All-Hazards Communications Technician (COMT)

Training Course

Unit 4: Radio Systems Technology Awareness

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Unit 4: Objectives

- Explain the operational capabilities of the various types of radio systems the COMT may encounter
- Understand the appropriate applications of the various technology resources
- Understand the technical and physical principles behind the appropriate technologies

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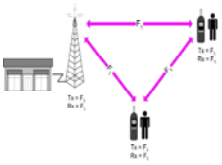
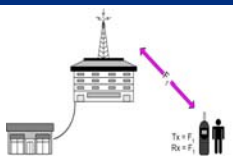
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

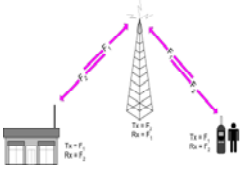
Radio System Designs



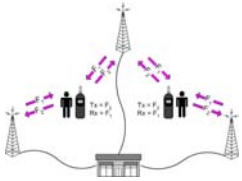
Simplex



Remote Radio

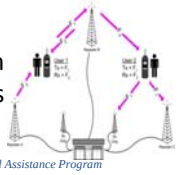


Repeater



Simulcast

Repeater System with Remote Receivers



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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Radio System Terminology

Frequency

- A discrete piece of radio spectrum.
- Land mobile radio frequencies are written as follows:
  - **155.4750W** MHz
  - Written with four digits to the right of the decimal
  - Shown with a "**W**" or an "**N**"
    - Indicate wideband or narrowband (until 2013)

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Radio System Terminology

Channel

- A channel is a “talk path”
  - May represent a single frequency, two frequencies, or a virtual channel called a “talk group”

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Radio System Terminology (Cont)

Simplex

- Uses one frequency for both Transmit and Receive on a given channel
  - Pressing Push-To-Talk disables the receiver and activates Transmit function

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Radio System Terminology (Cont)

Full Duplex

- Uses two frequencies for talk path or channel at the same time
  - Both radio ends transmit and receive simultaneously, allowing both units to talk and hear at the same instant (used on telephone and cell phones - not typical in Land Mobile Radio [LMR] systems)

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Radio System Terminology (Cont)

Half Duplex

- Also uses two frequencies for talk path, but only one at a time
  - Mobile Unit - Pressing Push-To-Talk disables the receiver and activates Transmit function on frequency F1 of the pair
  - Repeater - Detects mobile unit on frequency F1, activates transmitter (simultaneous with Receive) and repeats the audio on frequency F2

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Radio System Terminology (Cont)

Half Duplex (Cont)

- Other mobile units detect and listen to transmitting mobile unit via repeated frequency F2
- Typical of LMR repeated systems (which includes trunked radio systems)

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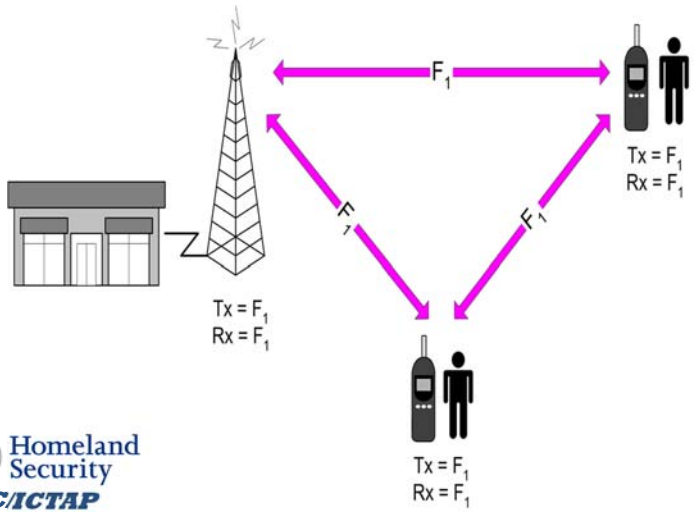
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Simplex Radio System



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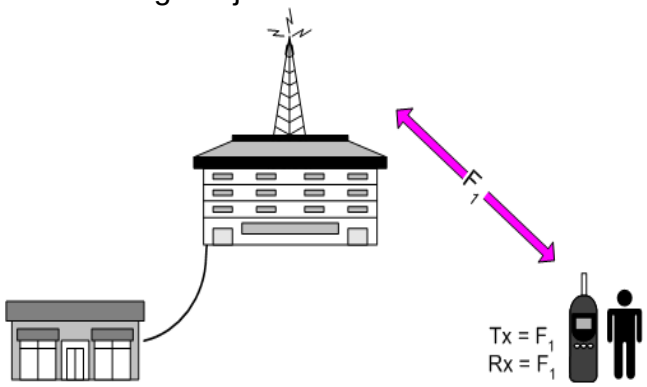
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Remote Base System

