RADIO FOR IT PROFESSIONALS

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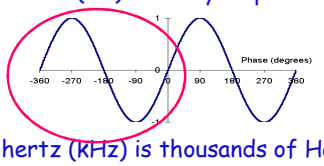
Today's Program

1 Units of Measurement
2 The FCC
3 The RF spectrum
4 Frequency and Bandwidth
5 Defining modulation
6 Analog vs. digital modulation
7 How radios work
8 Basic circuit understanding
9 System definitions
10 Antenna performance
11 Tower information
12 Coverage requirements
13 Radio specifications
14 Interference
15 Unlicensed data systems (2.4 GHz)
16 Radio system performance
17 Conventional radio systems
18 Trunked radio systems
19 P25 standard
20 Broadband over radio (LTE)
21 RF Safety
22 Definitions

Units of Measurement

Frequency is measured in Hertz

One Hertz (Hz) = one cycle per second



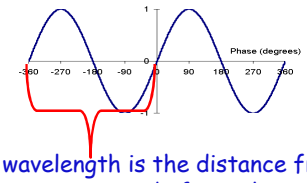
Kilohertz (kHz) is thousands of Hertz

Megahertz (MHz) is millions of Hertz

Gigahertz (GHz) is 1000 Megahertz

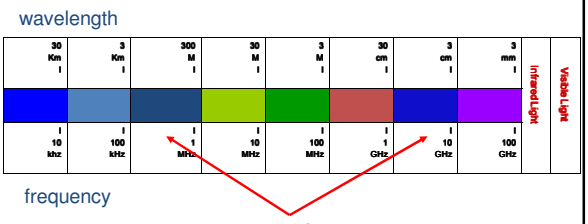
Units of Measurement

Wavelength is measured in meters (or fractions of meters)



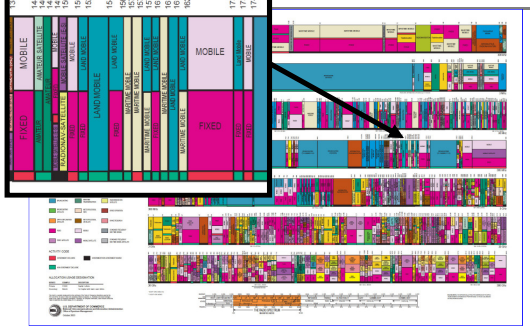
One wavelength is the distance from start to end of a cycle

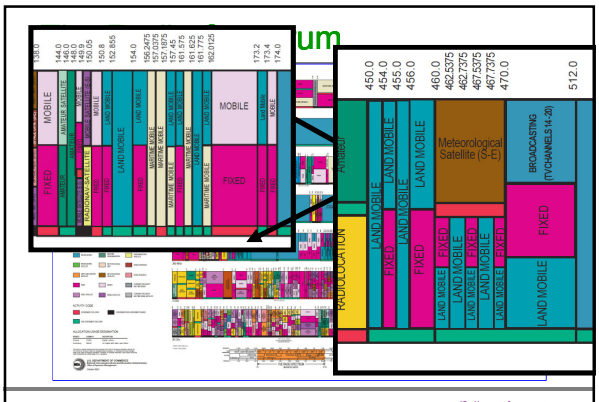
The Radio Spectrum



Our area of concern

um





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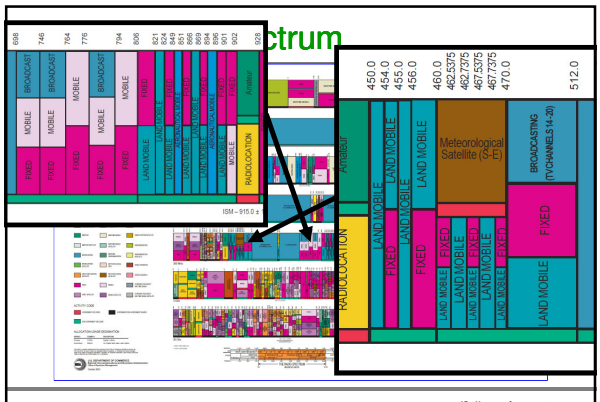

