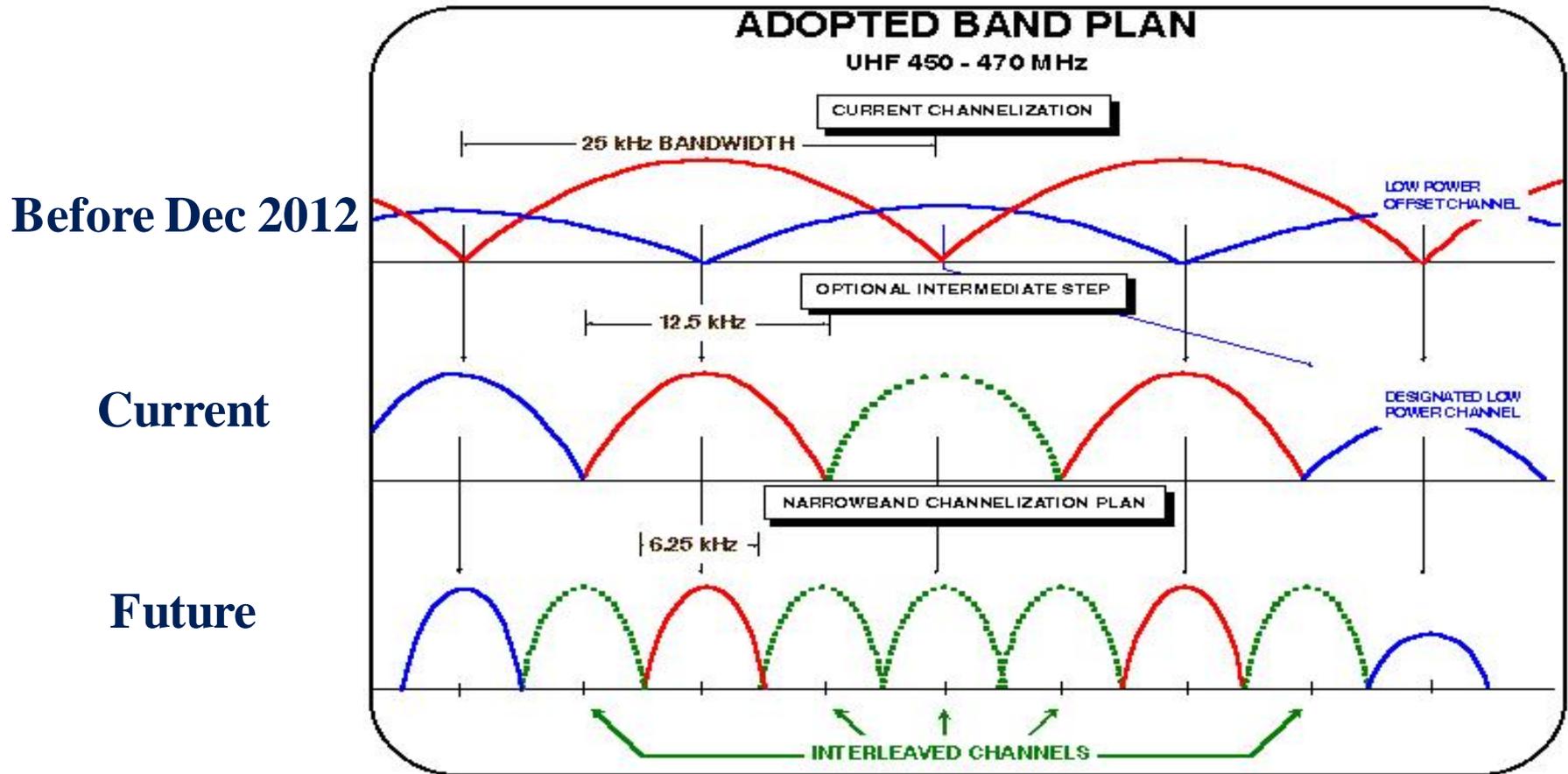
- Paired splits
  - The standard split for 406 to 420 MHz is 9 MHz
  - The standard split for 420 to 470 MHz is 5 MHz
  - The standard split for 470 to 512 MHz is 3 MHz
- Usage
  - Analog, digital or mixed mode
  - Conventional or trunked
  - Repeater, base, mobile

# Narrowband – VHF/UHF

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- **FCC Deadline – *December 31, 2012***
  - **Part 90 Land Mobile Radio Service including all public safety and business industrial land mobile radio systems (Amateur, Maritime Mobile services are except as well as paging-only channels)**
  - **VHF band 150-174 MHz and 421-512 MHz**
  - **Convert**
    - **From 25 kHz bandwidth channels to 12.5 kHz bandwidth channels**
    - **(Or equivalent voice talk paths – one per 12.5 kHz)**

