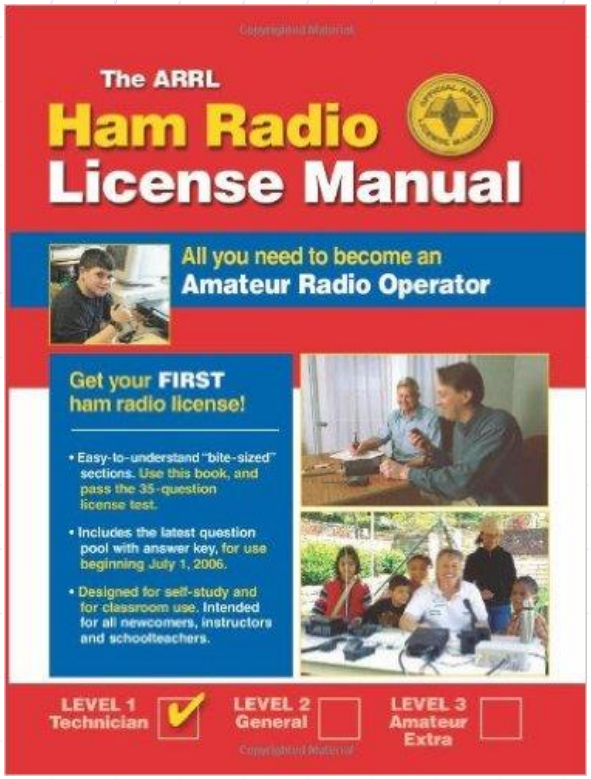
Amateur Radio Technician Class Training

Alan Wolke – W2AEW

(based on the No-Nonsense, Technician Class Study Guide by Dan Romanchik KB6NU

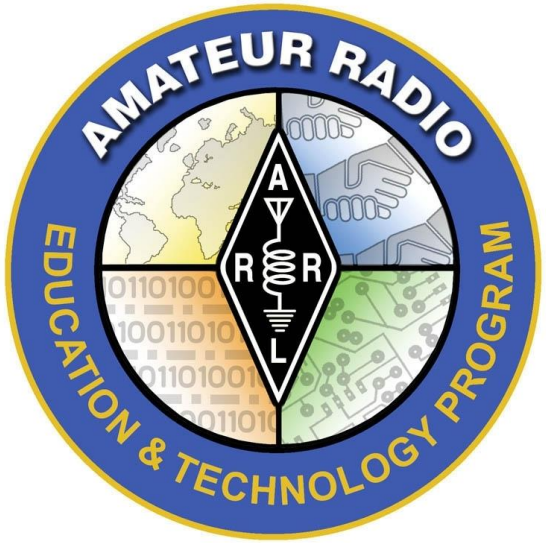
Agenda

- Introduction
- Electrical Principles
- Electronic Principles & Components
- Radio Wave Properties
- HF Propagation
- Antennas & Feedlines
- Amateur Radio Signals
- Safety Concepts
- Station Setup & Operation
- Operating Procedures
- Rules & Regulations



What is Amateur Radio

- A Hobby – yes!
- A Service – yes!
- Fun – yes!



- It's what you make of it!

Communicate, Experiment, Serve, Interact, Compete

- Regulated, but non-commercial
- Experimentation is allowed/encouraged
- Community Service
- Technical learning and discovery
- Ways to "compete"
- *Something for everyone!*

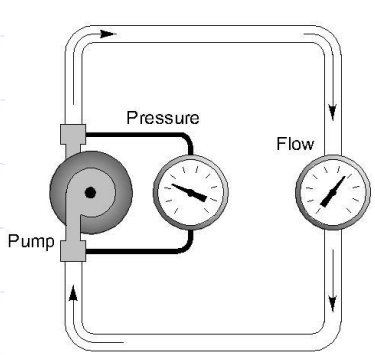
Cool things to do…

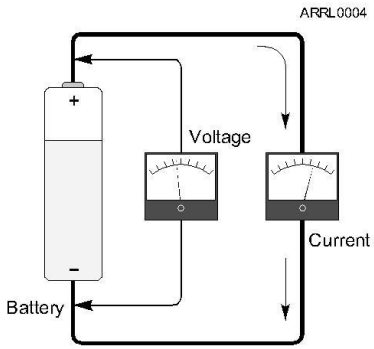
Electrical Principles

Voltage

Current

Resistance





Amps

AC

DC

Volts

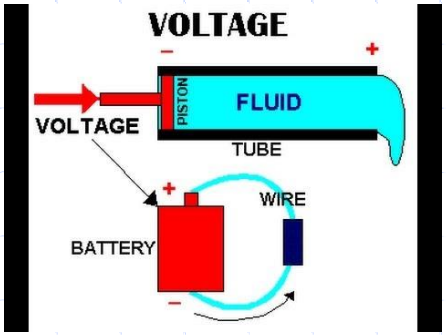
Insulator

Ohms

Watts

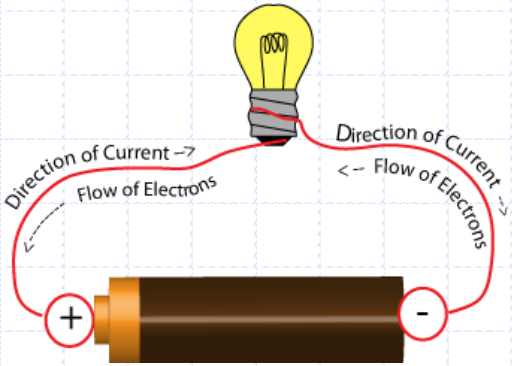
Conductor

Voltage



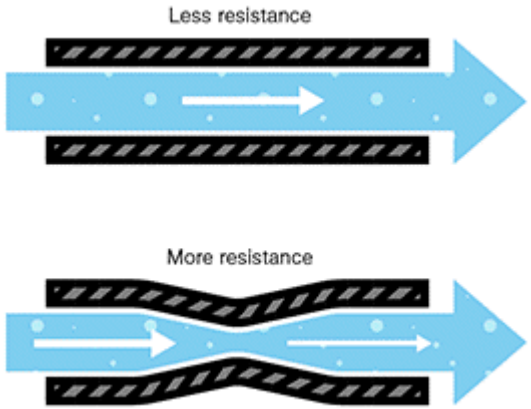
- The **force** that pushes electrons around
- Also called Electro-motive force: **EMF**
- Measured in units called **VOLTS**
- Measured with a **Voltmeter**
- Symbol is **E**, unit symbol is **V**
- Typical mobile radios require 12 volts to operate

Current



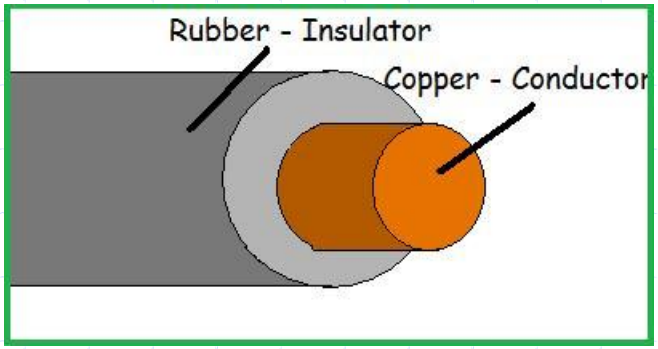
- The flow of electrons in a circuit
- Measured in units of **Amperes** (amps)
- Symbol is **I**, units symbol is **A**
- Measured with an **Ammeter**
- **DC**: Direct Current flows in one direction
- **AC**: Alternating Current flows back and forth, changing direction

Resistance



- Opposes the flow of electrons
- Measured in ***Ohms***
- Symbol is ***R***, unit symbol is **Ω**
- Measured with an ***Ohmmeter***

Conductors & Insulators



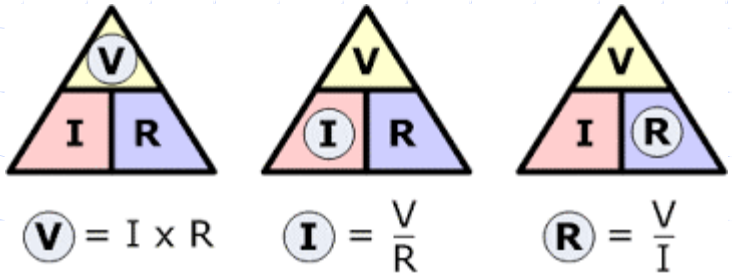
- **Conductors**
  - Low resistance, allow current to flow
  - Copper, aluminum, gold, silver, etc.
- **Insulators**
  - High resistance, little/no current flow
  - Plastic, wood, glass, mica, paper, etc.

Power

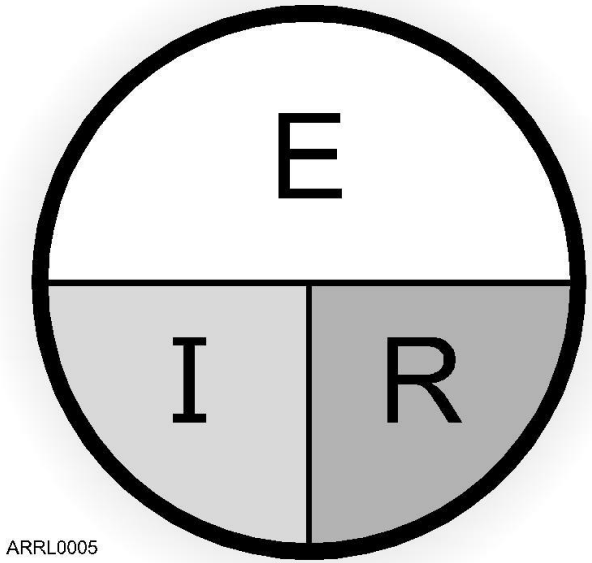
- Rate at which electrical energy is used
- Measured in **Watts**
- Symbol is **P**, unit symbol is **W**

- Often not measured directly, but calculated – *more on this shortly…*

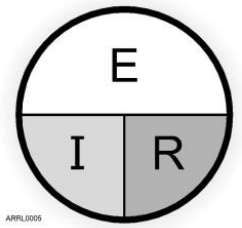
Ohm's Law



- Relationship between:
  - Voltage
  - Current
  - Resistance
- E = I * R
- I = E / R
- R = E / I



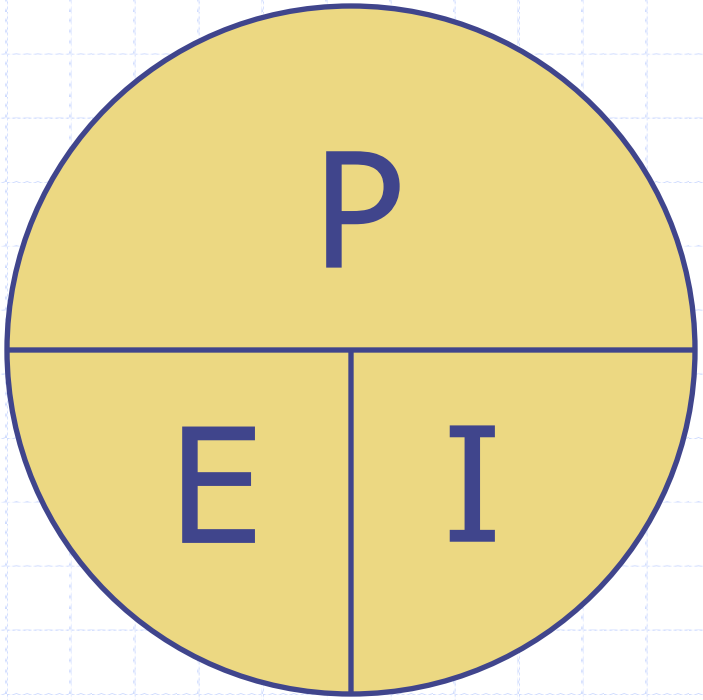
Ohm's Law Examples



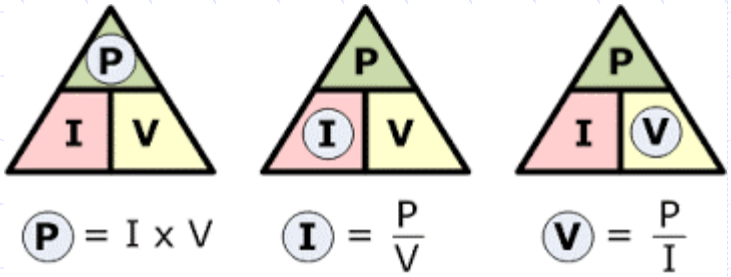
- 90 volts is applied across a resistor resulting in 3 amperes of current. What's the resistance?
  - R=E/I 90V/3A = **30Ω**
- 120 volts applied to a circuit with 80 ohms of resistance – how much current flows?
  - I=E/R 120V/80Ω = **1.5 amperes**

Calculating Power

- Power is Voltage * Current
  - P = E * I
  - E = P / I
  - I = P / E



Power Examples



- How much power is being used by a circuit that draws 10A from a 13.8V source?
  - P=E*I 13.8V * 10A = **138 Watts**
- Applied voltage is 12V and current is 2.5A, what is the power?
  - 12V * 2.5A = **30W**

Math for Electronics: Prefixes

- Used with electrical quantities
  - **milli** = 1/1000th, such as 1**mA** is 1/1000th of an ampere, or 0.001A
  - **micro** = 1/1,000,000th (one millionth), such as 3**µV** which is 0.000003V
  - **pico** = 1 trillionth (millionth of a millionth) such as 5**pA** = 0.000005µA

Prefixes continued

- **kilo** = 1000x, such as 1**kV** = 1000V
- **mega** = 1 million times (1,000,000x) such as 1**MΩ** = 1,000,000Ω
- **giga** = 1 billion times, such as **2.4GHz**

- Prefixes are often used on many different electrical quantities

Prefix examples

- 1,500 milliamperes = 1.5 amperes
- 1,000 volts = 1 kilovolt (1kV)
- 1 millionth of a volt = 1 microvolt (1µV)
- 3000mA = 3A

Bonus…

- 3500 kilohertz = 3.5 megahertz
- 2425 MHz = 2.425 GHz

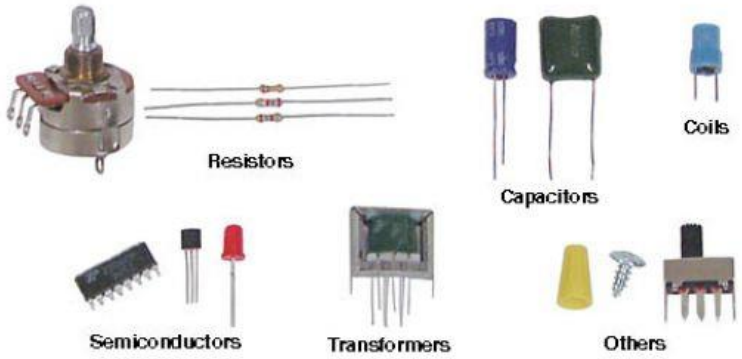
Decibels, or dB

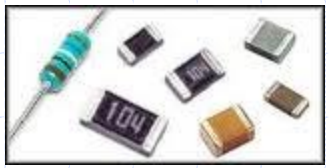
- When dealing with ratios, often power ratios, we use decibels
- Easy to express large ratios with small numbers
- Cascading ratios multiply or divide
- Cascading decibels add or subtract
- +dB represents an "increase"
  -dB represents a "decrease"