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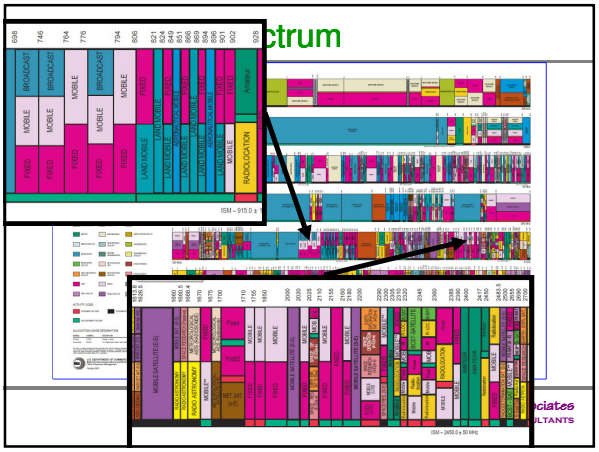

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FCC Rules

- Part 0 - FCC organization
- Part 1 - Practice and procedures
- Part 2 - Spectrum Table and Equip. Cert.
- Part 15 - Unlicensed devices
- Part 17 -Antenna Structures
- Part 22 - Public Land Mobile
- Part 80 - Maritime Services
- Part 90 - Private Land Mobile
- Part 101 - Microwave Services

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Getting A License

Licensing begins with a frequency coordinator

In public safety services - AASHTO, APCO, FCCA, IMSA

In business and industrial services - MARFAC, PCIA, ITA, AAR, FIT, AAA, API, UTC, AMTA, ITLA, TELFAC, MOTION PICTURE ASSN, EWA

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Follow the Rules – Or Else!

- It is well established that the Commission does not consider ignorance of the law or reliance on erroneous or misleading advice from third parties as mitigating circumstances that justify cancellation or reduction of a forfeiture
- Section 312(f)(1) of the Act defines "willful" as the "conscious and deliberate commission or omission of [any] act, irrespective of any intent to violate" the law
- The term 'repeated,' when used with reference to the commission or omission of any act, means the commission or omission of such act more than once or, if such commission or omission is continuous, for more than one day
- The Commission has long held that corrective action taken to come into compliance with the Rules is expected, and such corrective action does not nullify or mitigate prior violations or associated forfeiture liability

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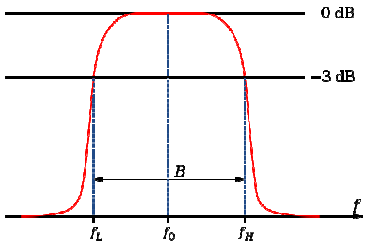
Bandwidth



Bandwidth is the frequency range between the 3 db (half-power) points

Modulation

Modulation is the way that "intelligence" is put on a radio wave

The wave is made up of two parts

The carrier that oscillates at the radio frequency

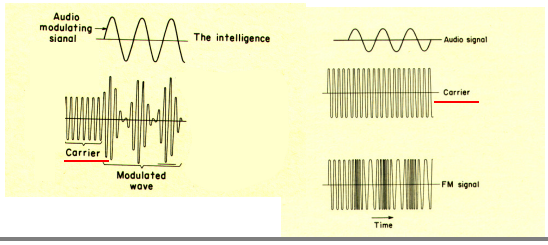
The intelligence which can be voice, data, video, etc.

Modulation

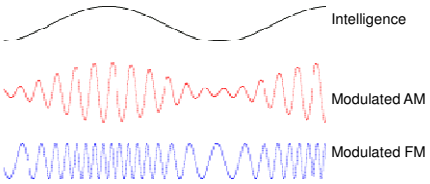
What are AM and FM ?

They are types of modulation

Amplitude modulation | Frequency Modulation



Modulation



Digital Modulation

Digital signals have very complex wave shapes but are generally just ON or OFF (zero or one)

Some types are:

QPSK	TDMA
CDMA	CQPSK
C4FM	

High data rates require bigger bandwidths

Digital Radio

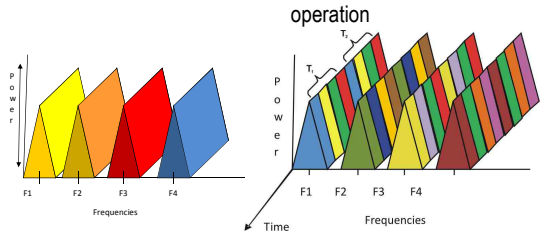
Digital technology expands the versatility of RF systems

The wireless industry embraced digital technology to bring smart phones to the populace.