# Narrowband – Adopted Band Plan



# 800 MHz

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- **Part of UHF band**
  - **806-824 MHz/851-869 MHz prior to rebanding, 806-815 MHz/851-860 after rebanding**
  - **Paired channels – 45 MHz separation**
  - **Mobile channel loading requirements trunked or conventional**

# 800 MHz (cont'd)

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- **800 MHz is split into two bands**
  - **806/851.0125 – 808/853.9875 NPSPAC managed**
  - **809/854 – 815/860 General Pool**
  - **NPSPAC channels are 25 KHz channels spaced every 12.5 KHz**
  - **NPSPAC non-P25 usage recommended deviation should not exceed 4 KHz to protect adjacent channels**
  - **8CALL/8TAC may use a 5 KHz deviation**

# 800 MHz (cont'd)

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- **Usage**
  - **Analog or digital**
    - **Not limited to P25 digital**
  - **Conventional or trunked**
  - **Repeater, base, mobile**

# 800 MHz (cont'd)

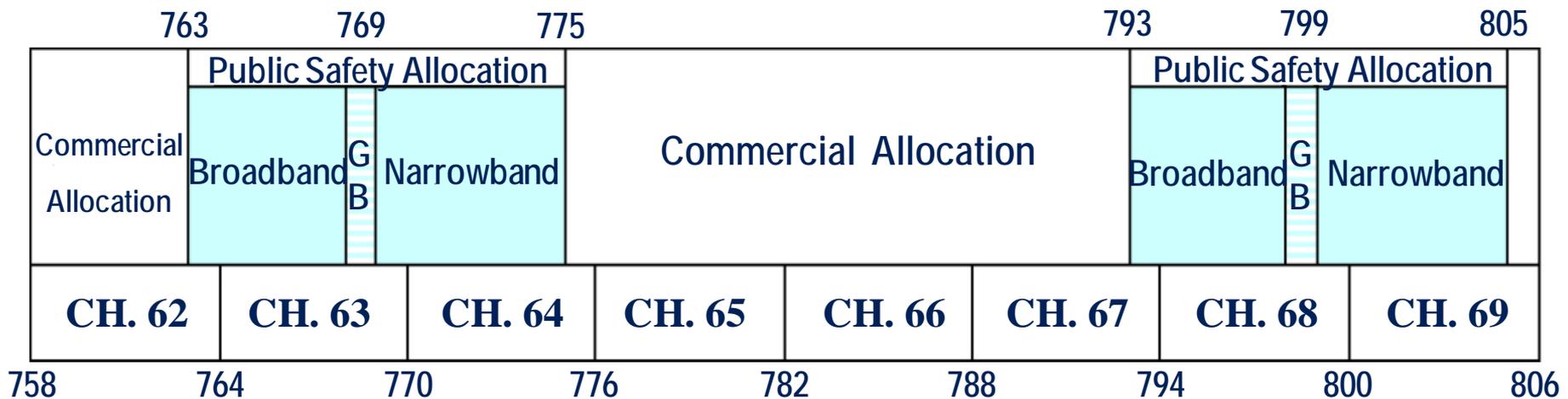
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- **5 dedicated interoperability channels (8Call/8TACs)**
- **General and Regional planning channels**
  - **Normal coordination/licensing**
- **RPC (Regional Planning Committee) channels**
  - **Pre-allocated – coordination by local RPC**
- **Rebanding (NEXTEL interference)**

# Revised 700 MHz Band Plan

- 700 MHz Band prior to its being licensed to FirstNet
  - 763-768 MHz (5 MHz for fixed base, repeater outputs)
  - 793-798 MHz (5 MHz for mobile, repeater inputs)

## Revised 700 MHz Band Plan for Public Safety Service



# 700 MHz NB

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- **700 MHz Narrowband Channels**
  - **769-775 MHz (Old TV band channels 63 and 64)**
  - **799-805 MHz (Old TV band channels 68 and 69)**
  - **All 700 assignments are narrowband or ultra-narrowband**
    - **Mandated P25 Phase I Common Air Interface (CAI) digital emissions with a few exceptions for 12 low-power analog pairs**
    - **Dedicated Interoperability channels (32 channel pairs that also provide “talk-around” capability)**

# 700 MHz NB (cont'd)

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- **6.25 kHz equivalency (Frequency-Division Multiple Access [FDMA] versus Time-Division Multiple Access [TDMA])**
  - **Temporary 12.5 kHz authorization**
- **General – RPC channels**
  - **Pre-allocated – coordination by local RPC**
- **“State” – licensed frequencies**
  - **Coordinated by State entity**