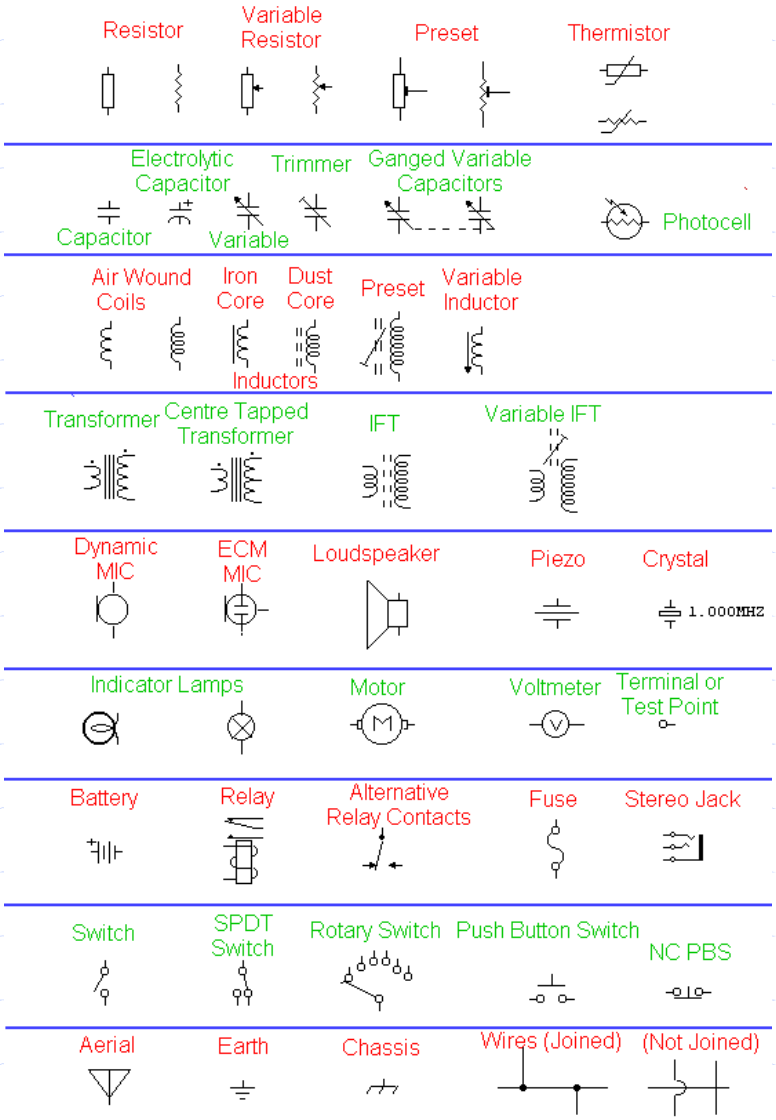
Ratios to remember

- 3dB is a factor of 2x
  - A change from 5W to 10W is a 3dB increase, a ratio of 2 to 1
- 6dB is a factor of 4x
  - A change from 12W to 3W is a 6dB decrease (-6dB change), ratio of 4 to 1
- 10dB is a factor of 10x
  - 20W to 200W is a 10dB increase, ratio of 10 to 1
- Combinations (dB values add and subtract)
  - 13dB change is a factor of 20x (10*2)

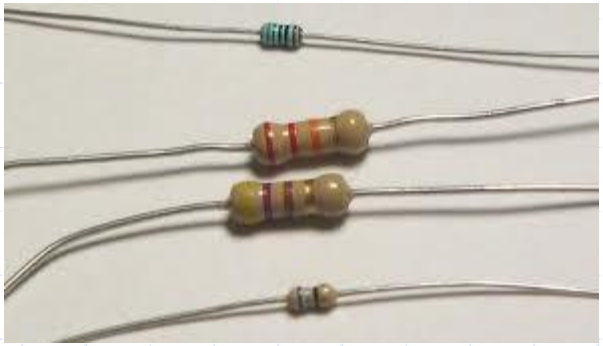
Electronic Principles & Components



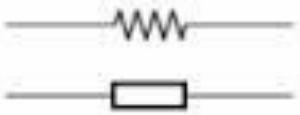


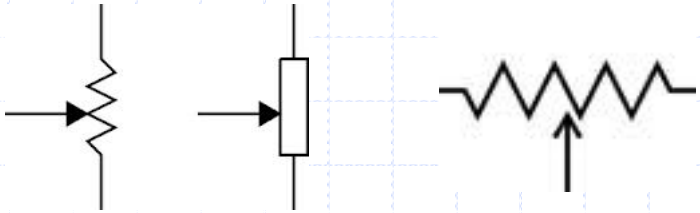


Resistors



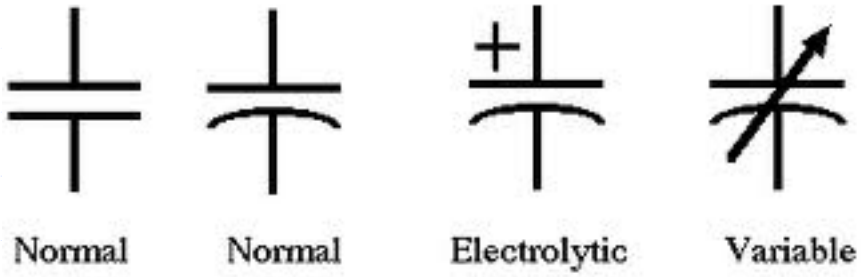
- **Resistors** oppose the flow of current
- Variable resistors are called **Potentiometers** (or **Rheostats**)
- Resistor value expressed in **ohms**



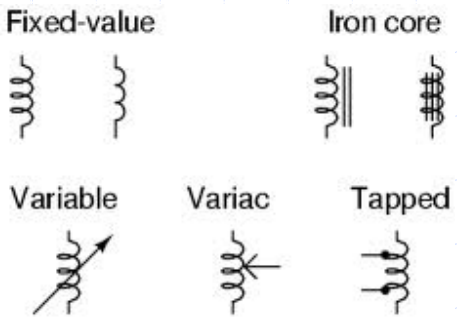


Capacitors

- Two conductors separated by an insulator is a **Capacitor**
- Stores energy in an *electric* field
- Capacitance is the ability to store energy in an electric field
- The unit of measure is the **Farad**

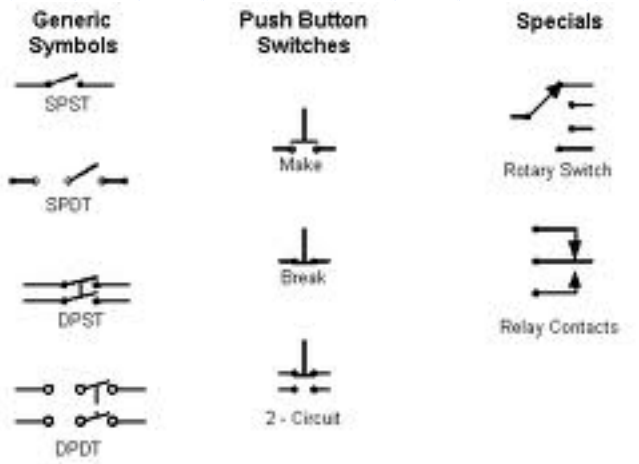


Inductors



- An **inductor** stores energy in a *magnetic* field
- Often just a coil of wire!
- The ability to store energy in a magnetic field is called **Inductance**
- Unit of measure is **Henry**

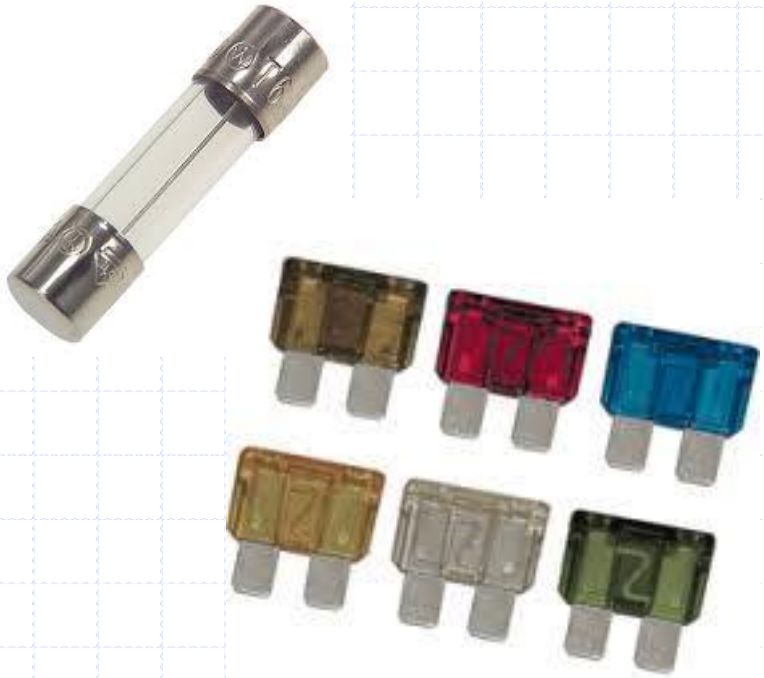
Switches



- Used to connect and disconnect electrical circuits
- Pole: "movable part"
- Throw: the places the pole can go
- SPST: single-pole, single-throw
- DPDT: double-pole, double-throw

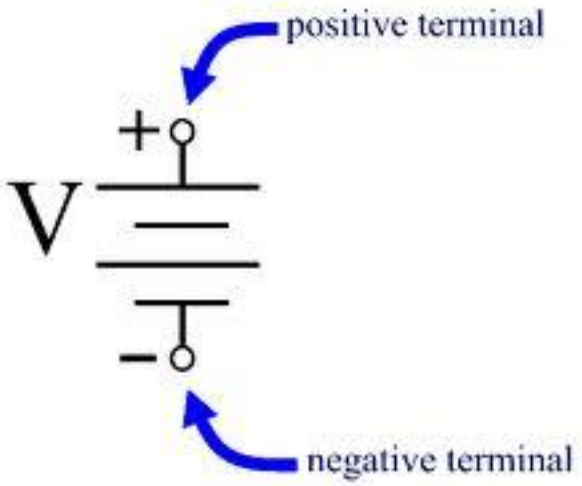
Fuses

- Protects circuits from overload (excessive current)
- Rated in **Amps**



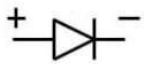
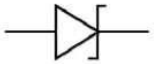
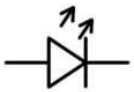
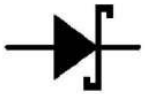
Batteries

- Primary batteries are not rechargable
  - Carbon Zinc, Alkaline
- Secondary batteries are rechargable
  - NiCad, NiMH, Lithium
- Different types have different voltages
  - NiCad typically 1.2V



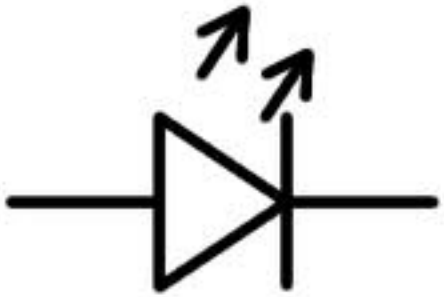
Diodes

- Allows current to flow in only one direction
- Terminals are:
  - *Anode (+)*
  - *Cathode (-)*
- Cathode has the *stripe*
- Often called **Rectifier**

Name	Symbol	Image
Diode		
Zener Diode		
LED (Light Emitting Diode)		
Schottky Diode		

LEDs / Light Emitting Diodes

- A diode that creates light when current passes through it

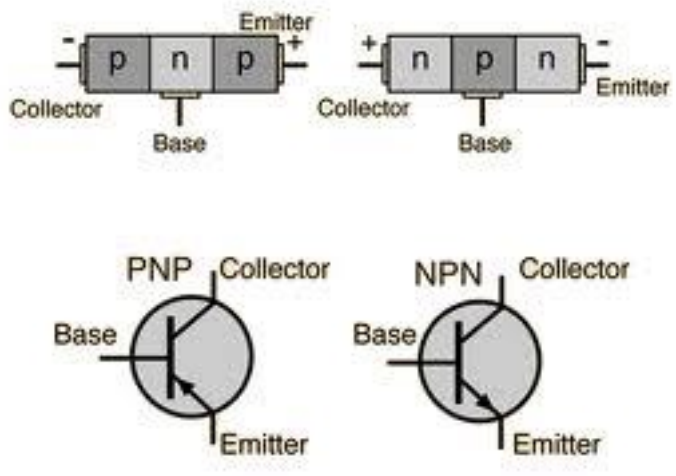


Transistors

- Component where current flow is controlled by another current or voltage
- Used as a *switch* or *amplifier*
- **Gain** is a measure of the ability to amplify

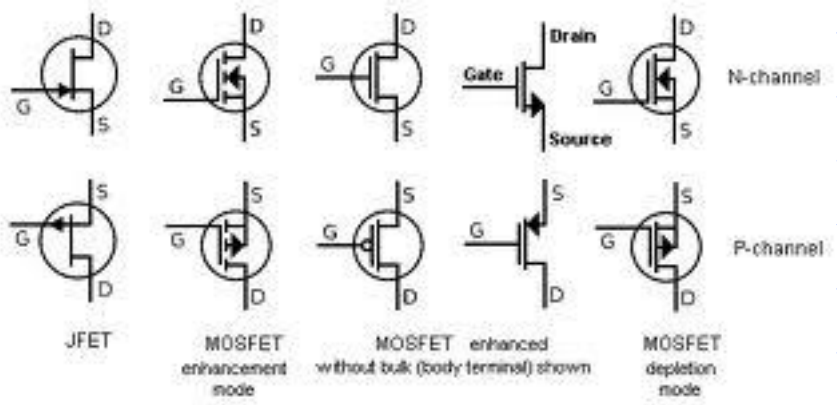
Some transistor types

- **Bipolar transistors** are made of three layers of semiconductor
  - NPN or PNP
- Terminals are:
  - Base, Collector, *Emitter*