This is the same as Simplex, except the transmitter is on a hilltop or other high object



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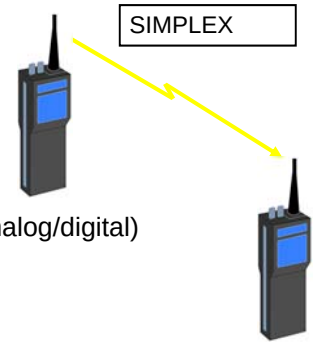
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Simplex

- Advantages:
  - Simple to implement – cost-efficient
  - Subscriber to subscriber(s)
  - Direct mode communication
- Limitations:
  - Range limited to immediate area
  - Frequency-specific
  - Requires compatible technology (analog/digital)
  - Pre-planning required
- Best applications:
  - Localized events
  - Tactical incident communications



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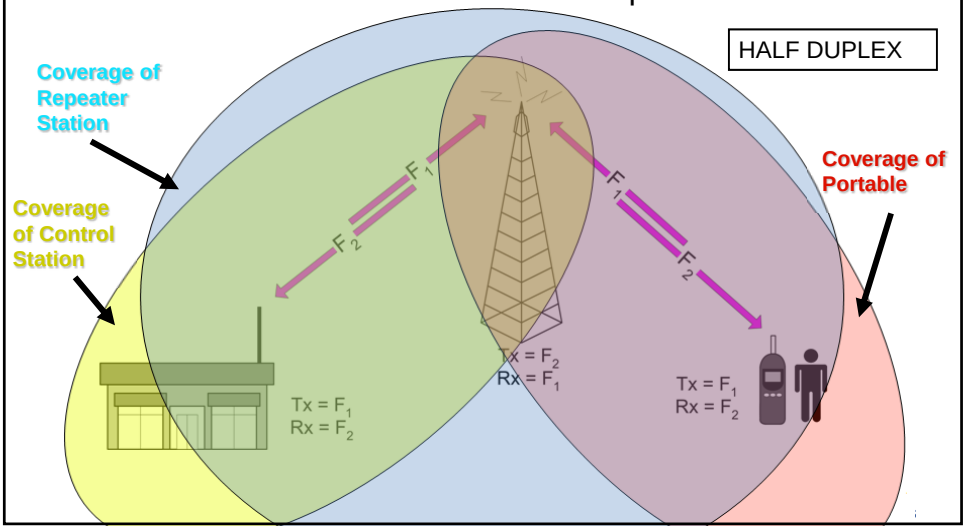
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

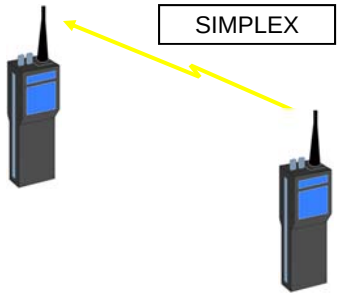
Repeater Systems

Transmit and Receive on different frequencies



Talkaround

- Method:
  - Multiple radios talk directly to each other in conventional mode using compatible radios on the repeater's TX channel (F2) - bypassing infrastructure requirements
- Advantage:
  - Low cost to setup
  - Simple to initiate calls



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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Talkaround (Cont)

- Disadvantage:
  - Very limited range
  - Limited advanced features available to users
  - Requires compatible technology/frequency band for subscribers
  - Might not be monitored by dispatch (and logging recorders)

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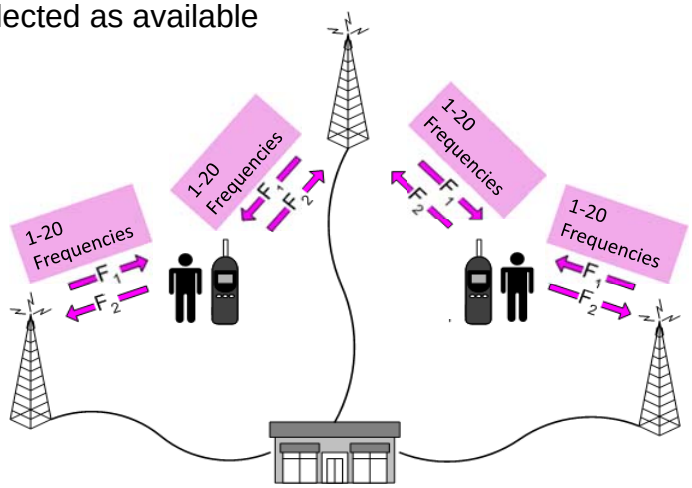
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Trunked Radio System

Transmit and Receive on many frequencies randomly selected as available



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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Trunking