# 700 MHz NB (cont'd)

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- **700 MHz narrowband channels are managed by the 55 National Public Safety Planning Advisory Committees (NPSPAC)**
- **2 Nationwide Calling channel pairs, 26 Tactical channel pairs, 2 Data channel pairs, 2 Mobile Repeater pairs managed by State SIEC or RPC**
- **Low power analog channels have 2 watt limitation**
- **State License Channels managed by the States unless relinquished to the RPC**

# 700 MHz NB (cont'd)

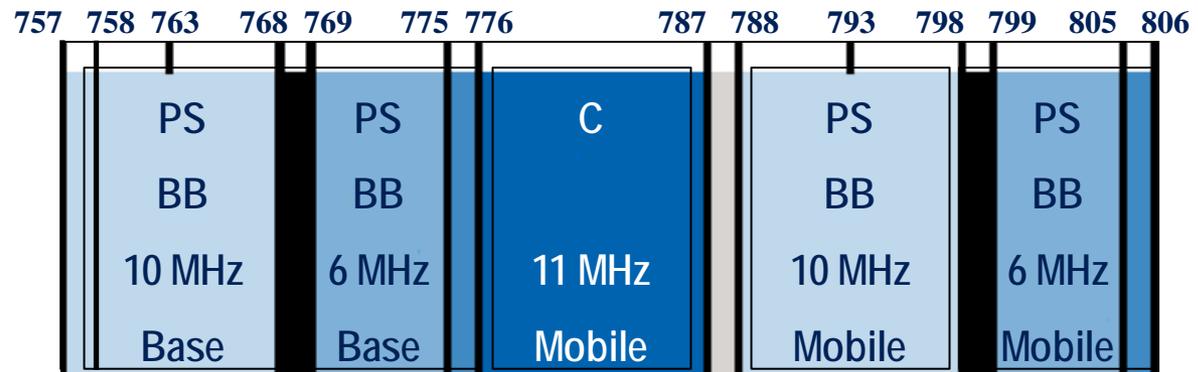
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- Usage
  - P25 digital with the exception of the low power channels
  - Conventional or trunked
  - Repeater, base, mobile

# 700 MHz FirstNet

- 700 MHz Broadband Channels (FirstNet)
  - 758-768 MHz (10 MHz for fixed base)
  - 788-798 MHz (10 MHz for mobile)

## 700 MHz PS Spectrum Layout



Guard-bands



# 4.9 GHz

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## 4.9 GHz

- **Mesh Type Networks**
- **Point-to-Point Microwave Links**

# Aviation Radio

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- **Exclusive use for aircraft**
  - 108 MHz – 137 MHz
  - 225 MHz – 380 MHz (military)
  - AM modulation
- **Extreme caution must be used in frequency use**
- **Must coordinate with Aviation management**



# Aviation Radio (cont'd)

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- With appropriate licensing, may be used by ground mobile units for air-ground communications

*Air-to-ground operations should be on public safety FM channels (per FCC rule 90.423)*



# Analog Versus Digital Radio

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- **Analog radios use Frequency Modulation (FM) for Land Mobile Radio applications**
- **Susceptible to noise and sometimes noise can override intended traffic**
- **Usually users will know there is someone calling**
- **Gradual decay of signal quality versus distance**

# Analog Versus Digital Radio (cont'd)

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- Digital radio uses a vocoder to convert human voice into digital symbols for compression purposes
- Digital users either hear clear traffic or hear nothing
  - Sharp fringe area drop-off
  - Several studies have questioned the reliability of digital in high noise environments, such as fire ground operations (IAFC report link)

<http://www.iafc.org/displaycommon.cfm?an=1&subarticlenbr=719>

**Note: Problem solved in second version of the vocoder**

- Signal blocking by unintended third party transmission in conventional digital usage



# Trunking

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- **Trunked radio systems differ from conventional**
- **Trunked systems have a number of frequencies pooled into one system**
- **Primary difference is the use of “talkgroups” instead of discrete frequencies**
- **Each transmission is between talkgroups and is moved between frequencies as frequencies are available**
  - **Dynamic frequency assignments**
  - **Channel loading is based on probability**