Some transistor types

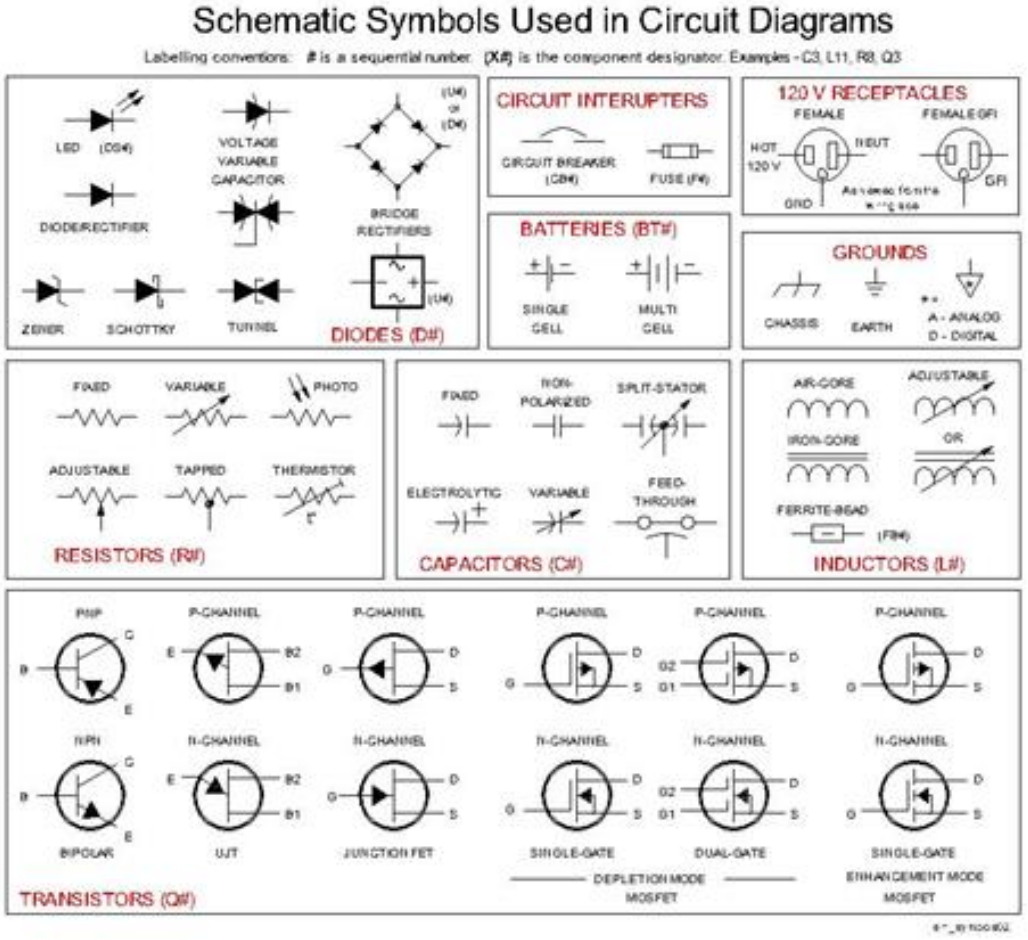
- **Field Effect Transistor** is abbreviated as *FET*
- Terminals are:
  - *Gate*, Drain, Source



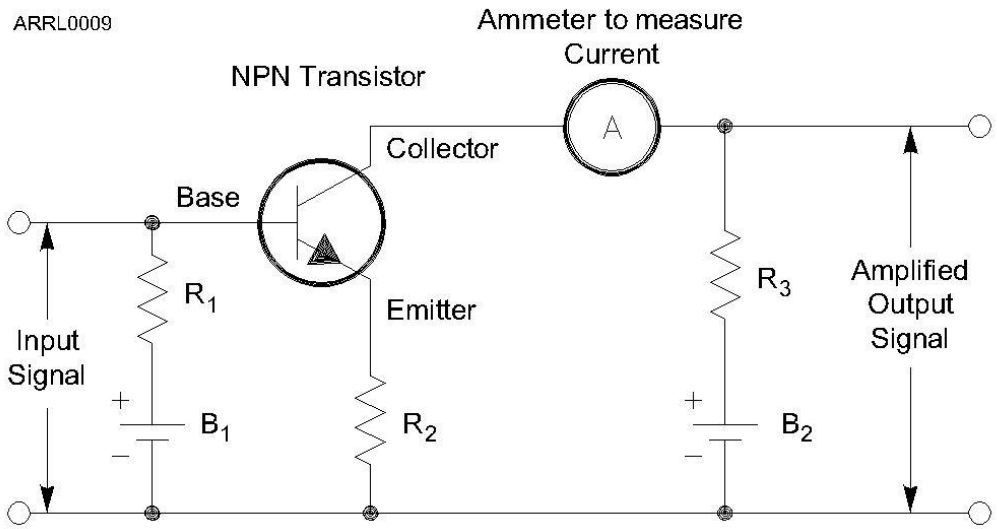
Schematic Symbols

- Schematic **symbols** are standardized representations for *components*
- Schematic **diagram** depicts the *interconnections* between components that make up a circuit

Schematic Symbols



Schematic Diagram



Schematic Diagram examples

- 1: **Resistor**, used to limit input current
- 2: **Transistor**, used to switch current on and off
- 3: **lamp**
- 4: **battery**, to supply current to light the lamp
- 5: chassis ground

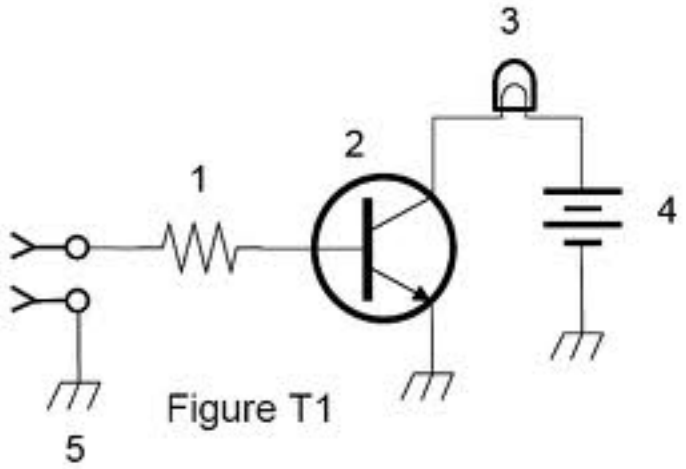


Figure T1

Turns on a light when a positive voltage is applied to the input

Schematic Diagram examples

- 2: **Fuse**
- 3: **Single Pole, Single Throw switch** (SPST) to turn the power supply on/off
- 4: **Transformer**, used to change 120VAC to lower AC voltage
- 5: **Rectifier diode** to change AC to a varying DC signal
- 6: **Capacitor** helps to remove the 60Hz variation in the signal (filter)
- 8: **LED** – pilot light to show it is on
- 9: **Variable Resistor** to vary the output current

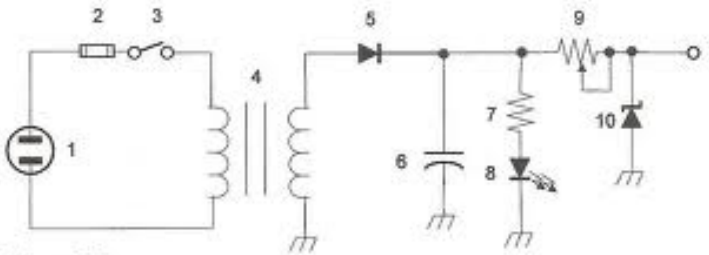


Figure T2

Simple AC – DC Power Supply

Schematic Diagram examples

- 3: **Variable Inductor**
- The **variable capacitors** together with the variable inductor together used as a *tuned circuit*
- 4: **Antenna**

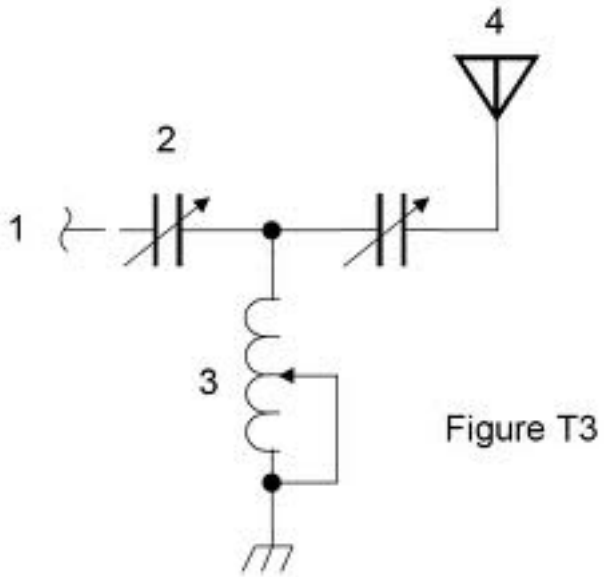


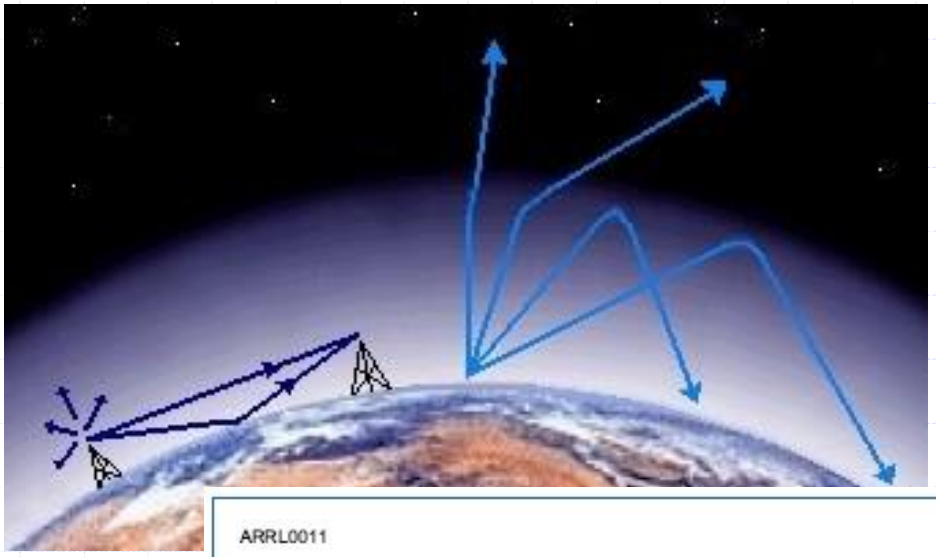
Figure T3

Output circuit of a transmitter

Other Components

- **Relay**: a switch controlled by an electromagnet
- **Meter**: used to display a signal strength on a numeric scale
- **Regulator**: controls the amount of voltage from a power supply
- **Integrated Circuit**: combines many parts in one package, perform analog and/or digital functions

Radio Wave Properties

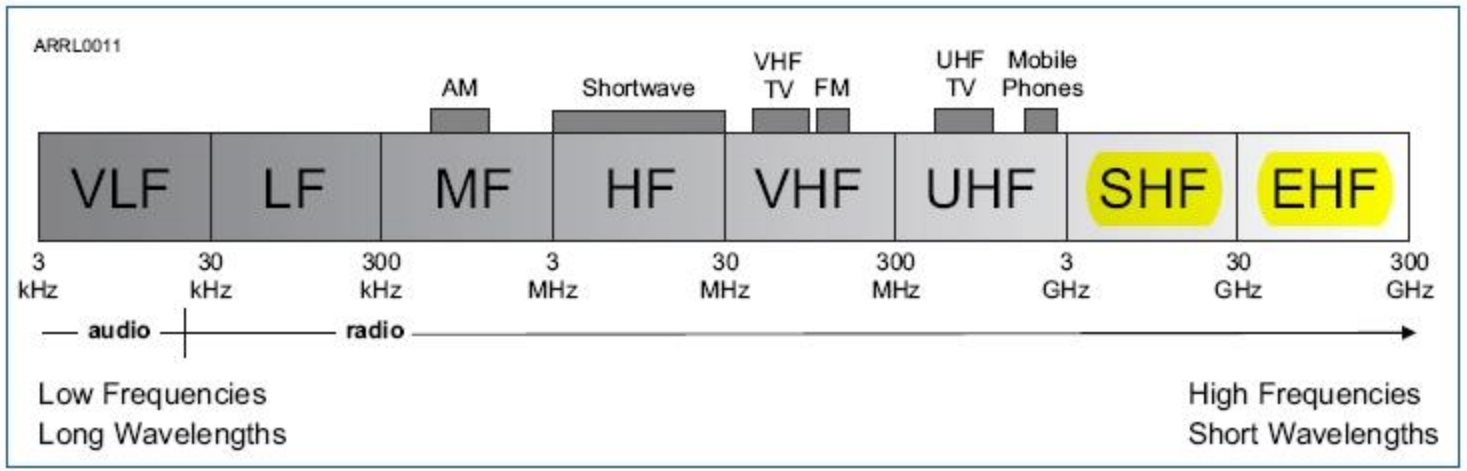


Frequency

Wavelength

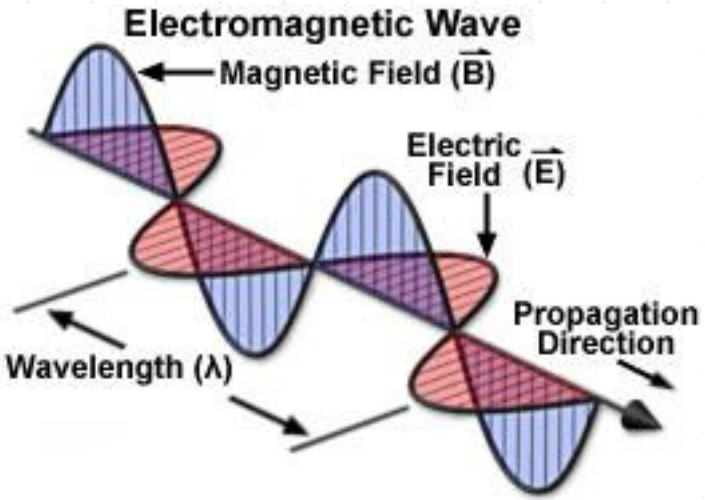
Spectrum

Propagation



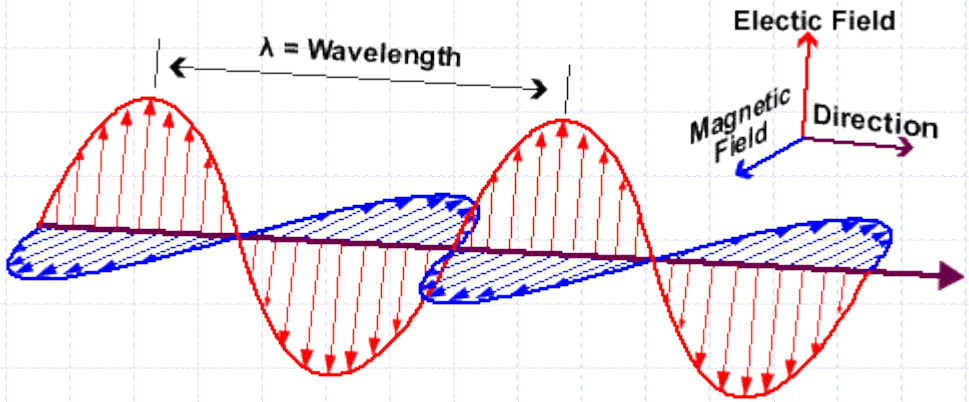
Radio Waves

- Radio waves are **Electromagnetic**
- Have an *electric* and *magnetic* field components
- *Radio waves* travel through space and they carry signals from transmitter to receiver