- Trunked radio systems differ from conventional in that they are infrastructure dependent.
- Trunked systems have a number of frequencies pooled into one system
- Primary difference is the use of “talk-groups” instead of discrete frequencies

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Trunking (Cont)

- Each transmission is between talk groups and is moved between frequencies as frequencies are available
  - Dynamic frequency assignments
- Talkgroups capacity enhanced by probability of channel availability
  - Instantaneous capacity is limited to the actual frequency capacity
- Fleet mapping should include interoperability talk-groups

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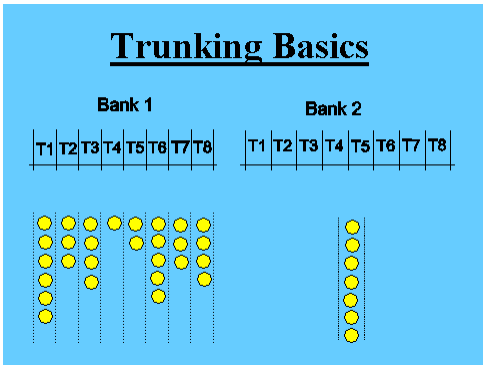
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Trunking (Cont)

- Bank 1 represents a system where users remained in line for a specific teller
- Bank 2 represents a trunked environment where the users are not waiting for a specific teller and use the first one that becomes available



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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Trunking (Cont)

- Spreads workload evenly across all tellers increasing efficiency
- The number of frequencies pooled determines the capacity of the system

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

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

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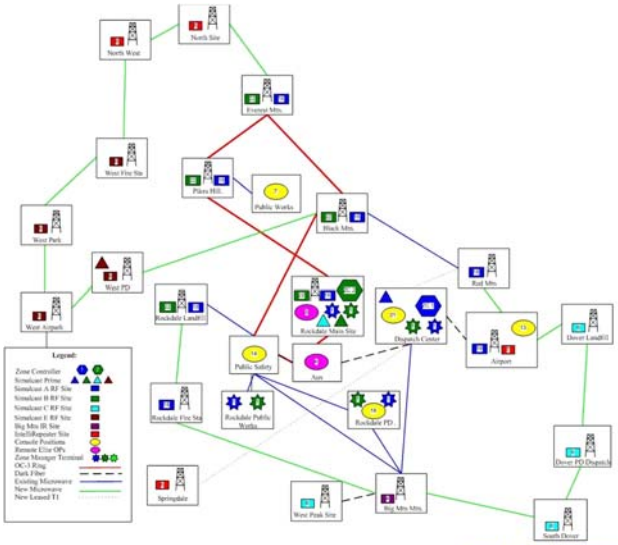
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Trunked Radio System



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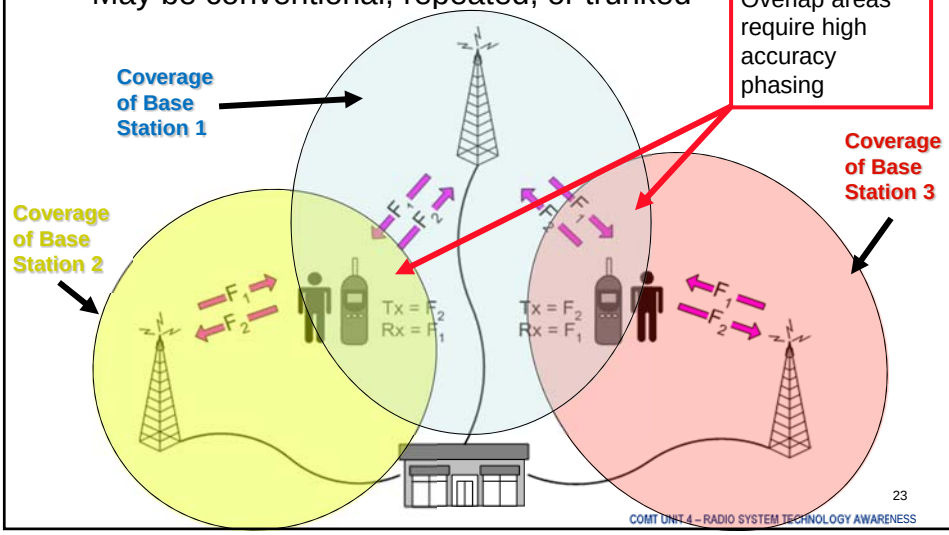
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Simulcast Radio System