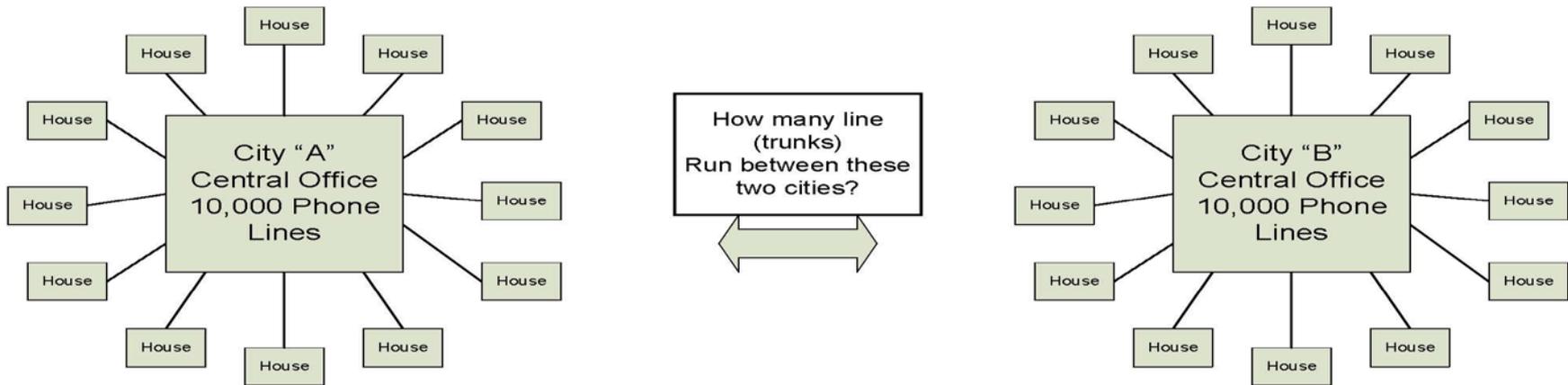
# Trunking (cont'd)

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- **When was trunking invented?**
- **Talkgroups capacity enhanced by probability of channel availability**
  - **Instantaneous capacity is limited to the actual frequency capacity**
- **Fleet mapping should include interoperability talkgroups**

# How Many Lines Run Between the 2 Cities?

- The answer is very few, possibly as few as 20. This is based upon the probability that a very small percentage of the City “A” population will want to talk to the City “B” population at the same time (Erlang Theory)
- This is the exact same theory used in Trunked radio, a large number of users sharing a small number of trunked channels, making the utilization very efficient



# How a Trunked System Differs



## Conventional System

Message on Channel 1 same frequency

Reply on Channel 1 same frequency

If the system uses a repeater, then TX and RX are different frequencies, but do not change



## Trunked System

Message on Talkgroup 1, uses frequency 1

Reply on Talkgroup 1, uses frequency 6

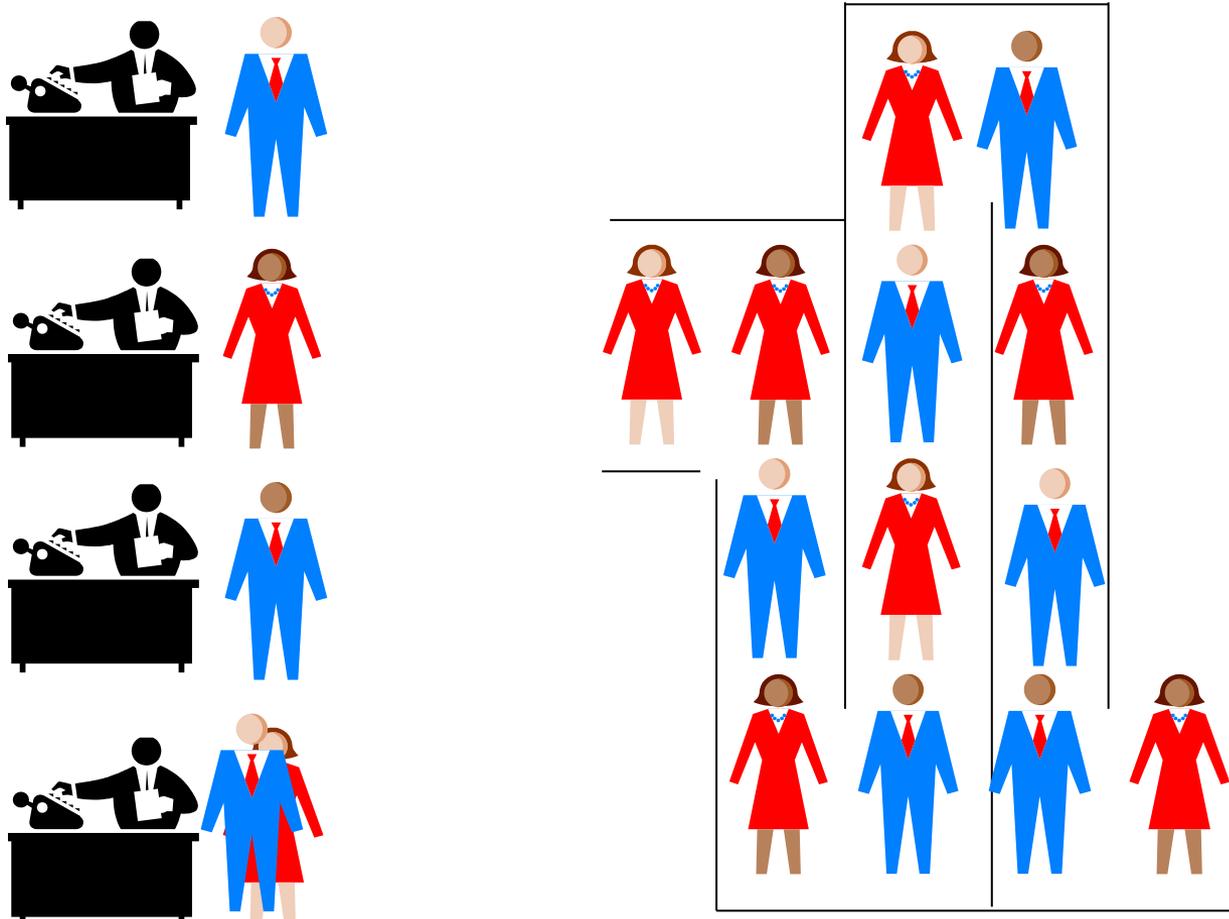
Next message on Talkgroup 1, uses frequency 3