The use of IP protocol has merged radio and computer technology

Digital Radio vs. Analog

- Analog technology requires discrete frequencies
- Digital Technology uses time slots for TDMA operation



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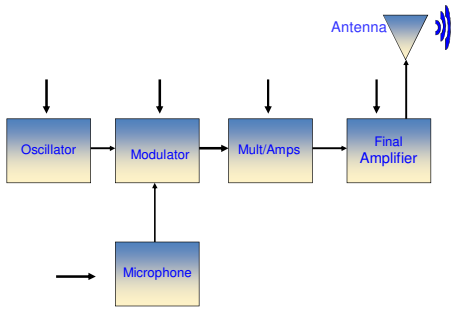
FM TRANSMITTER BLOCK DIAGRAM



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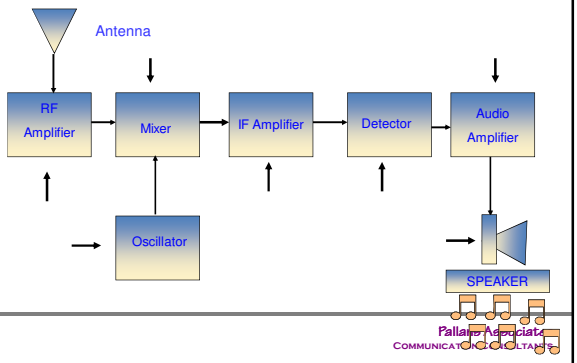
FM Receiver Block Diagram



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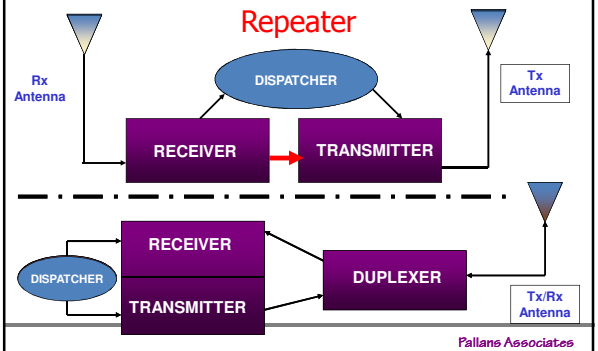
Typical Radio System Components



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WHY IS FM USED FOR 2-WAY RADIO?

It's clearer

It is not affected by noise

It is more consistent in performance

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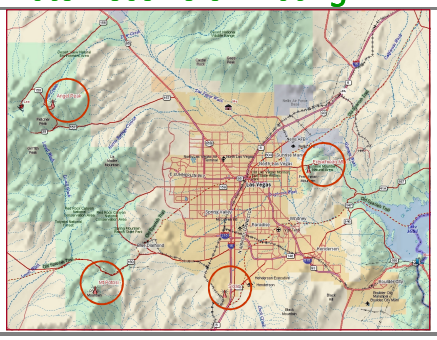
Remote Receivers - Voting



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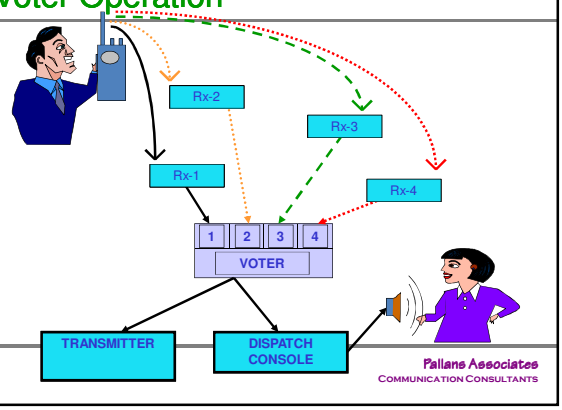
Voter Operation



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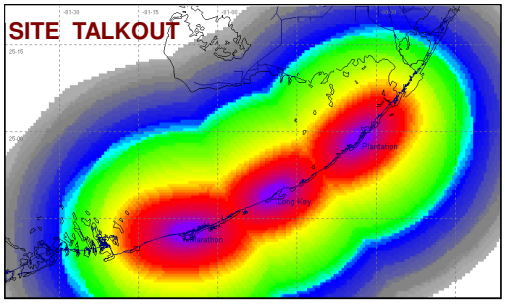
Satellite Receivers

3 SITE TALKOUT



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Satellite Receivers

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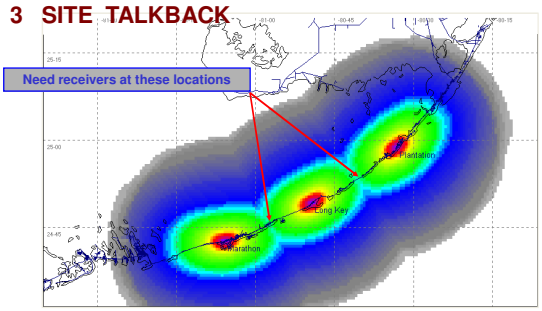