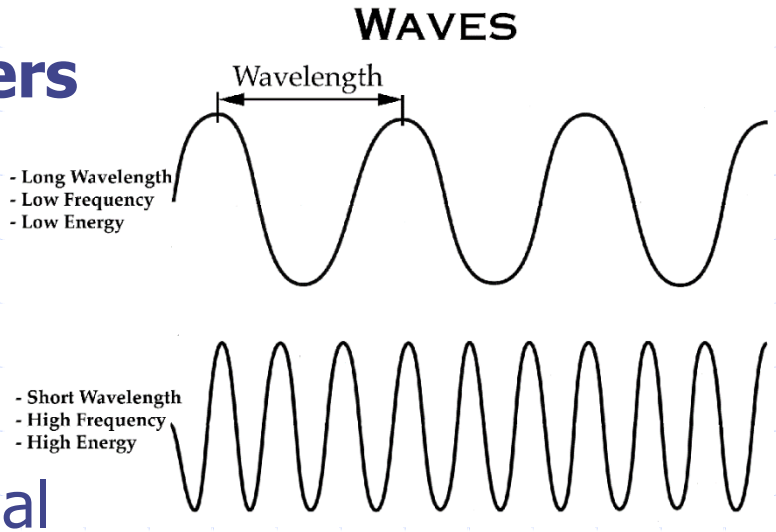
Frequency and Wavelength

- **Frequency**: number of times per second the signal repeats (cycles) {exam may say reverses…}
- Frequency measured in **Hertz** (cycles/second)
- **Wavelength**: how far the wave travels during one cycle



Radio Wave facts

- Travels at *speed of light* in free space
- …about **300,000,000 meters per second**!
- …regardless of frequency
- Wavelength is shorter as frequency increases
- Wavelength in meters is equal to 300 / frequency (MHz)

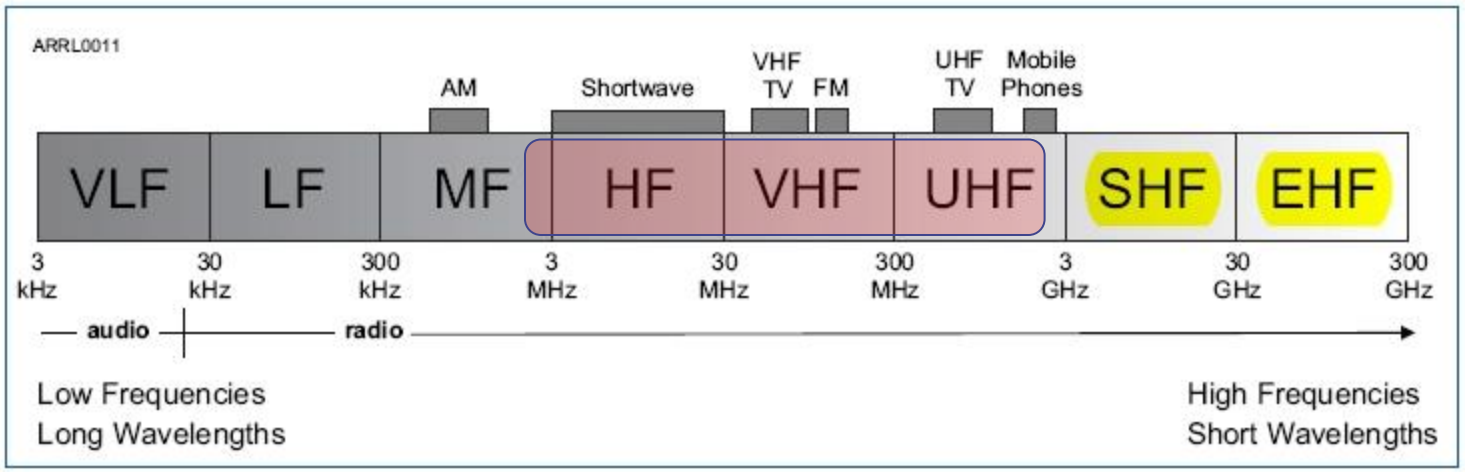


Radio Frequency Bands

- The **approximate wavelength** of radio waves is used to identify different bands
- Examples:
  - The 2m band spans 144 - 148MHz
  - The 40m band spans 7.000 – 7.300MHz
- It's not always "exact"…

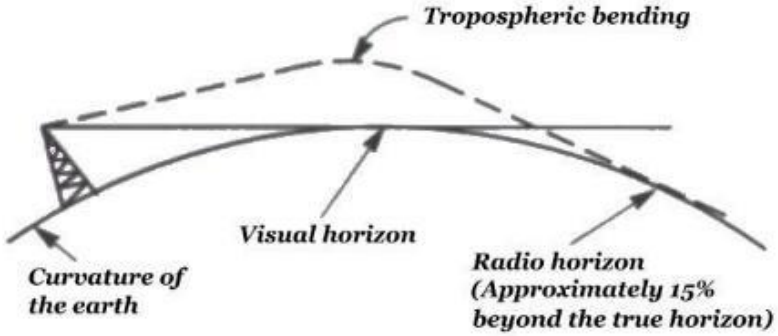
The RF Spectrum

- **RF = Radio Frequency**
- The full range of frequencies are divided into sub-ranges for convenience
- Most common for Amateur Radio: **HF**, **VHF** & **UHF**
  - *HF 3-30MHz* *VHF 30-300MHz* *UHF 300-3000MHz*



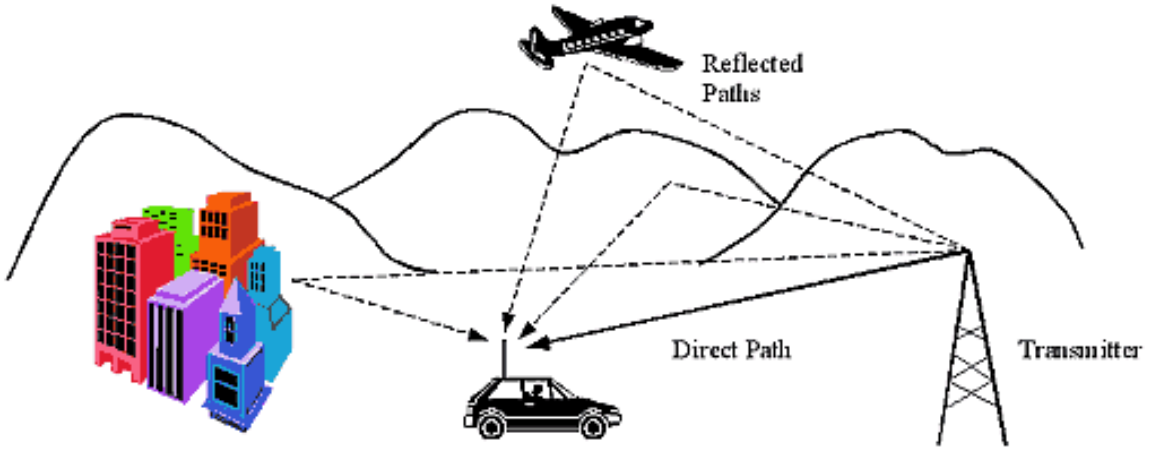
Frequency Band Properties

- Different bands have different propagation properties – thus different use cases
- **VHF & UHF** are typically **line-of-sight**
  - *Not reflected off of the ionosphere*
- *Radio horizon* is where the radio signals are blocked by the curvature of the earth
  - Although earth "seems" slightly less curved to RF, so the radio horizon is usually a little greater than the visual horizon



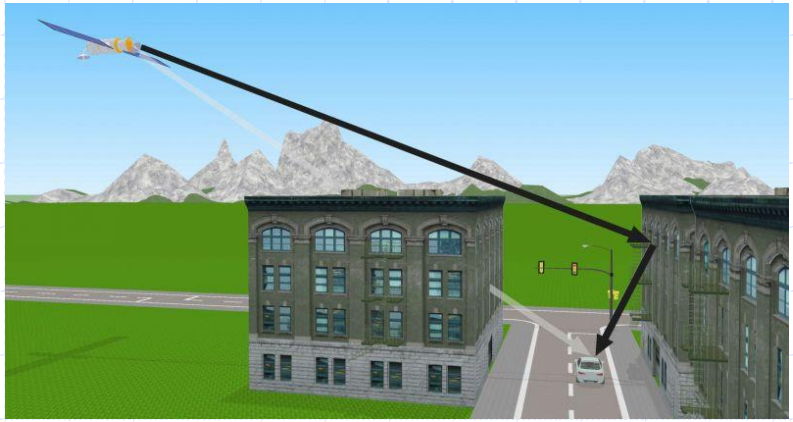
Multipath

- VHF & UHF often affected by **Multipath**
- Signals from different paths may be in phase or out
  - They can add to each other, or cancel each other out
- If you're affected by *multipath*, *try moving a few feet!*
- Multipath can affect digital signal *error rates*



Signal Reflections…

- If you can't reach a VHF / UHF station, try directing your antenna to a reflecting path if the direct path is blocked

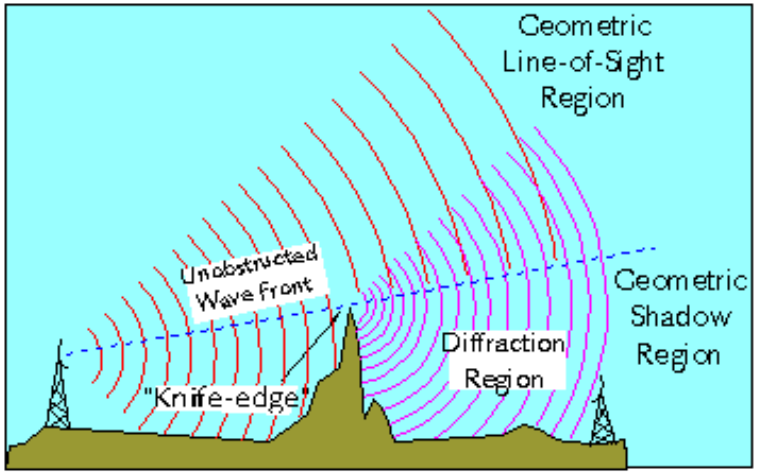


- Multiple / changing reflections due to being in a moving vehicle can often cause rapid fading or fluttering known as **"Picket Fencing".**

More VHF/UHF…

- **UHF** is better at penetrating building structures than VHF – so is better suited for use inside or around buildings

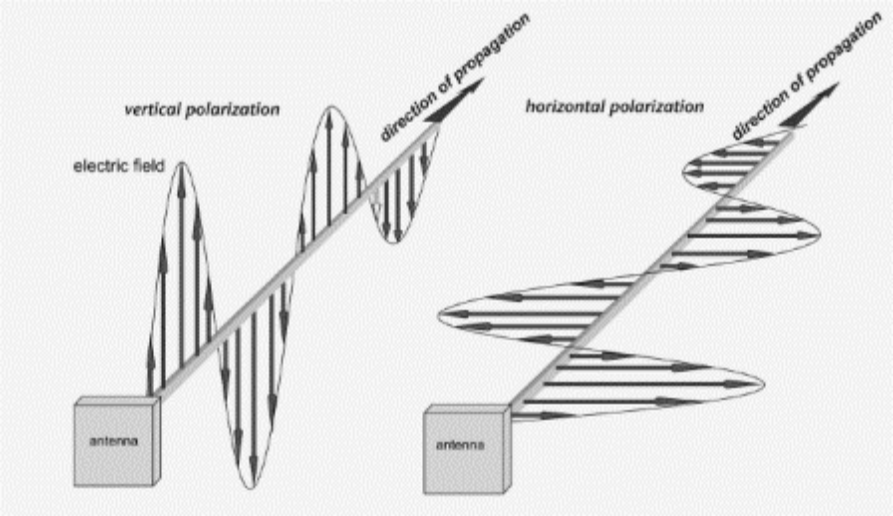
- *Knife Edge* diffraction helps radio waves "bend" around "sharp" objects



knife-edge effect

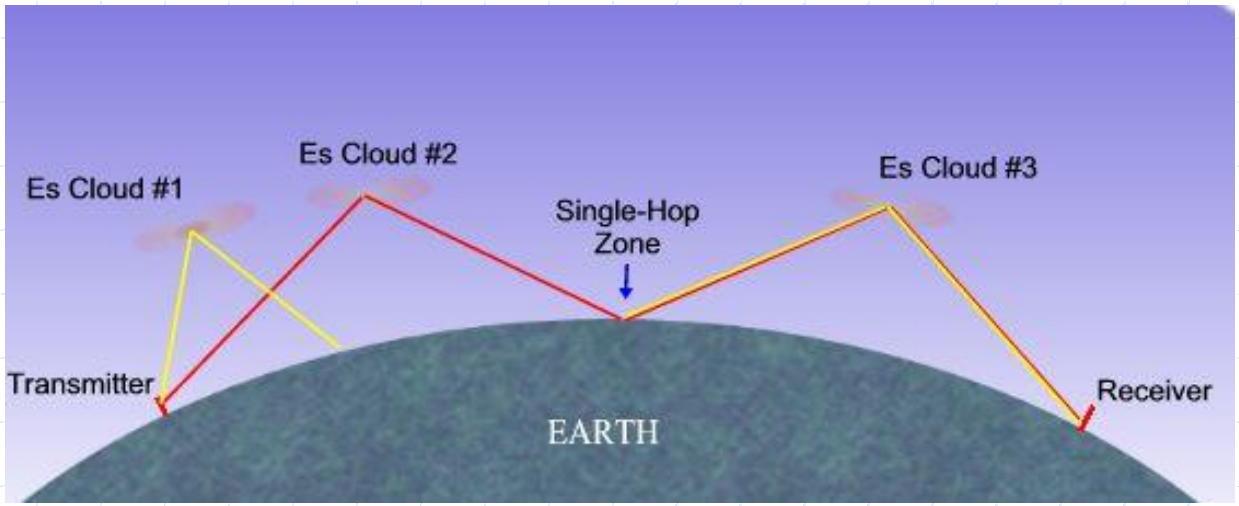
Signal Polarization

- **Polarization** is important for VHF / UHF
  - *Vertical* polarization often used for repeaters
  - *Horizontal* often used for weak-signal operation