Next reply on Talkgroup 1, uses frequency 8

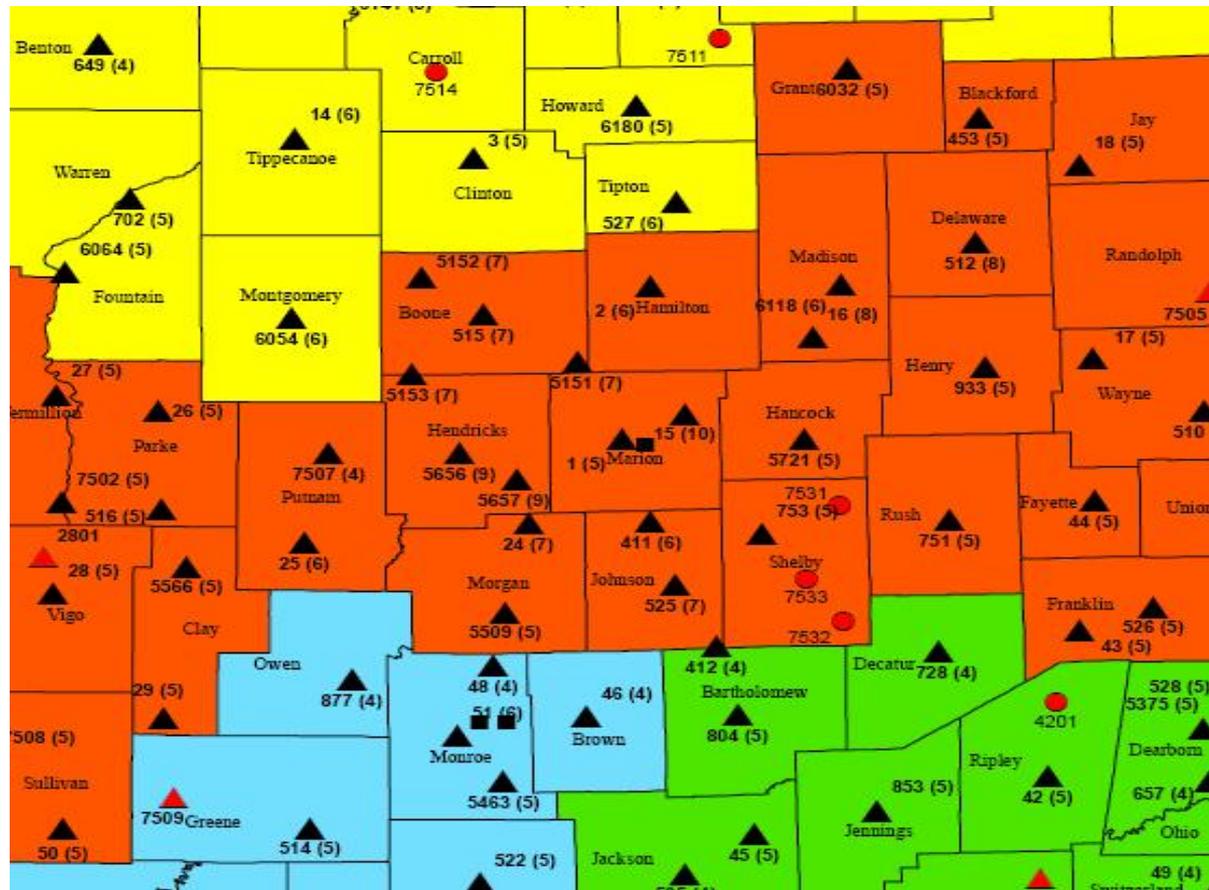
The frequencies are entirely random within the system, and dependant upon which frequencies are available at that exact moment