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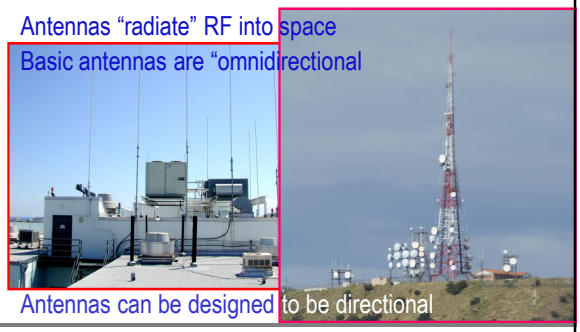
Antennas

Antennas "radiate" RF into space

Basic antennas are "omnidirectional



Antennas can be designed to be directional

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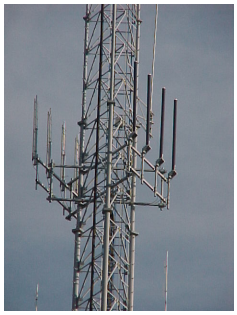
Directional Antennas



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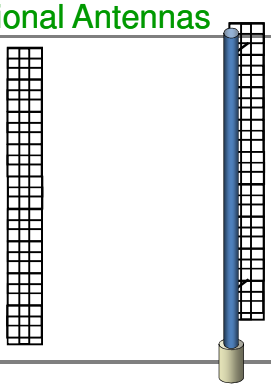
Directional Antennas



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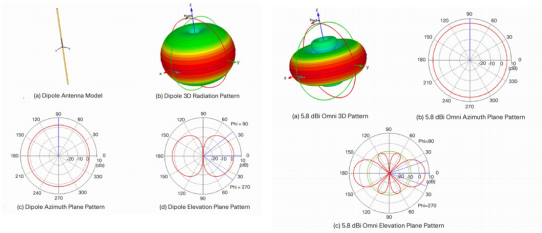
Antenna Gain

An antenna cannot increase power. It can only focus the power causing more power to be radiated/received horizontally (Effective Radiated Power "ERP")

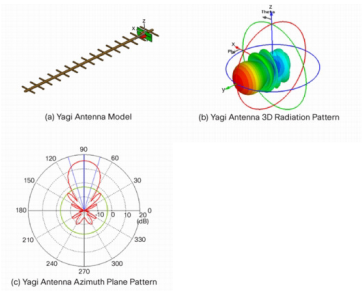
Further gain can be achieved by concentrating power in a single horizontal direction (antenna pattern)

Antenna Patterns

Variations of Directional Patterns

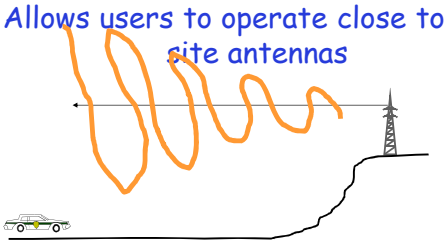


Antenna Patterns



Antenna Downtilt

Allows users to operate close to high site antennas



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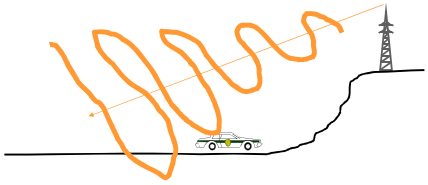


Some Tower Information

- Any Tower of 200 feet or greater requires notification to the FAA and registration with the FCC
- Proper tower construction should meet the TIA/ Standard (current version is "G")
- Local zoning rules must be complied with
- New federal rules require public notices and possible environmental studies

PUBLIC NOTICE:
UNION PACIFIC RAILROAD COMPANY

hereby provides notice of the proposed modification to a 68 foot monopole communications tower. **This site location is Milepost 325.05 Union Pacific Railroad, Clark County, Las Vegas, NV.** The Federal Communications Commission (FCC) Antenna Structure Registration Form 854 filing number is A0812718. No Lighting/Marking is anticipated. The application may be reviewed by going to www.fcc.gov/asr/applications and entering the Form 854 File Number. Environmental concerns may be addressed by filing a Request for Environmental Review online at www.fcc.gov/asr/environment alrequest or by mailing a request to: FCC Requests for Environmental Review, Attn: Ramon Williams, 445 12th Street SW, Washing-ton, DC 20554.

PUB: January 14, 2013
LV Review-Journal

Coverage Study?? Coverage Study??