Long Distance VHF: Sporadic-E

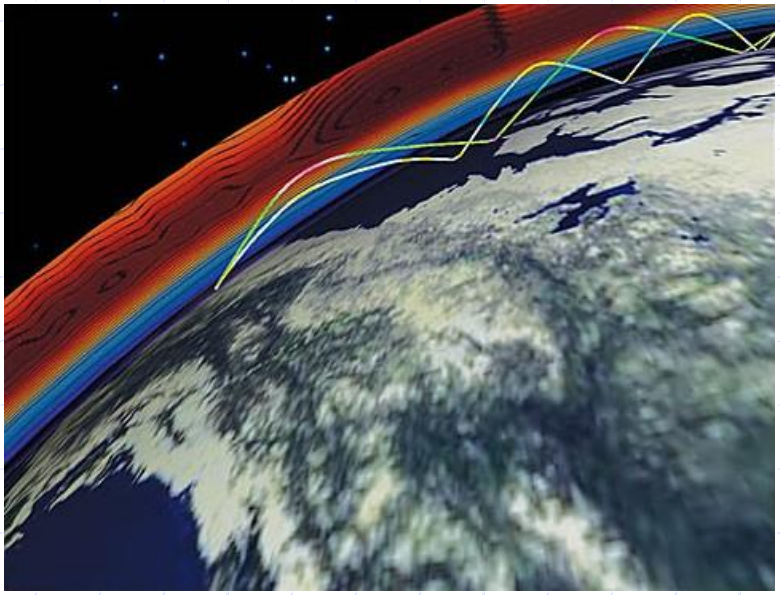
- Sometimes signals are refracted by the E-Layer - called **Sporadic-E**
- Results in strong over-the-horizon signals on 10m, 6m and 2m



More Long Distance VHF

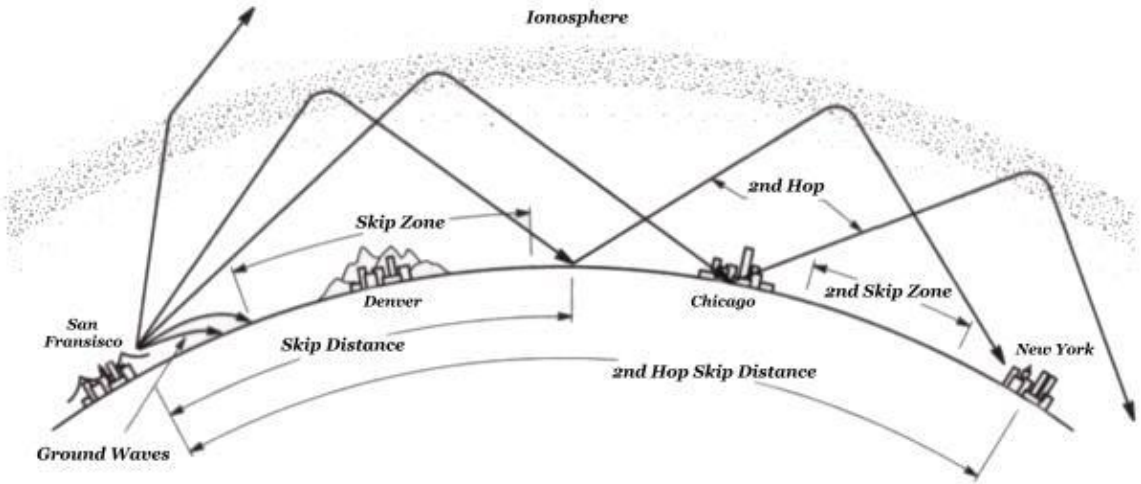
- Other long distance VHF propagation types:
  - Auroral reflection
  - Meteor scatter
  - Tropospheric scatter and ducting (tropo layer 6-10km up)
- ***Auroral*** reflected signals often have a lot of fluctuations in strength and sound distorted
- ***Meteor Scatter*** is popular on 6m
- **Tropospheric scatter** results in VHF/UHF propagation up to 300mi
- *Temperature inversions* result in **Tropospheric Ducting** – VHF propagation for hundreds of miles

HF Propagation



- HF signals can be reflected by the ionosphere
- The **ionosphere** is what enables worldwide propagation

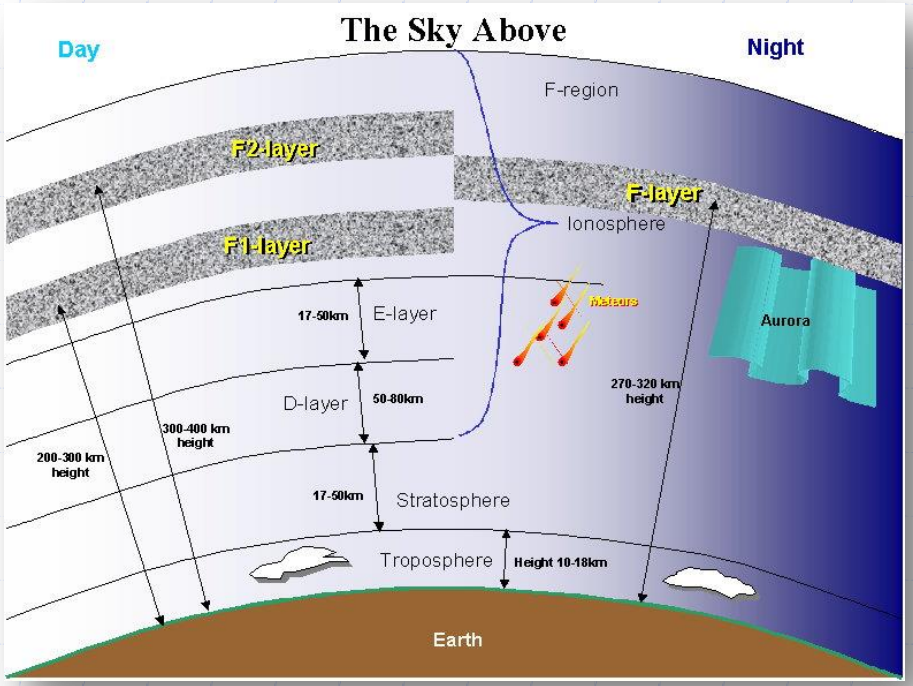
Ionospheric Skip



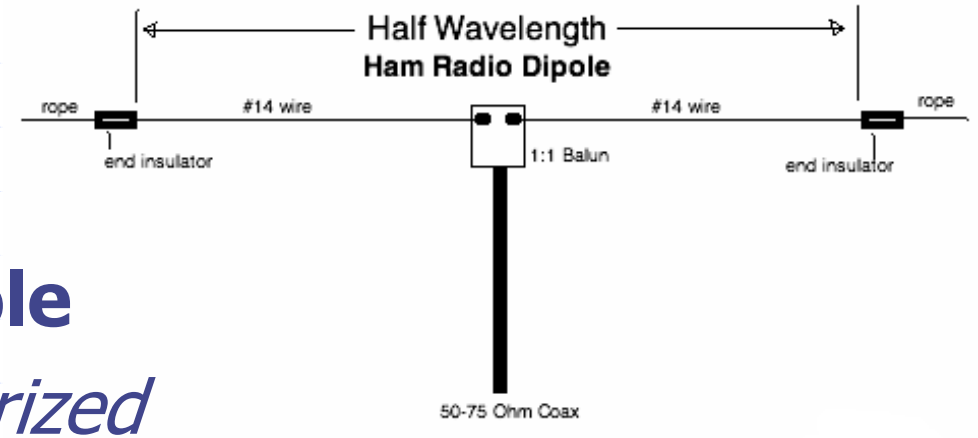
- *Fading* is common, due to random combination of signals arriving from different path lengths
- *Polarization* not so important, gets *randomized* by the reflection

Variations in Ionosphere

- Daily variations:
  - Higher bands like 10m, 15m, and 20m better during day
  - Lower bands like 40m, 80m, 160m better at night
- 11 year sunspot cycle affects ionization – thus propagation



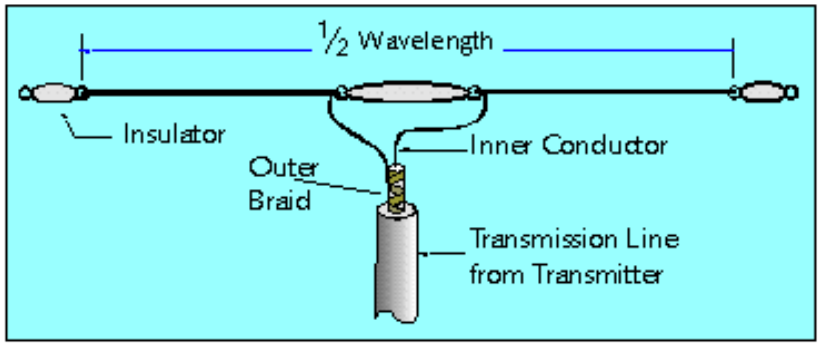
Antennas & Feedlines



- Most Common: **Half-wave dipole**
- Horizontally *polarized* when mounted parallel to earth
- Radiation is broadside to antenna

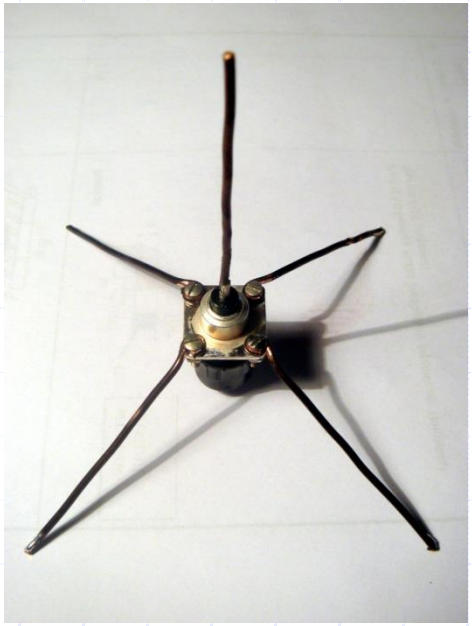
Half-Wave Dipole Details

- About 5% shorter than free-space half-wavelength
- Example: a *6m* dipole is about *112″* long
- To make it resonant on a higher frequency, you would shorten it
- L(ft) = 468 / F(MHz)

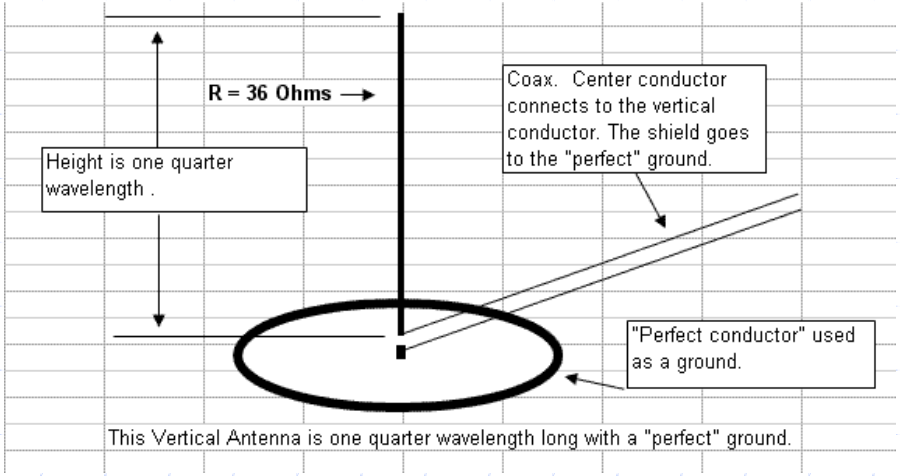


dipole antenna

Vertical Antennas

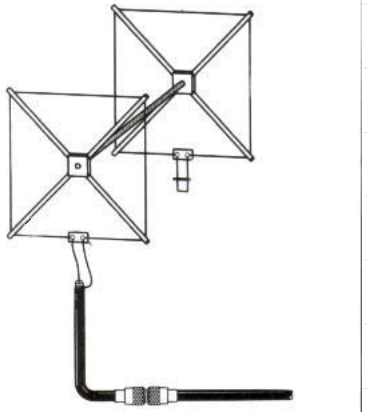


- Typically ¼ wavelength tall
- Vertically polarized, meaning the electric field is perpendicular to the earth
- A *2m* vertical is *~19"* long
- L(ft) = 234 / F(MHz)



Beam Antennas

- Concentrates energy in *one* direction
- *Quad*, *Yagi* and *Dish* are all **directional** antennas
- **Gain** is the increase in signal strength w.r.t. a reference antenna

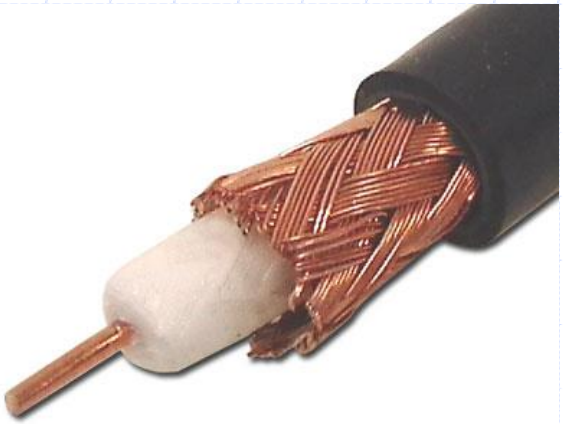


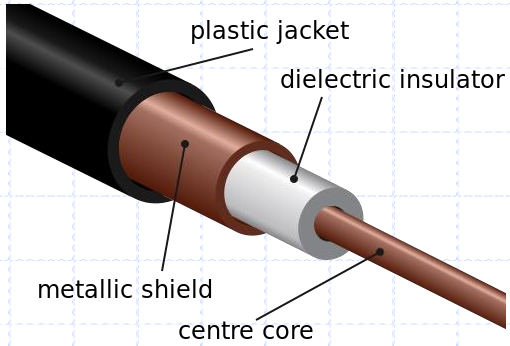
"Rubber Duck" antenna

- Flexible antenna on most handheld transceivers (HTs)
- *Disadvantage*: not as efficient as a full sized antenna
- Good reason **not** to use in a car is that the signals will be much **weaker** as compared to outside the vehicle

Feedlines

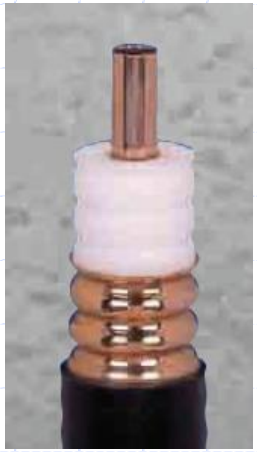
- **Coaxial** cable is used most often because
  - It is easy to use
  - Requires few special installation considerations
- Mainly used to *carry RF* between *radio* and *antenna*
- **Loss** in cable increases as frequency increases
- **Impedance** of feedline ideally matches the impedance of the transmitter and antenna – most common is **50 ohms**