May be conventional, repeated, or trunked

Overlap areas require high accuracy phasing



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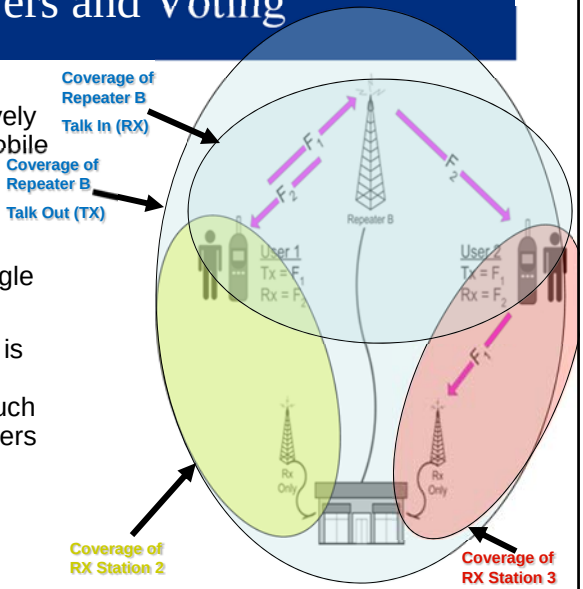
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Remote Receivers and Voting

- Remote receivers are used to pick up relatively weak portable and mobile signals
- Selected audio may come from multiple receivers during a single transmission
- Selected (best) audio is routed to the ultimate receiving locations, such as consoles or repeaters for retransmission



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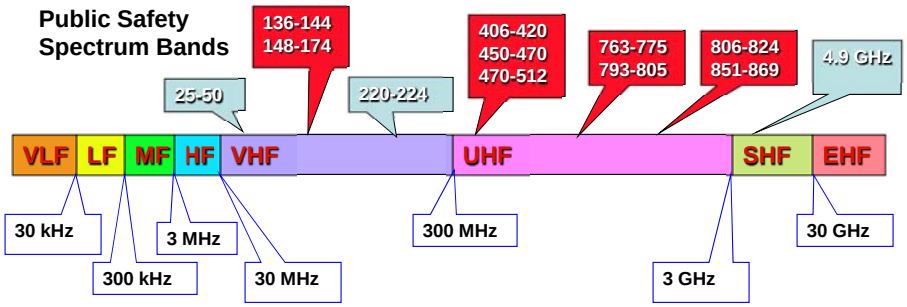
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Public Safety Spectrum Bands

The FCC and NTIA* have set aside spectrum for use by Land Mobile Radios



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*Federal Communications Commission (FCC) and National Telecommunications and Information Administration (NTIA)

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

VHF Low Band

- 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 well
- Susceptible to long distance “skip”, solar interference, and “industrially generated” noise

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

VHF High Band

- Widely mixed use – most commonly used public safety band
  - 108-136 MHz – Exclusive to aviation (AM modulation)
  - 138-144 MHz – Exclusive Federal (military)
  - 144-148 MHz – Amateur radio
  - 148-150 MHz – Shared mobile and satellite
  - 150-162 MHz – Non-Federal public and private
  - 156-174 MHz – Marine band
  - 162-174 MHz – Primarily Federal
- Frequency pairings are random
- Extensive Federal use
- Good long-range propagation

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

UHF Band

- Duplex use
  - 406-420 MHz – Primarily Federal
  - 420-450 MHz – Amateur radio and radiolocation
  - 450-470 MHz – Non-Federal public and private
  - 470-512 MHz – Non-Federal public and private (T-band)
    - Standard frequency pairings

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

UHF Paired Frequencies

- 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
- VHF has no designated pairs
  - Inconsistent use (high side/low side)
  - Inconsistent TX/RX splits
    - 175 kHz minimum

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Narrowband – VHF/UHF

- Federal Communications Commission (FCC) Deadline – ***December 31, 2012***
  - 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)

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Narrowband – VHF/UHF (Cont)

- Radios purchased in last 10 years are narrowband capable
  - Check specific models for full compliance on all available channels
  - Regional coordination and planning is needed for transition
  - Includes designated mutual aid channels
  - Link for the IAFC/IMSA Narrow Banding Guide http://npstc.org/documents/NarrowbandingV2R2.pdf

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800 MHz

- Upper part of UHF band
  - 800 MHz band
    - 806-824 MHz/851-869 MHz
      - Paired channels – 45 MHz
    - Trunked and conventional
      - Trunking requirements for certain capacity limits
    - 5 dedicated interoperability channels
    - General channels
      - Normal coordination/licensing
    - RPC (Regional Planning Committee) channels
      - Pre-allocated – coordination by local RPC
    - Rebanding (NEXTEL interference)

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

700 MHz

- 700 MHz
  - 763-775 MHz (Old TV band channels 62 and 63)
  - 793-805 MHz (Old TV band channels 68 and 69)
  - All 700 assignments are narrowband
    - Mandated digital emissions
    - Dedicated Interoperability channels
      - Mandated P25 Common Air Interface (CAI)

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

700 MHz (Cont)

- 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

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Aviation Radio

- Exclusive use for aircraft
  - 108 MHz – 136 MHz
  - 225 MHZ – 380 MHz (military)
  - AM modulation
- Extreme caution must be used in frequency use. Must coordinate with Aviation management.