We don't need no stinkin' coverage study!!

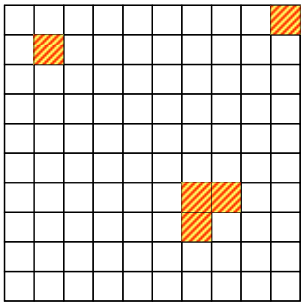
What is acceptable coverage?

This is "Radio City"

The required coverage is 95%.

Do we have it?

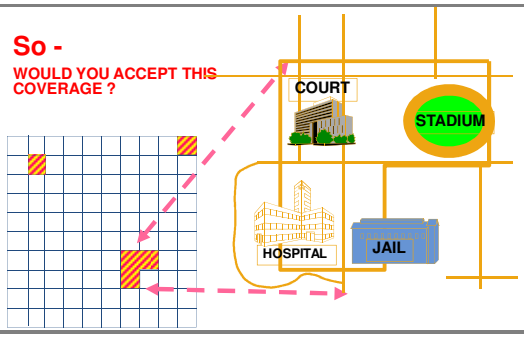
Shows unacceptable coverage



95% COVERAGE REQUIREMENT

So -

WOULD YOU ACCEPT THIS COVERAGE ?



Radio Specifications

Sensitivity

Selectivity

Signal to Noise Ratio

Adjacent Channel Rejection

IM Rejection

Interference

The main causes of interference are:

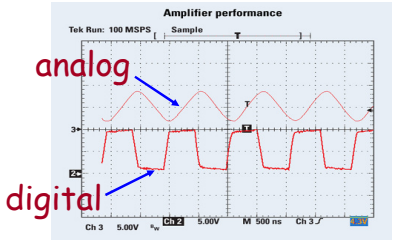
- "Skip" or atmospheric conditions
- Noise
- Intermodulation (or intermod)
- Nearby users or systems

Effects of RF Noise

All RF signals generate noise

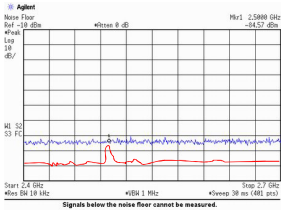
The amount of noise is determined by the waveshape

Digital signals create the most noise since the waves have sharp edges



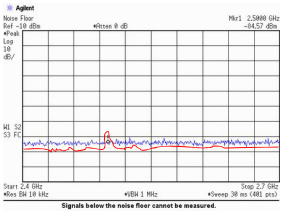
Effects of RF Noise

The "Noise Floor" is the level of the noise in relation to the level of signals



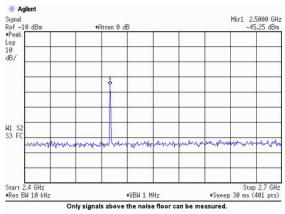
Effects of RF Noise

The higher the signal is with respect to the noise makes the signal more readable



Effects of RF Noise

The idea is to create a large **signal to noise ratio** to get the best signal



Unlicensed 2.4 GHz and 5 GHz Systems

You can't put 10 gallons of data in a five gallon bucket

Licensing provides coordination and protection to systems

Propagation

- The behavior of electromagnetic waves as they depart their source.
- In free space the inverse square law applies
  - For every doubling of distance, the available power is reduced by a factor of four, ie. ¼ as much power
- Often measured in microvolts per meter or decibels over 1 microvolt per meter dBuV/m

Power/Signal Strength Terminology

- Power is measured in WATTS
  - Typically used to describe transmitter or radiated power
- Field strength is used to define signal level at a distance from the transmitter
  - Volts per meter or
  - Watts per square meter

FCC Modeling of Coverage

- FCC developed R-6602 curves to predict service areas of television stations
- Uses average terrain between 2 and 10 miles from the transmitter even though predictions may extend to 100 miles
- Reasonably accurate over flat terrain
- Modified by -9 dB for land mobile use (receive antenna at 6 ft rather than 30 ft for TV)

DOES NOT CONSIDER GROUND CONTOURS

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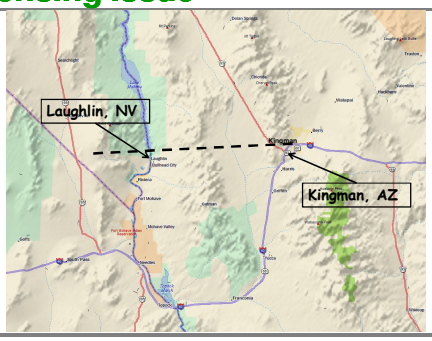
Licensing Issue