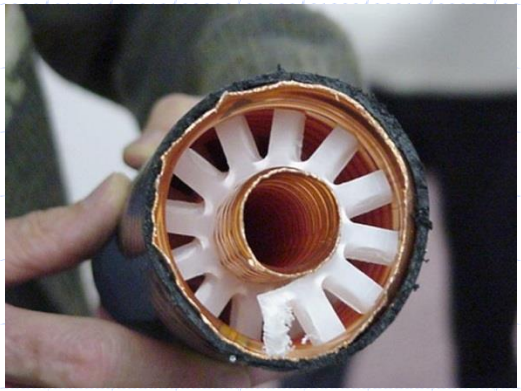




Common Coax types

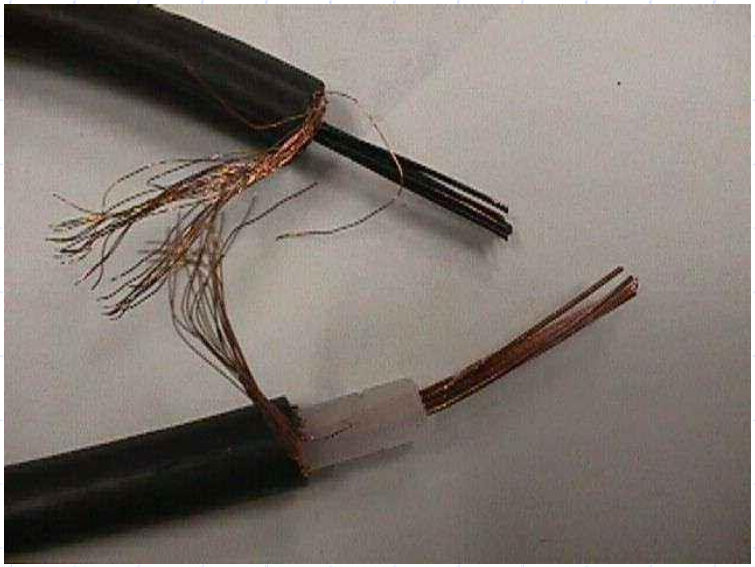
- **RG-58** and **RG-8** are the most common
- *Both* are 50 ohms
- RG-58 is thinner, but *higher loss* that RG-8
- Coax with lowest loss for **VHF** and **UHF** is *air-insulated hardline*





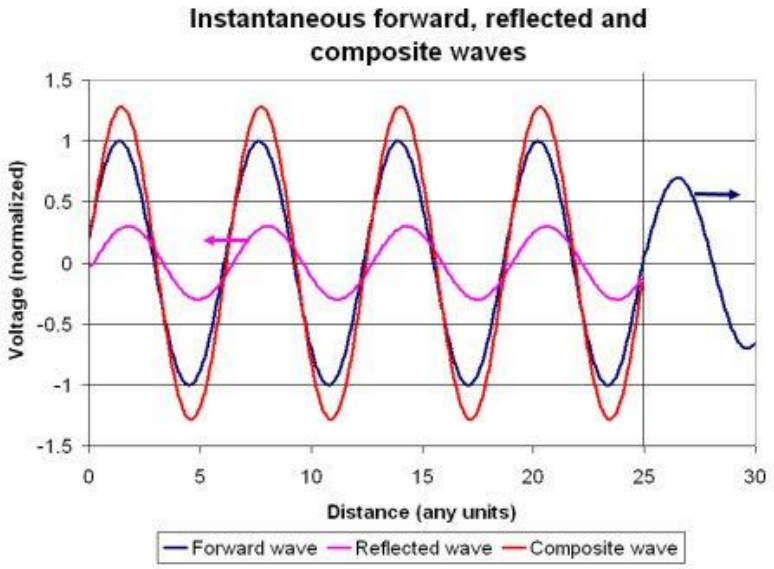
Common Coax Failure modes

- **Moisture contamination**
  - cracks in jacket
  - Around connections
- Jacket needs to be **UV resistant** to prevent cracking
- Air-Core coax requires special techniques to prevent water absorption

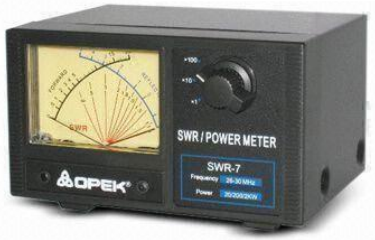


Standing Wave Ratio - SWR

- A measure of how well **matched** a *load* is to the *transmission line*
- *Low SWR needed* with coax feedlines:
  - *Efficient power transfer*
  - *Minimize losses*
- Power *lost* in a feedline is converted to **heat**



SWR Measurement



- SWR is measured with an **SWR meter**
- SWR meter is connected between the *transmitter* and *feedline*
- A **Directional Wattmeter** can also be used to determine if a feedline and antenna are matched properly
- **SWR** of 1 to 1, or 1.0:1 is a **perfect match**
- SWR of 2:1 or more is where *protection circuits* in most solid-state transmitters will *reduce power*
- *SWR of 4:1* means there is a large **impedance mismatch**
- An **antenna tuner** is used to match the antenna system impedance to the transmitter

More Measurements

- An **antenna analyzer** is commonly used to measure
  - SWR
  - *Antenna resonant frequency*
  - Capacitance
  - Inductance

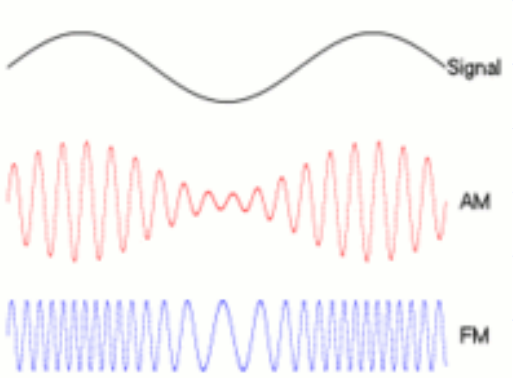
Feedline Connectors

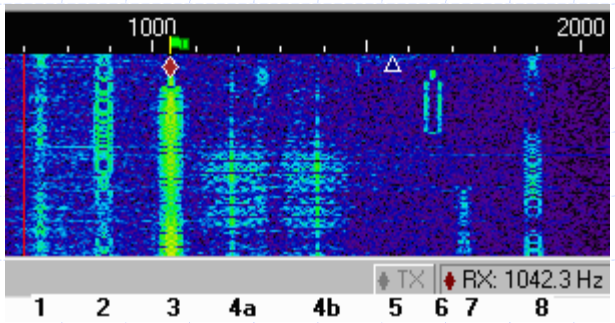
- **PL-259** is most common for **HF frequency** use
- PL-259 is not the most suitable at higher frequencies
- **Type-N** connector is most suitable above 400MHz
- Take care to *seal against water intrusion* to prevent increase in feedline loss
- **Keep 'em tight** – loose connections can cause *erratic SWR* readings

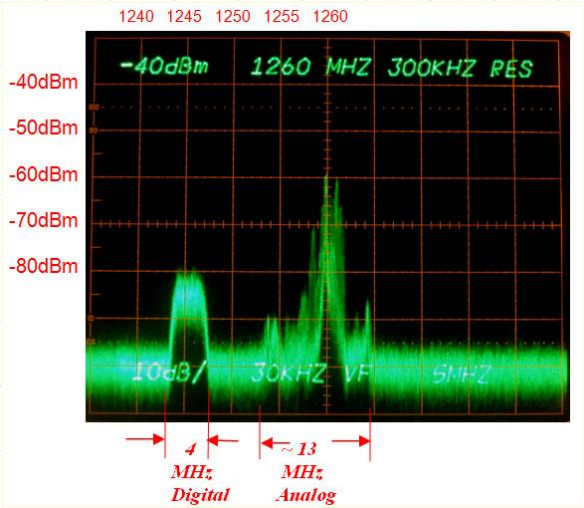
Amateur Radio Signals

Modulation Modes

Signal Bandwidth

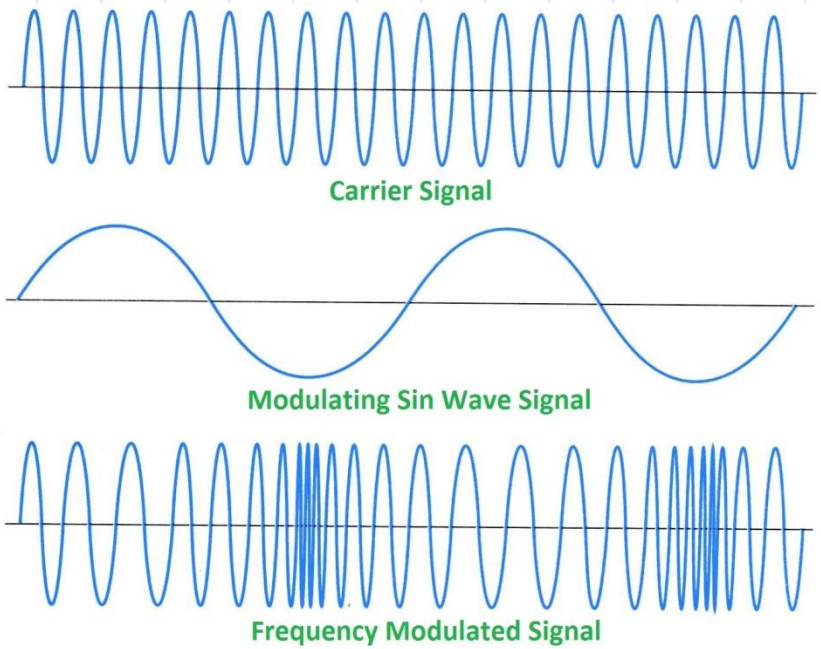






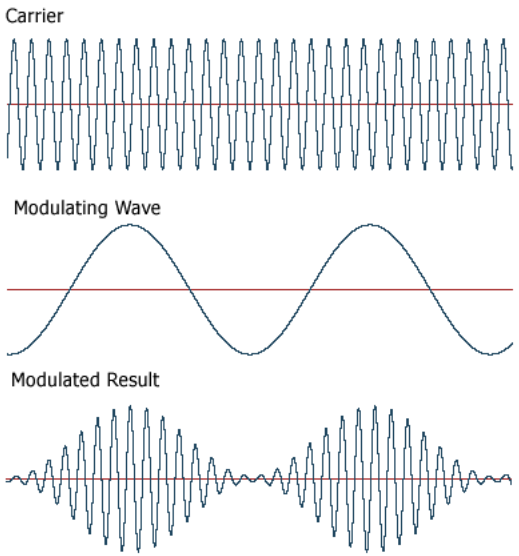
Modulation Modes: FM

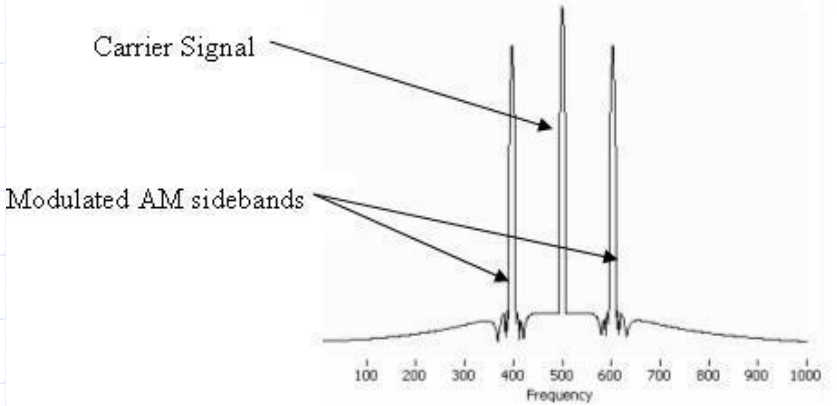
- **FM** is Frequency Modulation
- Most common on *VHF and UHF voice* repeaters
- Also used for *VHF packet radio* transmissions



Modulation Modes: AM

- AM is one of the simplest modulation modes
- The amplitude (size) of the RF carrier is varied
- Energy is present at the carrier frequency and in sidebands on either side of the carrier



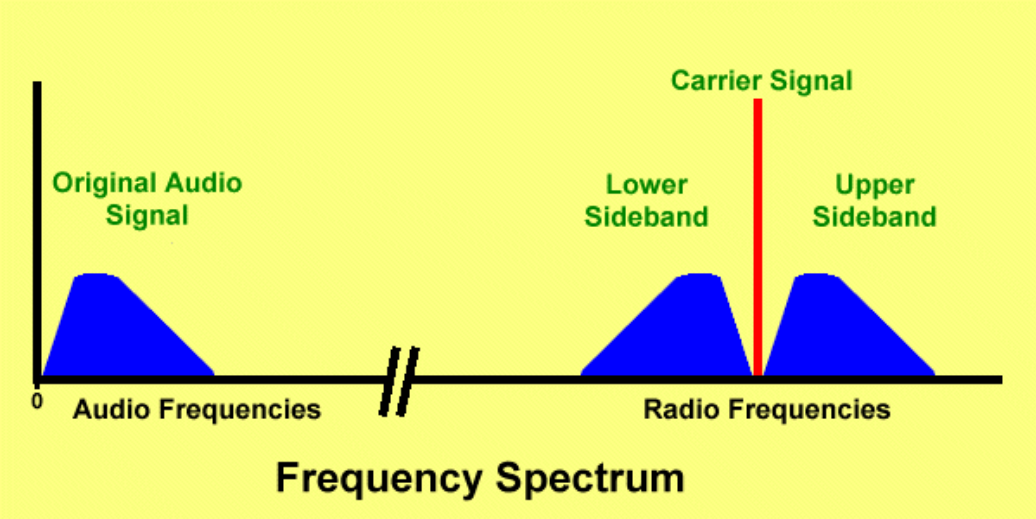


Single Sideband, or SSB

- **SSB** is a form of *Amplitude Modulation*
- Used for *long distance* and *weak-signal* contacts on *VHF & UHF*
- May be Upper or Lower (USB or LSB)
- **USB** used for 10m HF, and *VHF & UHF*

SSB Properties

- Advantage:
  narrower bandwidth vs. FM for voice
- Typically *~3kHz for SSB*
- …vs. 5-15kHz for FM



CW mode (Morse Code)

- Narrowest BW (not really) **~150Hz**
- *International Morse* is what we use
- CW can be sent using:
  - Straight Key
  - Electronic Keyer
  - Computer Keyboard