Air-to-ground operations should be on public safety FM channels

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Analog Radio

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

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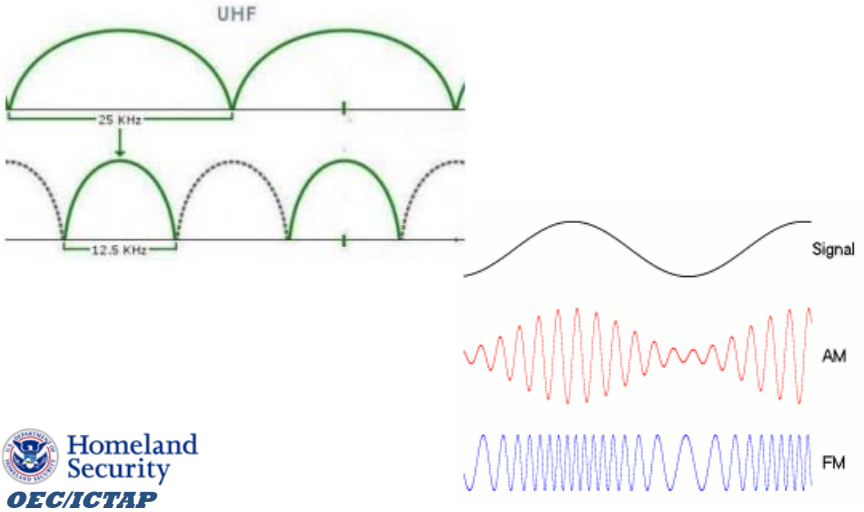
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Analog Radio



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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

APCO P25

- P25 developed to create an open standard for all manufacturers of subscriber equipment and systems.
- Intended to allow multiple manufacturers subscriber equipment to operate on any P25 system
- Intended to create competition that would result in competitive pricing
- Standard has provisions for proprietary functions.
- Common Air Interface-CAI
- The P25 Standard can be viewed at: http://www.project25.org/home

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

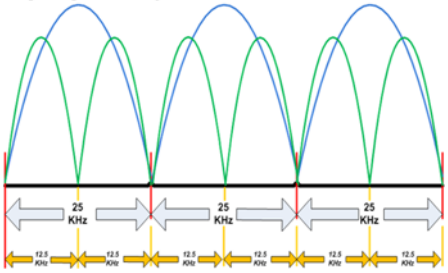
Digital Radio

Development of digital radios were seen as an advancement to:

- Provide users with more intelligible audio.
- Add additional features without a degradation of performance.
- Provide a pathway to narrower bandwidths

Multiple Manufacturers created proprietary formats

- EDACS, iDEN, Smartzone/ Smartnet, OpenSky



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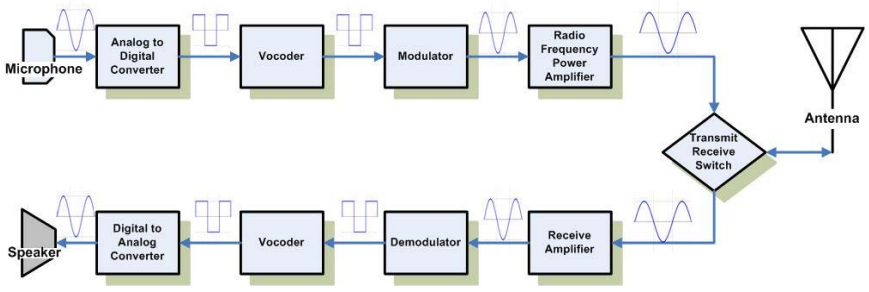
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Digital Radio



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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Analog – Digital Comparison

	Analog	Digital
Signal Weakening	Gradual fading until complete loss of signal	Clear until BER rises where digital artifact occurs, then abrupt loss of signal
High Noise Environment	Receiving radio hears transmissions with high noise.	Receiving radio may experience digital artifact to the point where it is unintelligible.
Simultaneous PTT	Receiving radios can still recognize some transmissions are occurring (Heterodyning).	Depending on signal levels the BER may rise to the point where it quiets a receiver.
Battery Life (Portables)	Battery life usually better.	Battery is sometimes less due to microprocessor requirements.