# Bank Teller Line



# Trunked System Capacity

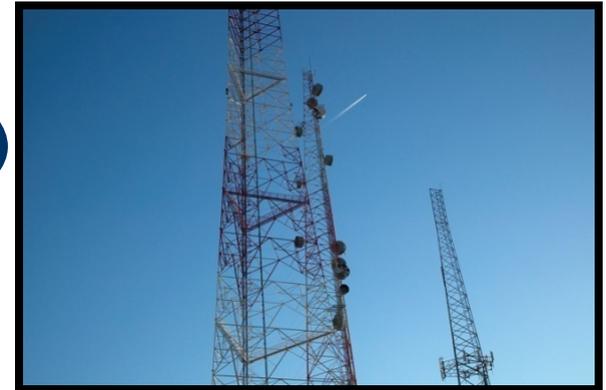


# Interference

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**This issue becomes bigger every day**

- **Mechanical interference – rusty bolts, bad grounds**
- **Broadband noise**
- **Inter-modulation (transmitter mixes)**
- **Co-channel – on frequency**
- **Adjacent channel – near frequency**
  - **Try to identify the offending station by monitoring; listen for call signs or geographical information to assist in locating the station**



**Be aggressive in eliminating interference. It can get worse at exactly the wrong time and compromise operations**

# Interference (cont'd)

- First choice may be to contact the agency or licensee directly, and try to find out if they changed something recently, such as antennas or power output
- Most public safety agencies will cooperate to rectify interference
- The FCC may also be of assistance finding the offending station
- Make contact; operator information can be obtained via the FCC Universal Licensing System (ULS) database  
<http://wireless.fcc.gov/uls/>



# Willful Interference

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- This is a criminal act; involve the FCC and law enforcement early in the process
- Willful interference can be a more pervasive problem, depending upon the motive of the perpetrator and their skill level
- The station may be moved to prevent easy detection
- They may or may not identify themselves
- The FCC, radio shops, and amateur radio operators may all be of assistance solving this problem

# Tone-Coded Squelch

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- **Continuous Tone-Coded Squelch System**
  - Analog sub-audible frequency tone continuously transmitted
  - 42 standard tones ranging from 67.0 Hz to 254.1 Hz
  - Provides protection from errant on-frequency RF signals
    - Radio will not open audio without the presence of the required tone
    - Particularly required for repeater operations to control repeat function
- **DCS – Digital-Coded Squelch**
  - Equivalent to analog CTCSS but uses low speed data at 134.4 bits per second – over 100 codes
  - The P25 Network Access Code (NAC) performs a similar function to CTCSS

# Radio Programming

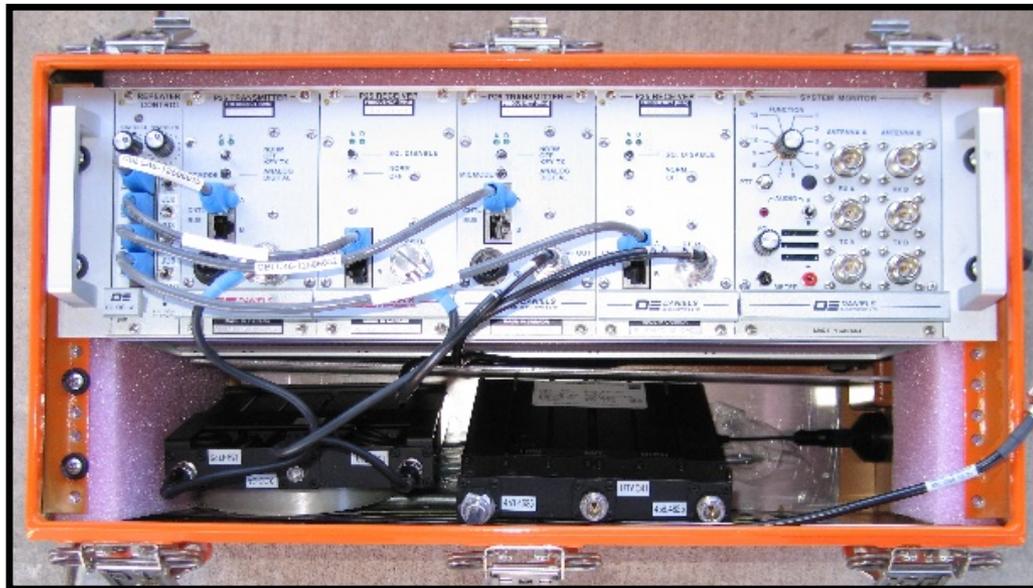
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- Laptop – Radio Interface Box (RIB)
- Cloning cables
- Logistics considerations
- De-programming radio