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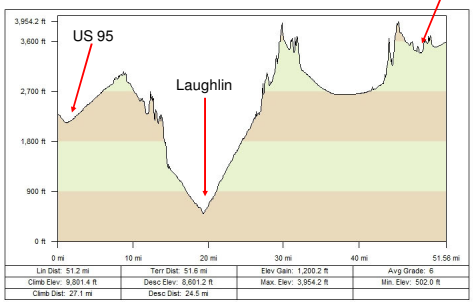

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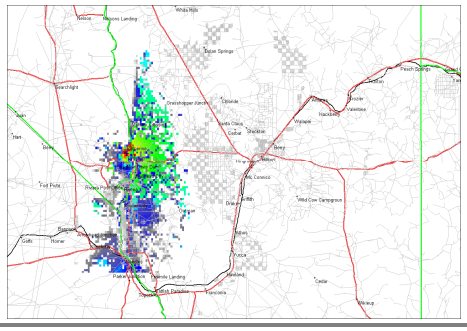

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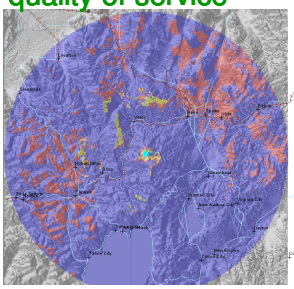
Factors affecting radio range and the quality of service



- Base Antenna Height
- Transmitter Power
- Mobile and portable antennas
- Mobile and portable location
- Topography and land coverage (trees - buildings)
- Weather (ice, rain, etc)
- Interference

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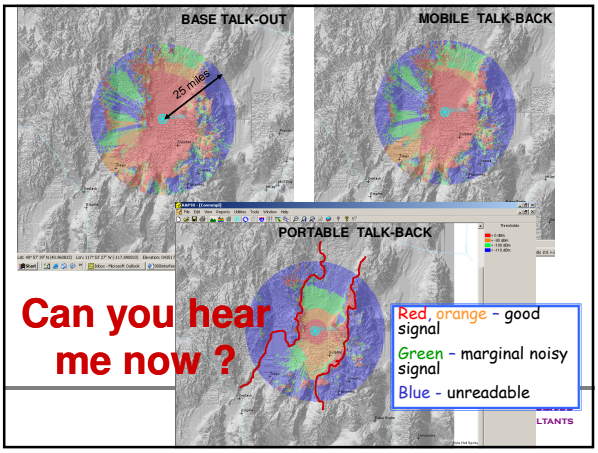
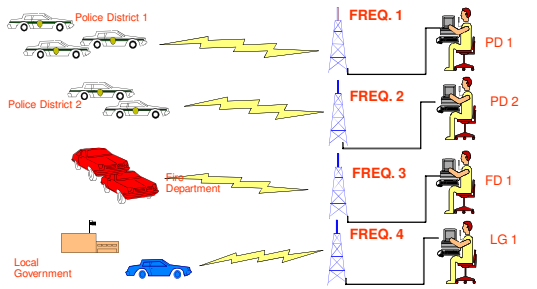


Can you hear me now ?

Conventional Radio System

One person – locked on one channel



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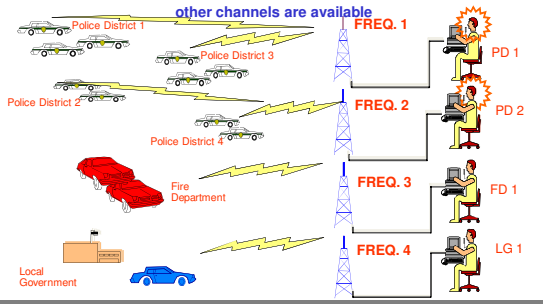
Conventional Radio System

One person – locked on one channel - means you can't get in even if other channels are available



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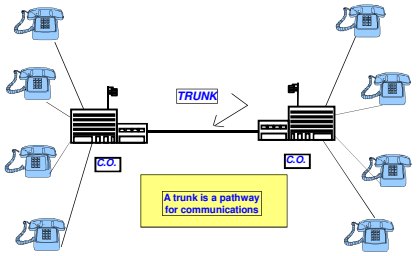
Telephone Trunking



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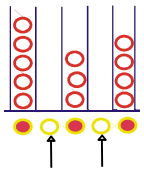
How Trunking Works

Trunking is based upon "queuing" theory

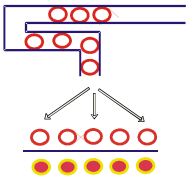
(JUST LIKE WAITING ON LINE AT THE BANK)