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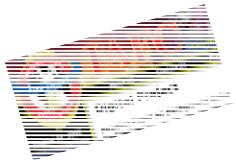
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Digital Radio Studies

- Several studies have questioned the reliability of digital in high-noise environments, such as fireground operations
- NTIA Technical Report, TR 08-453, “Intelligibility of Selected Radio Systems in the Presence of Fireground Noise: Test Plan and Results”
  - http://www.its.bldrdoc.gov/publications/2490.aspx
- IAFC report link
  - http://www.iafc.org/files/commComm_Narrowbanding.pdf



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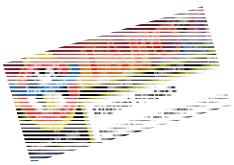
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Digital Radio Studies (Cont)

- Simultaneous Keying of Transmitters (Simplex)
  - Radio 1 Transmitting
  - Radio 2 Receiving
  - Radio 3 Keys up and transmits while Radio 2 is receiving.
  - If all radios are equidistant Radio 2 will go quiet due to high Bit Error Rate



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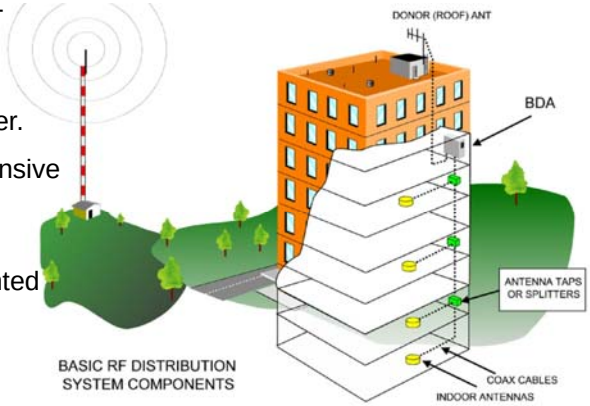
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Trunking Bi-Directional Amplifiers (BDA)

- Installed to provide In-Building coverage
- BDA's Installed in buildings require power.
- Sometimes have extensive cabling systems and antenna arrays.
- Can retransmit unwanted signals
- Must be maintained



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NPSTC (National Public Safety Telecommunications Committee) In-Building Best Practices for In-Building Communications

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Interference

- This issue becomes bigger every day
  - Mechanical interference – rusty bolts, bad grounds
  - Broadband noise
  - Intermodulation (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

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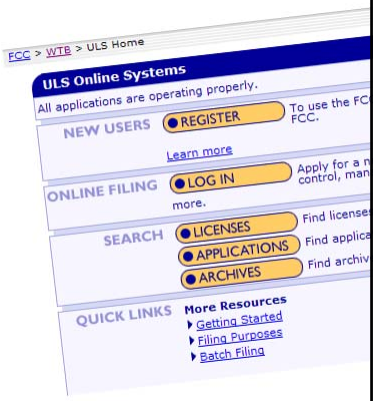
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Interference (Cont)

- First choice may be to contact the agency directly, and try to find out if they changed something recently, such as antennas or power output
- Most public safety agencies will cooperate in trying to rectify interference



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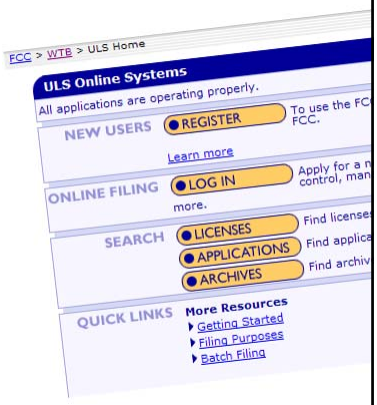
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Interference (Cont)

- 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/index.htm?job=home



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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Willful Interference

- This is a criminal act; involve the FCC and law enforcement early on 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

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Willful Interference (Cont)

- The FCC, radios shops, and amateur radio operators may all be of assistance solving this problem
- Trunked systems can be compromised by jamming the control channel. This disables all users in range of the jammer by denying access to the control channel. Willful interference is sometimes caused by jammer operations intended to deny phone services in restaurants and movie theatres.