# Portable Repeaters

- **Transportable**
  - **Repeat mode**
  - **Relay mode**



# NIFOG – Resource

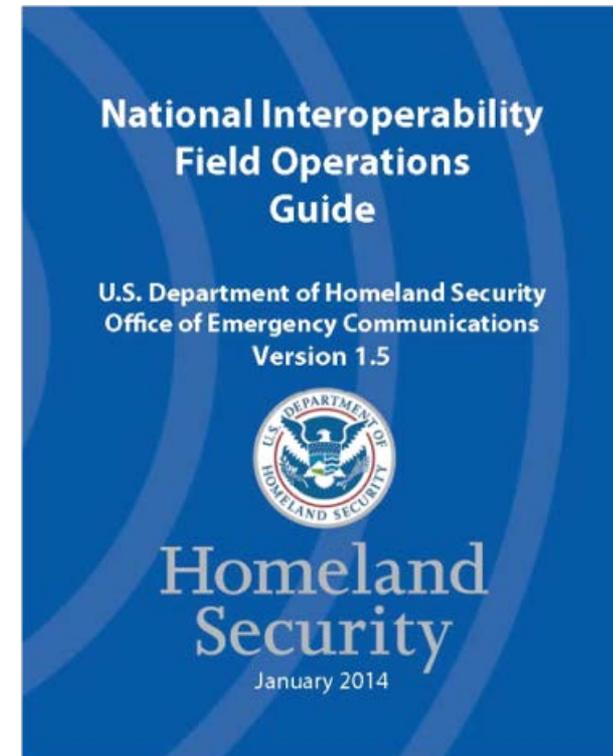
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## National Interoperability Field Operations Guide (NIFOG ) - reference guide to

- Rules and regulations
- Interoperability channels
- Operational contact info
- Technical information

## NIFOG is NOT

- A teaching guide
- A license to transmit
- An Incident Radio Communications Plan



# NIFOG – Resource (cont'd)

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## Rules and Regulations

- **Different rules for state, local, tribal, territorial governments (FCC) vs. Federal Government (NTIA)**
- **Some channels are authorized by rule, some require individual licensing**

# NIFOG – Resource (cont'd)

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## Interoperability Channels

- **National Interoperability Channels (FCC rules)**
- **Federal Interoperability Channels (NTIA rules)**
- **Mutual Aid Channels – require FCC License or NTIA Authorization**
- **Conditions on license can limit availability, e.g. near Canadian border**

# NIFOG – Resource (cont'd)

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## Operational Info

- **National-level Operations Centers**
- **Emergency Support Functions (ESF) at FEMA HQ**
- **FEMA Regional Offices**
- **USCG Rescue Coordination Centers**

# NIFOG – Resource (cont'd)

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## Technical Info

- **CTCSS, DCS, NAC**
- **Connectors: DB25, DE9, RJ45**
- **Non-routable IP Address Ranges**
- **Telco Wiring Color Codes**
- **Satellite Phone Dialing, WPS, GETS**
- **Aviation and Maritime Channels**
- **State Government (Part 90) HF Channels**

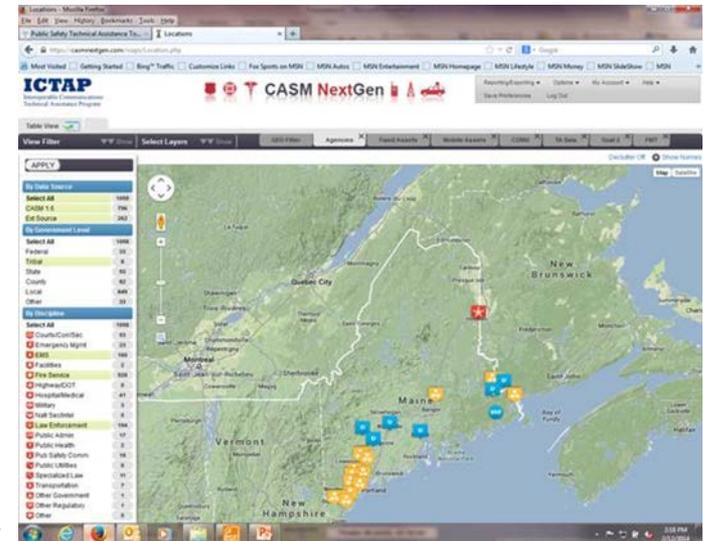
# NIFOG – Resource (cont'd)

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- Downloadable versions and hard-copy request form are in the “NIFOG Info” section at <http://publicsafetytools.info>
- Downloadable file “Programming Template” – ICS-217A of all interop channels