CONVENTIONAL RADIO



UNUSED CHANNELS

TRUNKED RADIO



ALL CHANNELS USED

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Trunked Radio System Advantages

- Computer Control
- More Users
- User Privacy
- Higher Security
- User Priorities
- Emergency Calling

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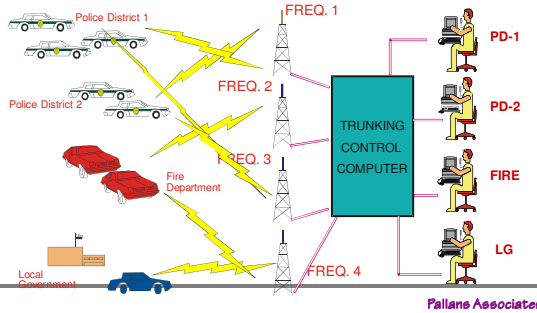
Trunked Radio System

If ANY channel is available you can get in



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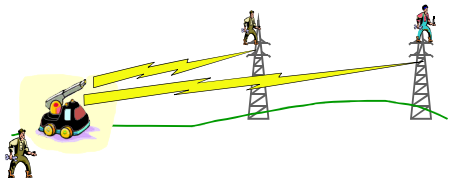
Point-to-Point Operation



For communications that are within sight of each other use unit-to-unit (direct or simplex) channels

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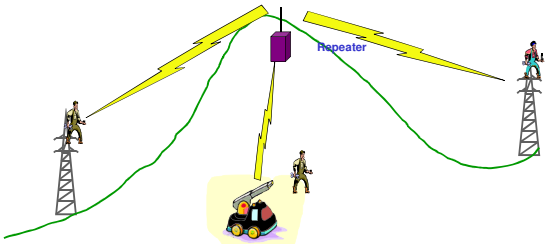
Repeater Operation



For communications that are a few miles apart or not visible between users - use a repeater channel

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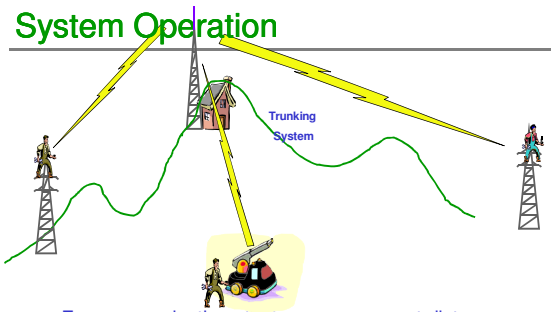
System Operation



For communications that are over a great distance or when it is not possible to use the direct or repeater channels, use a talkgroup on the main radio system

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The P25 Digital Standard

- Conventional or trunked systems
- Establishes a standard technology so any vendor can provide a competitive product
- Interfaces are designed for:

RF subsystems	Over the air
Intersystem	Telephone interconnect
Network Management	Data hosting
Fixed Stations	Consoles

Using the standard will support basic P25 functionality

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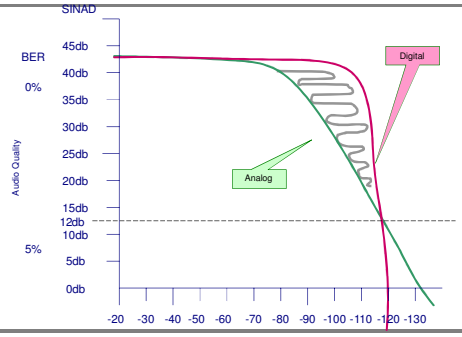
Analog vs. Digital Coverage



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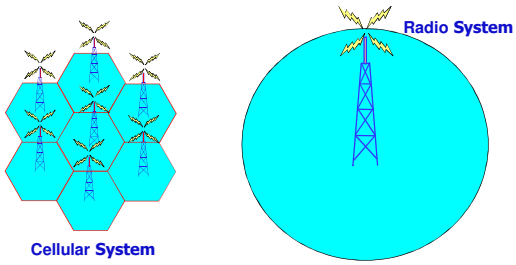
Why does my $30 cell phone work better than my $3,000 handheld?



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Why does my $30 cell phone work better than my $3,000 handheld?