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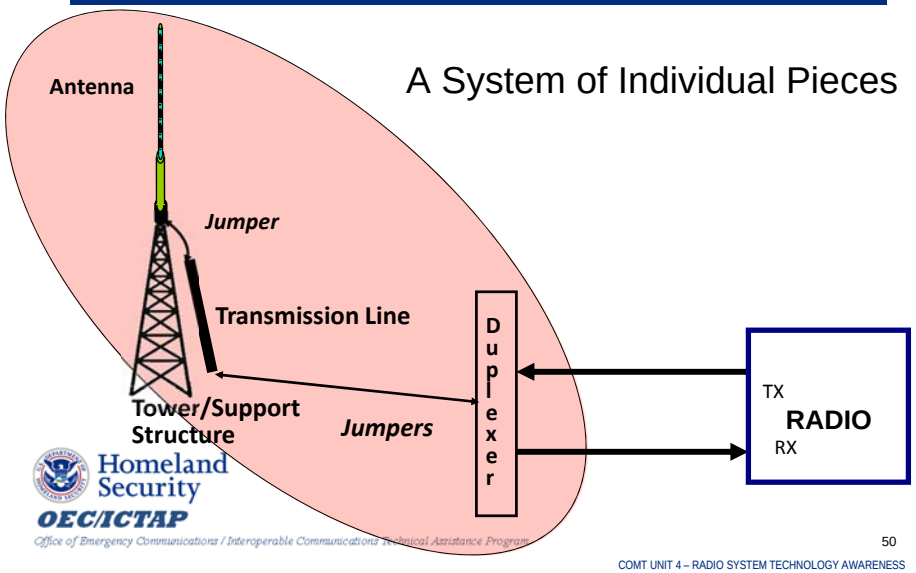
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Antenna System Components



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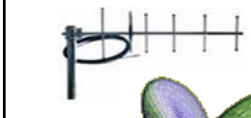
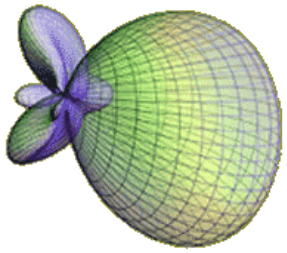
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Antennas

Directional



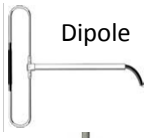


Directional Pattern

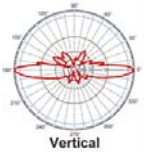
(3D view)

Panel
Directional

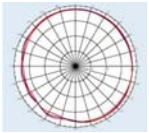
Omni – Non-Directional



Dipole



Vertical (side view)



Horizontal (top view)

Vertical
Omni

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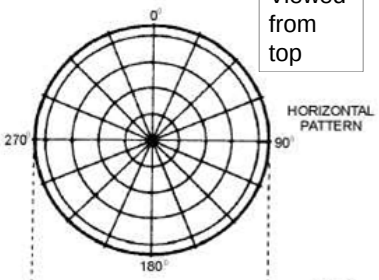
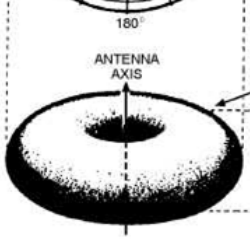
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Antenna Gain – Omni Direction

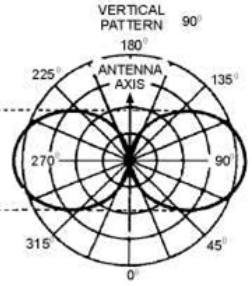
Viewed from top



- Theoretical antennas (“isotropic”) radiate power in all directions equally (perfectly round bubble)
- Most measurements are in reference to a “half-wave” center-fed dipole antenna
- The re-direction of radiation from undesired directions to desired directions results in “gain”
- Two-way radio antennas are typically “vertically polarized”



Half-Wave Dipole Antenna



Viewed from side

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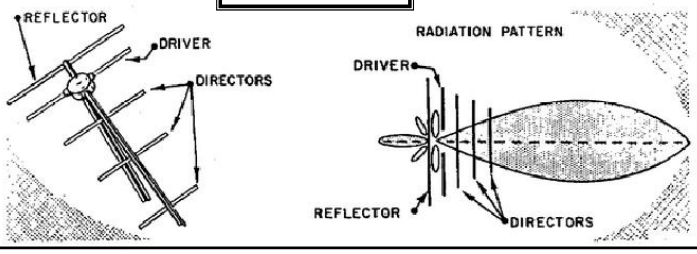
EM TECHNOLOGY AWARENESS

Antenna Gain – Directional

- A typical YAGI antenna will have from 7 – 12 dB of gain depending on the number of elements
- Focus energy in a primary direction
- Most measurements are in reference to a "half-wave" center-fed dipole antenna
- The re-direction of radiation from undesired directions to desired directions results in "gain"
- Two-way radio antennas are typically vertically polarized (TV antennas are horizontally polarized)

View of Antenna and "Elements"

"YAGI" Style Directional Antenna



Viewed from side

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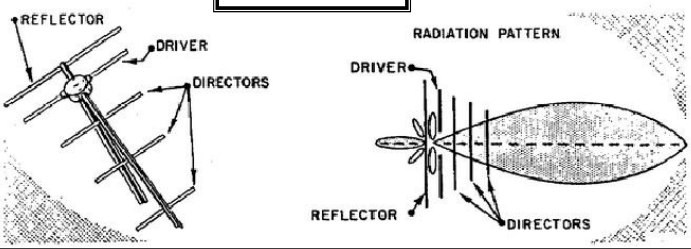
OLOGY AWARENESS