# Other Interoperability Planning Tools

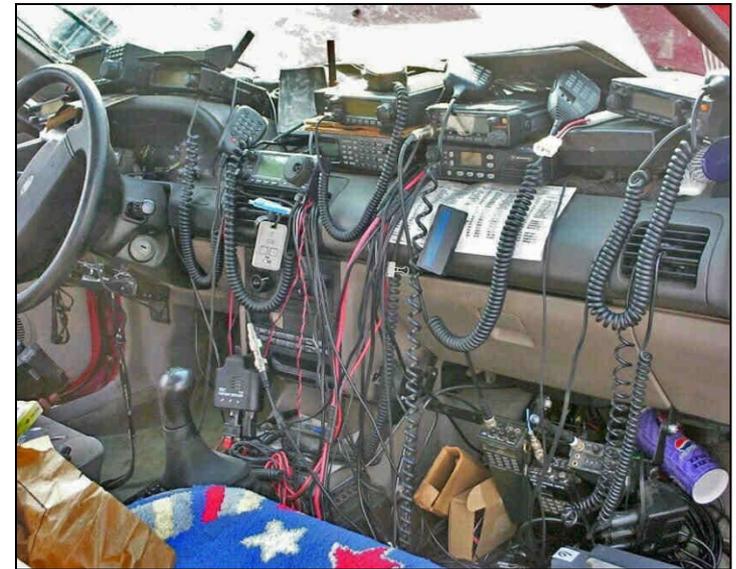
- **Communication Assets Survey and Mapping Tool Next Generation (CASM NextGen)**
  - Designed as a strategic planning tool, but has tactical use and utility
  - Password access is granted through a local area manager
- **Tactical Interoperable Communications Plan (TICP)**
- **Other regional plans and field guides**



# Communications Interoperability

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- One of the most misunderstood terms
- Does not mean everyone is speaking to everyone else
- Must be carefully managed to avoid mass confusion
- Extremely easy to overload a system



# Interoperability Channels

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- **National Interoperability Channels:**
  - **VHF: 1 Calling, 4 Tactical, and 6 Tactical Repeater**
    - **Calling: VCALL10**
    - **Tactical: VTAC11, VTAC12, VTAC13, VTAC14**
    - **Tactical Repeater: VTAC33, VTAC34, VTAC35**
    - **Tactical Repeater: VTAC36, VTAC37, VTAC38**
  - **UHF: 1 Calling and 3 Tactical**
    - **Calling: UCALL40**
    - **Tactical: UTAC41, UTAC42, UTAC43**

# Interoperability Channels (cont'd)

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- **National Interoperability Channels:**
  - **800 MHz: 1 Calling and 4 Tactical**
    - **Calling: 8CALL90**
    - **Tactical: 8TAC91, 8TAC92, 8TAC93,**
  - **700 MHz band: 32 interop repeater pairs listed in the NIFOG**

**Note: A “D” appended to the channel name denotes direct / Talk-around channel**

# Local Use Agreements FCC rule 90.421

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- These are agreements for one agency to use another agency's system for a specific purpose
- These agreements are limited, are not in lieu of licensing, and are usually associated with mutual aid, use of gateways, or other special uses



# Special Temporary Authorizations

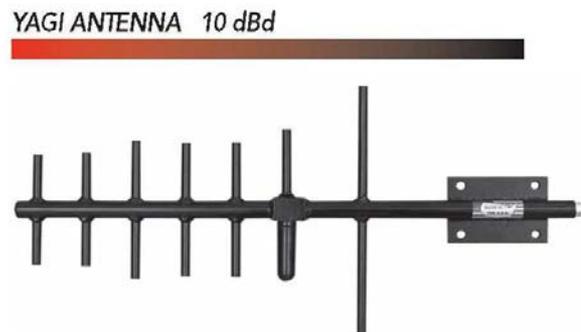
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- It is possible to receive a Special Temporary Authorization to use a frequency
- These are obtained from the FCC licensees
- This is not to be used in lieu of normal licensing procedures
- More information at:  
<http://www.fcc.gov/pshs/services/sta.html>

# RF Exposure

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- RF Exposure can harm human tissue
- Typically not an issue with the relatively low power and relatively low frequency equipment used in Public Safety
- RF hazards analysis required for FCC license applications and OSHA workplace safety
- Can be an issue with high-power base stations



# RF Exposure (cont'd)

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- Easiest protection is distance; RF exposure drops off very quickly
- High power broadcast (AM, FM, or TV) and radar antennas are the most hazardous
- If in doubt, get an engineer to evaluate your situation



*Exercise 5*

# *Frequency Usage*

Unit 5:

Frequency Regulations and Usage

Visual 5-64

# Objectives Review

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- 1. What are the factors influencing frequency coordination efforts?*
- 2. Describe local use agreements and special temporary authorizations.*
- 3. What are considerations in recognizing and preventing interference?*
- 4. What are the modes of typical types of radio systems in use today?*
- 5. Describe the Public Safety spectrum bands.*
- 6. Identify issues related to RF safety.*

*Questions?*