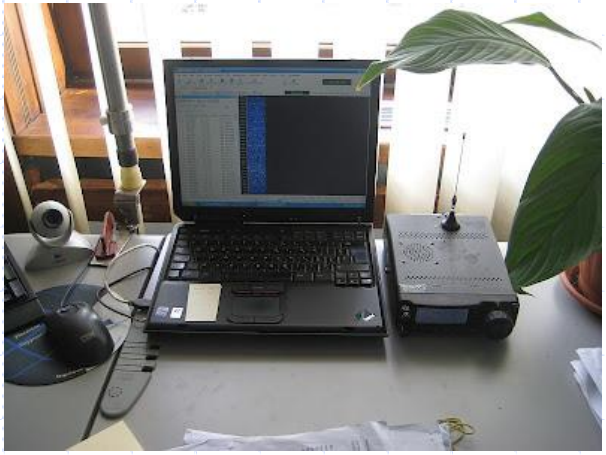
Amateur Television signals

- **Analog fast-scan TV** on 70cm band occupy *6MHz BW*
- **NTSC** refers to analog fast scan color TV signal transmission

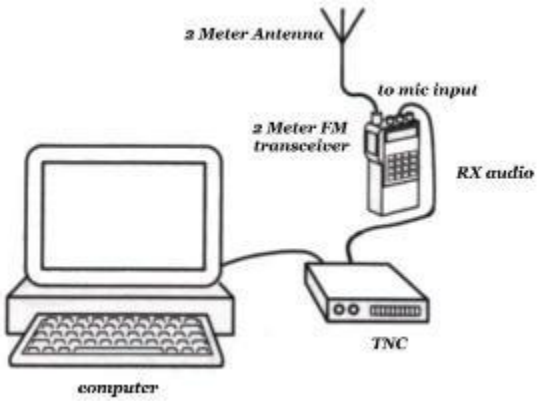
Digital Modes

- Usually using a computer + radio to communicate
- Data (not voice) is sent back and forth
- *Technician Class* can use **Data** transmission on **219-220MHz**
- Some digital modes use **parity** – *an extra code element used to detect errors in reception*

- Examples of Digital Modes:
  - Packet
  - PSK31
  - MFSK



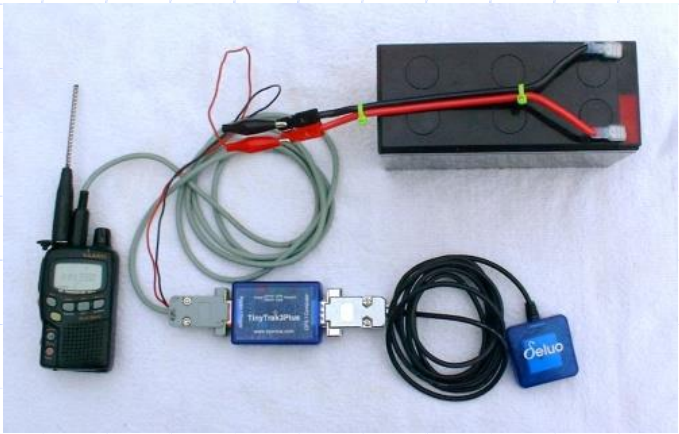
Packet Radio

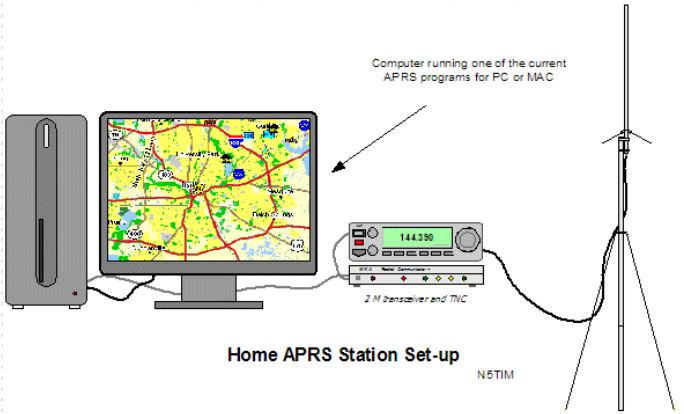


- One of the first digital modes
- Data grouped and sent in "packets"
- Packet radio includes:
  - A check sum which permits error detection
  - A header containing call sign of recipient
  - Automatic repeat request in case of an error

APRS

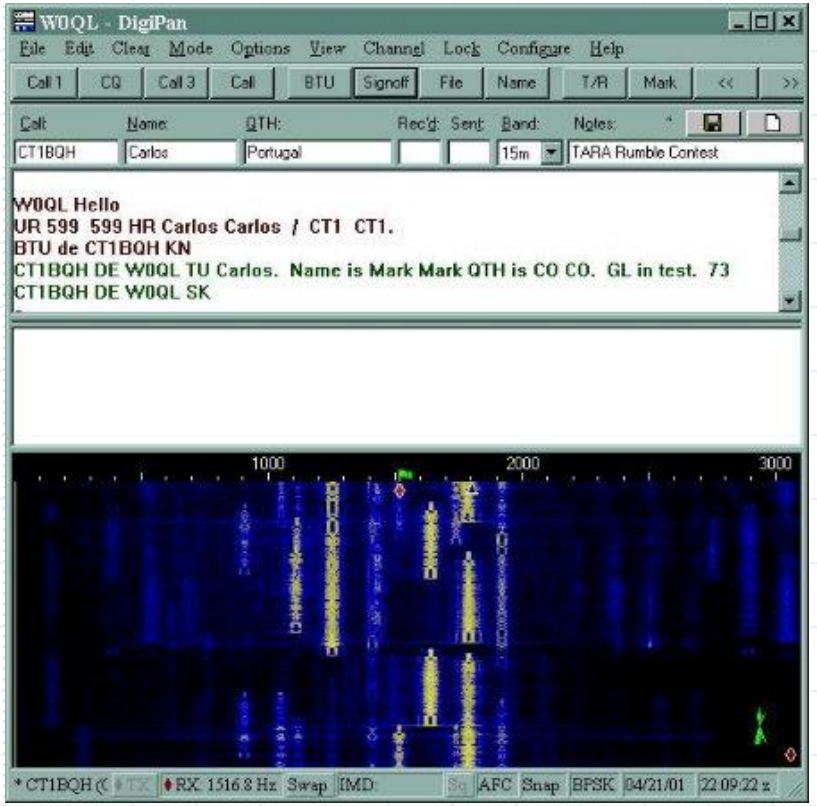
- **Automatic Position Reporting System**
- Uses Packet radio
- A **GPS** *(Global Positioning System)* receiver is used when sending position reports





Phase Shift Keying: PSK

- **PSK = Phase Shift Keying**
- A popular HF digital mode
- **PSK31** is a *low-rate data transmission mode*



Safety Concepts

- AC Power
- Hazardous Voltages
- Fuses
- Circuit Breakers
- Battery Safety
- Antenna & Tower
- Power Lines
- RF Safety

General Electrical Safety

- Easy to come in contact with dangerous voltages
- **30 Volts** or more can result in dangerous shock
- **100mA** flowing through body can cause death

- **How does current flowing in the body cause harm?**
  - *Heating tissue*
  - *Disrupts electrical function of cells*
  - *Involuntary muscle contractions*

AC Power Safety

- 3-wire outlets and plugs are safer
- 3rd wire is a **Safety Ground**
- **Safety Ground** is often connected using a **green** wire

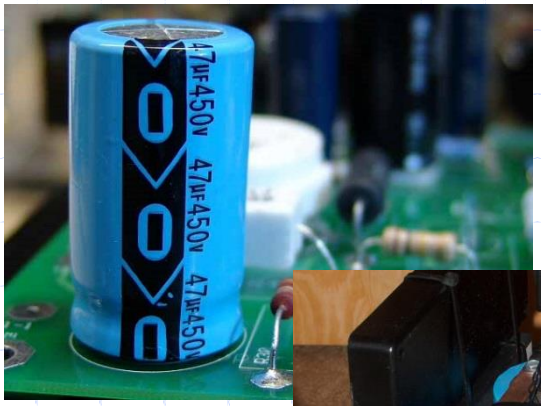
- Good ways to guard against electric shock:
  - *Use 3-wire cords and plugs for all AC equipment*
  - *Connect all AC powered equipment to a common safety ground*
  - *Use a circuit protected by a ground-fault interrupter*

Fuses & Circuit Breakers

- *Interrupts power* in case of an overload
- Always replace fuses with *same type and rating*
- Putting a 20A fuse in place of a 5A fuse can cause a *fire* from excessive current flow
- Always include fuse or circuit breaker in home-made equipment
- Fuses in 120V AC powered equipment are used in the "hot" lead.

Working on Equipment

- Disconnect from power
- **Capacitors** in power supplies can *store charge and shock you* – even when disconnected
- Work with one hand



Battery Safety

- 12V Lead-Acid Battery Hazards
  - Explosive gas can collect if not vented
  - If charged/discharged too quickly – can overheat and give off flammable gas or explode
- If power is out, re-charge 12V battery by connecting to car battery and running the engine (well ventilated area)

Antenna Safety: Installation

- Look for and stay clear of overhead electrical wires
- Keep 10ft of clearance to power lines, even if the antenna should fall
- Never use a utility pole as a support

What's wrong with this picture?

Antenna Placement

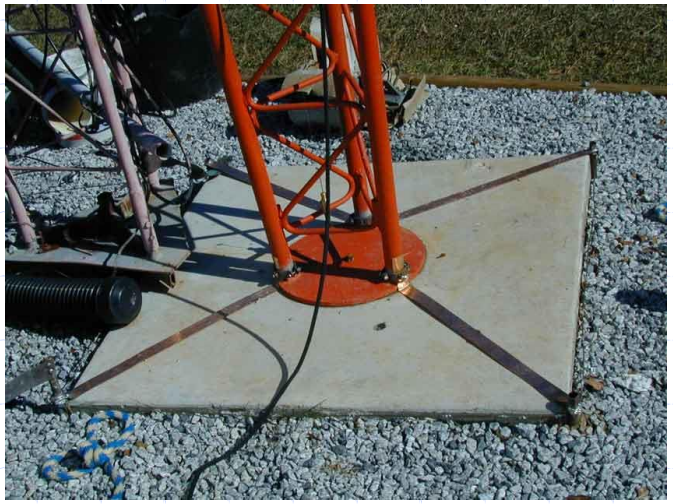
- Position antenna so no one can come in contact when transmitting
- RF burns are painful and dangerous

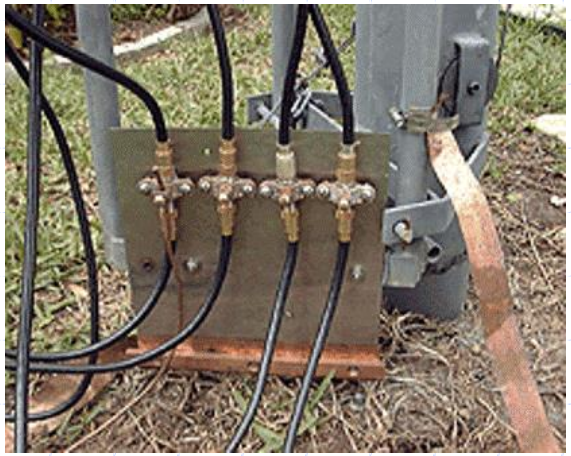
Tower work

- Use a **gin pole** to lift tower sections or antennas
- Always use **safety harness**
- *Everyone* wears **hard hat** and **safety glasses**
- *Never climb alone*
- Crank-up towers must be fully *retracted* before climbing

Tower Grounding

- Very important – the tower is a *big lightning rod!*
- **Local electrical codes** should be consulted
- Separate 8’ ground rods per tower leg is good practice
- Bond all legs and rods together
- Short / direct connections
- Avoid sharp bends
- All feedline lightning protection devices should be mounted to a common plate and connected to an external ground





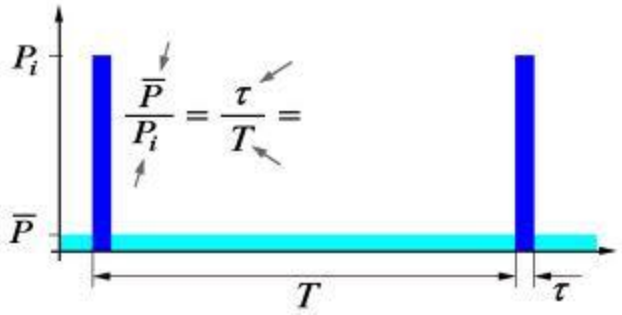
RF Exposure

- When using high power
  - you are *required* to perform an **RF Exposure evaluation**
  - even though VHF & UHF are **non-ionizing radiation**
- On *VHF*, you can run up to **50W PEP** at the antenna without performing an exposure evaluation

- RF Exposure Evaluation can be performed:
  - *Calculation based on FCC OET Bulletin 63*
  - *Calculation based on computer modeling*
  - *By measurement of field strength using calibrated equipment*

RF Exposure: Duty Cycle

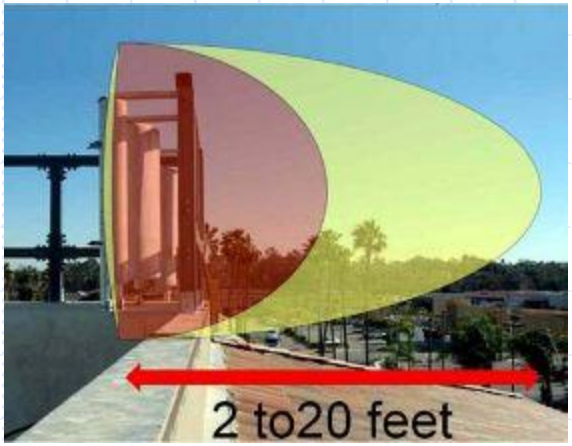
- Ratio of on-air time to total operating time
- **Duty Cycle** is factored into exposure because affects the *average exposure level*



RF Exposure Limits

- Vary with Frequency
- The human body absorbs more energy at some frequencies than others
- The **50MHz** band has the lowest **Maximum Permissible Exposure Limit**

- Factors that affect Exposure
  - Frequency & Power level of RF Field
  - Distance from antenna to person
  - Radiation pattern of antenna