Antenna Gain – Reciprocity

- Three dB of transmit power equates to "double" of the effective wattage power
- The radiated power of a 3 dB antenna provides twice the ERP (Effective Radiate Power) in the direction of focus (20 watts transmit power=40 watts ERP)
- When receiving, a 3 dB antenna will double the effective Receive level of a remote transmitter (Reciprocity)
- May be used to "decrease" interference from an unwanted direction (front-to-back ratio)

"YAGI" Style Directional Antenna



Direction of max gain

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OLOGY AWARENESS

TX/RX Components

Combiner
(Transmitters)

Duplexer

Mobile Duplexer

Multicoupler
(Receivers)

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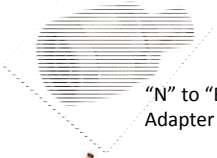
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Radio Connectors

"N" Connector

"UHF" Connector

"F" Connector
(75 ohm - TV)



"N" to "BNC"
Adapter

"UHF"
to "N"
Adapter

Connector
Adapter Kit

Semi-Rigid
Cable

Rigid Cable
Connector

RG-8 Cable

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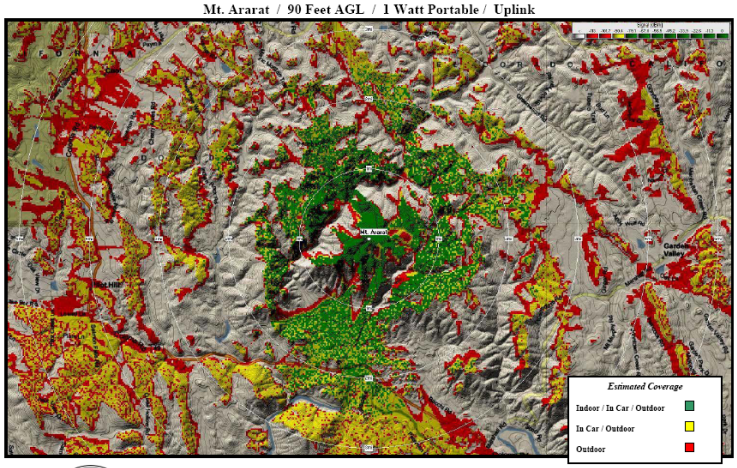
COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Radio Propagation

Mt. Ararat / 90 Feet AGL / 1 Watt Portable / Uplink



Site: Mt. Ararat – 8TAC91
Coordinates (NAD 83): 38-51-13.0 N 120-56-27.0 W Elevation: 2000 Ft AMSL
Date: September 22, 2009

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Propagation – Field Verification

- Drive/walk test
  - Real-world verification versus propagation software
  - Software propagation
    - Error potential when entering data
    - Steep learning curve
  - Verify with field tests

"Can you hear me now?"

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Tone-Coded Squelch

- CTCSS – Continuous Tone-Coded Squelch System
  - Analog sub-audible frequency tone continuously transmitted
  - 42 tones ranging from 67.0 Hz to 254.1 Hz (see NIFOG page 54)
  - 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

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Tone-Coded Squelch (Cont)

- DCS – Digital-Coded Squelch
  - Equivalent action as analog using digitally encoded 134.4 Hz sub-audible tone
- P25 uses network access code (NAC) a digital equivalent of tone-code squelch

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Radio Programming

- Radio Programming
  - Laptop – Radio Interface Box (RIB)
  - Cloning cables
  - Logistic considerations
  - De-programming radios

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Radio Caches

- Radio – Cache Management
  - National caches
    - NIFC – GACC 12 Interagency Support Caches
  - Local/Regional caches
  - Cache management
    - Sources
    - Assigning
    - Tracking/accountability

http://gacc.nifc.gov/index.php

NATIONAL INTERAGENCY FIRE CENTER (NIFC)
GEOGRAPHIC AREA COORDINATION CENTERS (GACC)

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Portable Repeaters

- Transportable
  - Repeat mode
  - Relay mode

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

NIFOG – Resource

- NIFOG
  - National Interoperability Field Operations Guide
  - Common interoperability channel lists
  - Technical reference for radio technicians
  - A downloadable version can be found at http://publicsafetytools.info/start_nifog_info.ph

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Amateur Radio

- Amateur radio
  - ARES - Amateur Radio Emergency Service
  - RACES - Radio Amateur Civil Emergency Service
  - MARS - Military Auxiliary Radio Service
  - Integration into incident communications
    - Provide alternate communications in cases where local services fail
    - Provide auxiliary support to active emergency communications
  - Local involvement protocol varies

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COMT UNIT 4 – RADIO SYSTEM TECHNOLOGY AWARENESS

Unit 4 Questions

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