Cellular bandwidth is much wider giving better "fidelity"

Cellular "hands off" between close spaced sites as you move

Cellular companies can spend BILLIONS on their infrastructure

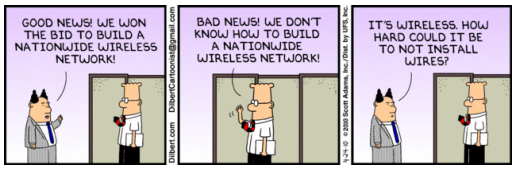
Cellular uses digital audio

There are MILLIONS of cell phones and only thousands of radios so the costs are lower

Broadband Over Radio

- Focuses on the 700 MHz spectrum
- The developed standard is "LTE"
- Public carriers are developing it
- Public safety will benefit in the LONG term
- Some local governments are developing their own area wide systems

Broadband Over Radio



RF Safety

IT IS THE LAW

- National Environmental Policy Act of 1969
- FCC identified RF energy as a potential environmental factor
- 47 CFR 1.1307(b) - dealing with RF
- 47 CFR 1.1310 - Exposure limits
- OSHA

You MUST comply with these guidelines!!

Who Is Being Protected?

OCCUPATIONAL CONTROLLED

These limits apply to individuals who should know there is a potential for exposure to RF energy

GENERAL POPULATION UNCONTROLLED

These limits apply to individuals assumed to have no knowledge of or control over their possible exposure to RF energy

Maximum Permissible Exposure

(A) Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	(900/f^2)*	6
300-1500	--	--	f/300	6
1500-100,000	--	--	5	6

(B) Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	(180/f^2)*	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

Affected Facilities

FCC Rule 1.1307(b)(1) establishes "Categorically Excluded" facilities

- Type of service
- Height above ground
- Height above accessible level
- ERP

Affected Facilities

Even with all of the antennas, this is a Categorically Excluded site because the lowest antennas is at 60 feet above the adjacent building roof

Do You Have to Evaluate

Private Land Mobile Radio Services (Part 90)

Non-building mounted antennas:

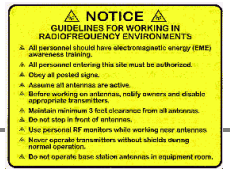
height above ground level to lowest point of antenna

< 10m and power > 1000 W ERP (1640 W EIRP)

Building mounted Antennas:

power > 1000 W ERP (1640 W EIRP)

Warnings



Where to Look

- http://www.fcc.gov/oet/rfsafety
- OET Bulletin 56 - Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields
- OET Bulletin 65 - Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields
- A Local Government Official's Guide to Transmitting Antenna RF Emission Safety: Rules, Procedures, and Practical Guidance
- Electromagnetic Energy – Evaluation and Management for Antenna Sites (Motorola)

Radio Jargon

- **TRANSMITTER:** A device which takes voice or data, converts it to electromagnetic waves (radio) and sends it into space
- **RECEIVER:** A device that picks up electromagnetic waves and converts it into a useable form such as voice
- **REPEATER:** A combination of a transmitter and a receiver that automatically re-transmits any signal that is received.
- **BASE STATION:** the term generally applied to the main transmitter of a system. Sometimes a repeater is called a base station
- **MEGAHERTZ:** The unit of measurement of frequency of radio waves. Abbreviated MHz
- **VHF:** The part of the radio spectrum from 30 to 300 MHz
- **UHF:** The part of the radio spectrum from 300 to 3000 MHz

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Radio Jargon

- **DUPLEX:** The ability to transmit and receive simultaneously (a telephone works in a duplex mode)
- **SIMPLEX:** Typical push to talk operation or – transmitting and receiving on the same frequency
  Simplex is also called **DIRECT**
- **DUPLEXER:** a device that lets one antenna be shared by both a transmitter and a receiver
- **COMBINER:** A device that allows one antenna to be shared by many transmitters
- **MULTICOUPLER:** A device that allows one antenna to be used by many receivers
- **GIGAHERTZ:** The unit of measurement of higher frequencies of radio waves (over 1000 MHz). Abbreviated GHz – typically used for microwave systems
- **MODULATION:** The process by which voice or other signals are applied to a radio signal
- **FM:** Frequency Modulation: a method of applying voice to a radio signal

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Radio Jargon

- **KEYING:** The term usually applied to turning on a transmitter or base station by pressing the push to talk switch
- **LAND-LINE:** Refers to the telephone lines used to bring signals in from remote sites or from consoles to the base stations
- **MICROWAVE:** A transmitter Receiver combination operating above 2000 MHz. It is used the same way as land lines but without wires
- **TRUNKING:** A technology combining transmitters using computers to greatly improve performance
- **TALKGROUP:** The trunking equivalent of a radio channel

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Now's the time for any questions

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