Keeping Exposure safe

- Relocate antennas
- Lower power levels
- Transmit less

- Re-evaluate if you make any changes in station or antenna setup

Station Setup and Operation

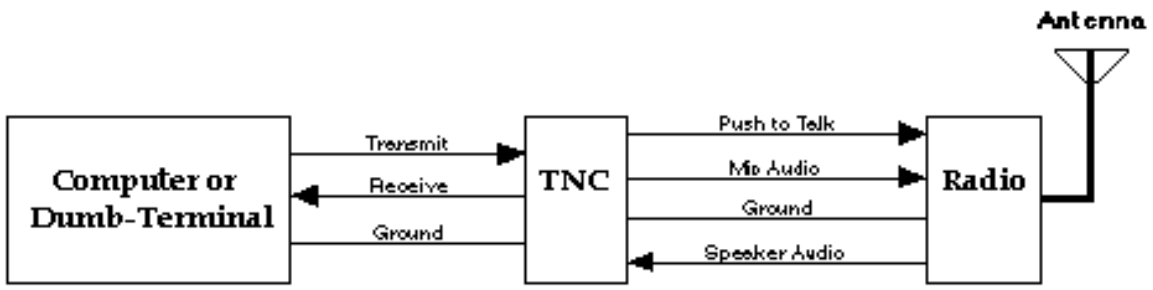
- Station accessories
- Dealing with Interference
- Grounding
- Operating controls
- Station Equipment
- Troubleshooting
- Repair and Testing

Station Accessories

- Power Supply
  - Regulated, *to prevent voltage fluctuations from reaching sensitive circuits*
  - Sufficient voltage / current
- Headphones
  - Helps copy in *noisy areas*
- Microphone
  - *Rig connector includes push-to-talk and sometimes power for mic*

Digital Mode Accessories

- **Packet**
  - Terminal Node Controller (TNC)
  - Converts 1's and 0's to audio tones
- **RTTY or PSK31**, etc.
  - *Sound card* often performs TNC/modem function
  - Provides audio to microphone input, converts received audio to digital
  - Often an audio interface is used to adjust audio levels and provide some ground isolation



Interference killers

- Ferrite chokes
  - *Help eliminate stray RF from power supply and other cables*
  - *Reduce RF flowing on shield of audio cables*
- Low Pass Filter
  - *Used between the transmitter and antenna to eliminate harmonic emissions*

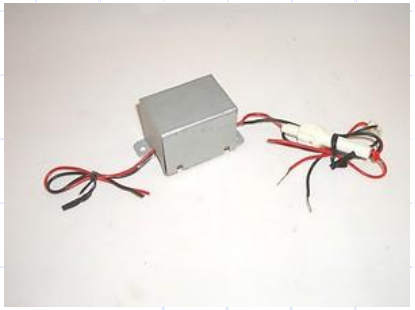
More Interference killers

- TV Interference
  - *Band-Reject* filter at TV input
  - Helps prevent overload from nearby transmitter

Grounding helps too…

- Flat strap is best
- Connect all equipment to a common ground
- Car installations
  - Radio ground connection to chassis or engine block strap
  - Bond all grounds

More Car install tips…



- Positive supply
  - Direct to battery
  - Unused fusebox terminal
- Alternator noise/whine
  - *Varies with RPM*
  - *Filters help*
- Ignition noise
  - *Pulsing/ticking*
  - *Noise Blanker helps*

Operating Controls

RIT: *Receive Incremental Tuning* used to fine tune receive frequency (not transmit frequency). Sometimes called *Clarifier.* Helpful if a SSB signal is high or low pitched.

AF: Audio Frequency gain – just a fancy name for Volume control

Sets RF power output

Microphone Gain: *too high and your signal will be distorted*

Adjusts Receiver gain

Squelch: *mutes the receiver when no signal is being received. Don't set it too high, or you'll miss weak signals!*

Operating Controls

HF Transceivers often have a selection of filters which *permits noise or interference reduction by selecting a filter bandwidth that matches the mode.*
Examples:
2400Hz for SSB
500Hz for CW

Operating Frequency is set by *VFO knob or keypad entry*

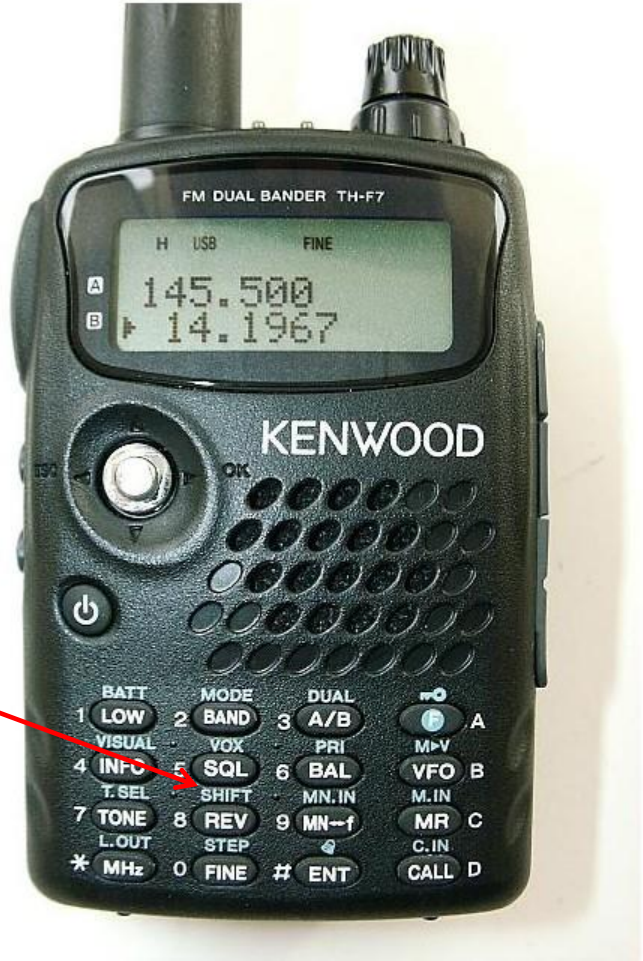
Favorite frequencies can be stored in a memory channel for easy access

Operating Controls

Offset Frequency: *the difference between a repeater's transmit and receive frequencies*

The transceiver's offset is set by an Offset or Shift control.

The REVerse control toggles between transmit and receive frequencies



Station Equipment

- Most basic pieces are **transmitter** & **receiver**
- When in one unit it is called a **transceiver**
- Antenna is switched between transmitter and receiver

Station Equipment

- The figure shows a **transceiver**
  - 1: transmitter portion
  - 3: receiver portion
  - **2: transmit-receive switch**

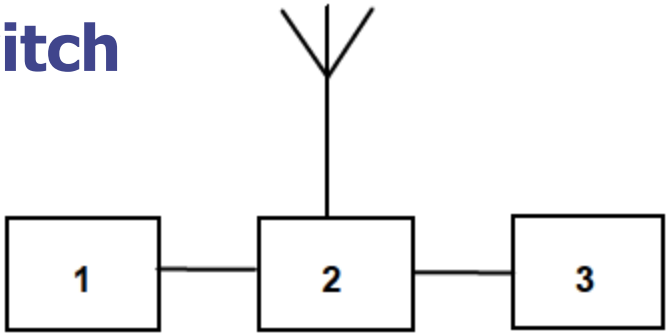


Figure T5

Receiver block diagram

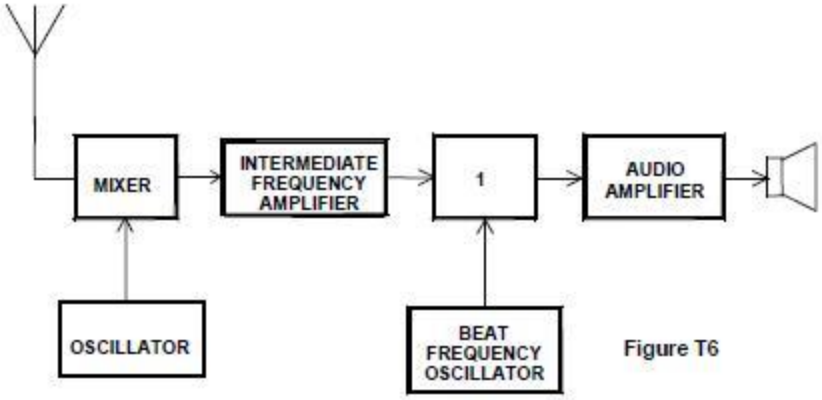


Figure T6

- Figure T6 shows a **single-conversion superheterodyne receiver**
- The **mixer** *shifts the incoming signal to an intermediate frequency*
- **Block 1** is a **Product Detector**, *used to detect CW and SSB signals*

Receiver characteristics

Selectivity

- *The ability of a receiver to discriminate between multiple adjacent signals*
- Receive filters can improve a receiver's selectivity

Sensitivity

- How weak a signal the receiver can detect
- An RF preamplifier can help improve sensitivity
- *An RF preamplifier is installed between the antenna and receiver*

FM Receiver

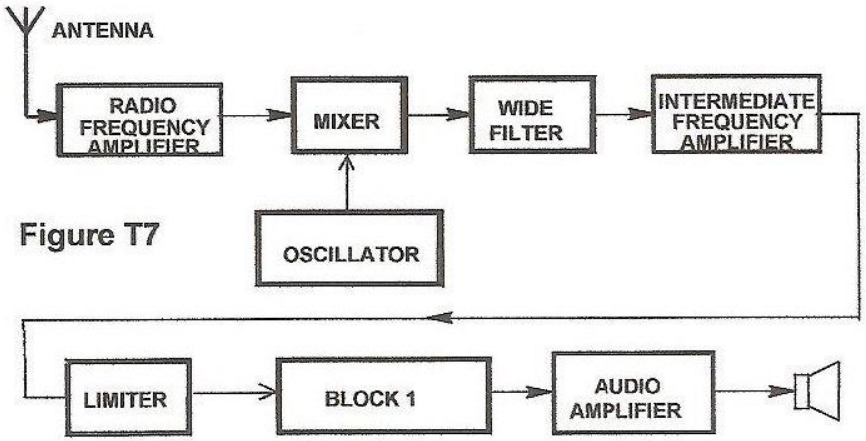


Figure T7

- If **Block 1** is a *frequency discriminator*, then the circuit pictured is an *FM Receiver*
- A **discriminator** is the circuit that *demodulates* FM signals

CW Transmitter

- Simplest transmitter
- **Block 1** is an **oscillator**
- The oscillator generates the frequency that you are going to transmit on

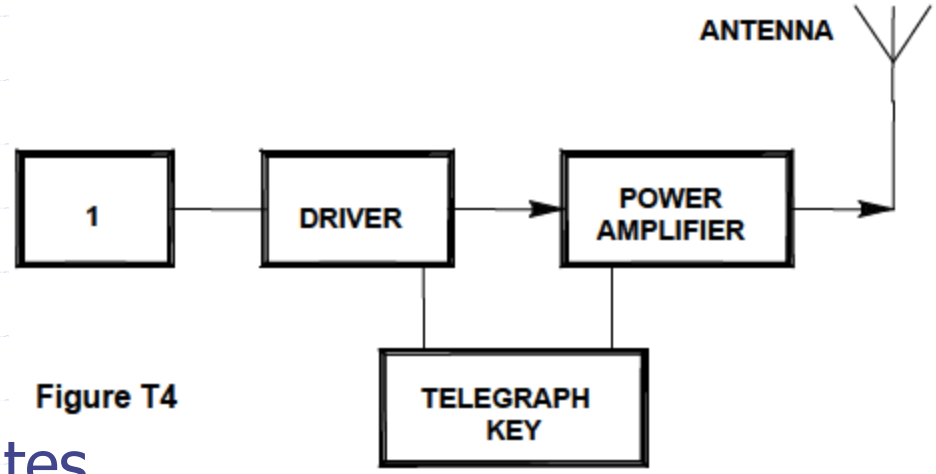
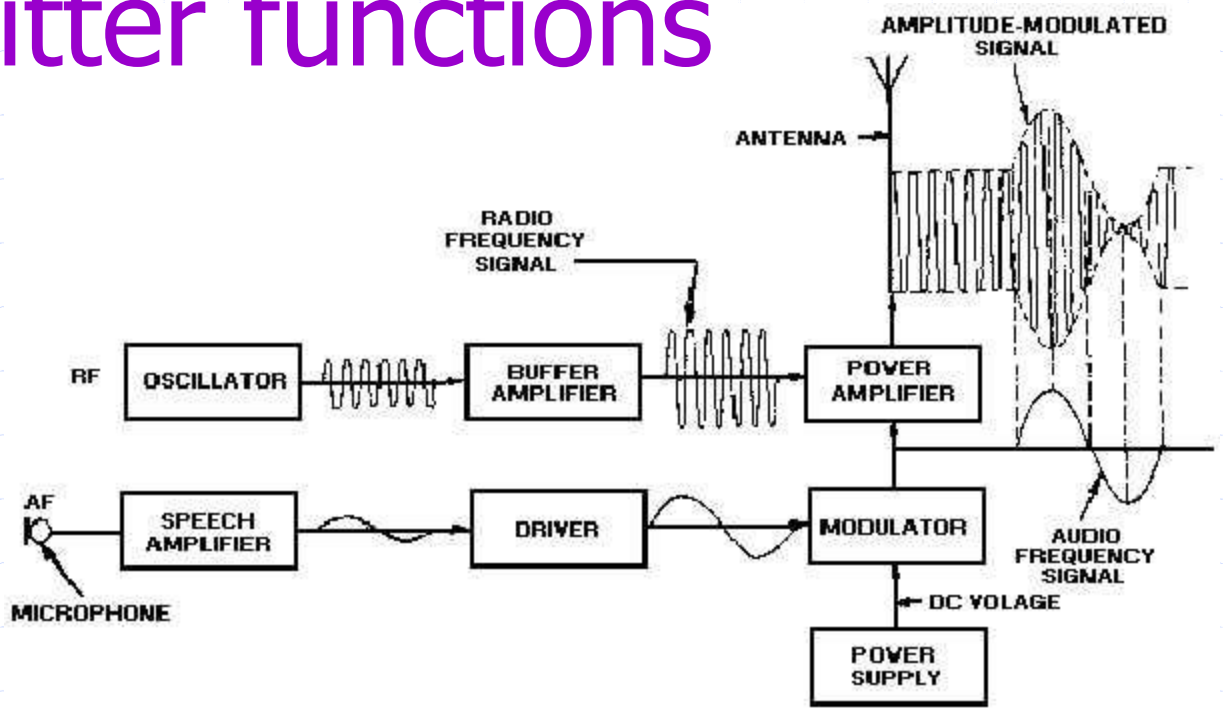


Figure T4

Transmitter functions



- Voice modes like *SSB* and *FM* need a modulator
- A **modulator** *combines the RF carrier and the audio/speech signal*

Transverter

- Used to operate on a frequency which a radio was not designed for
- A **transverter** *is a device that takes the output of a low-powered 28MHz SSB exciter and produces a 222MHz output signal*
- It also converts an incoming 222MHz signal to a 28MHz signal for the receiver

Some VHF & UHF info…

- Most operation is using FM and Repeaters
- CW and SSB is also popular – often weak signals
- *The device most useful for VHF weak signal communications is a **multi-mode VHF transceiver***

- Handheld transceivers (HTs) have low power transmitters (5W or less), which limits range
- *The device that increases the low-power output from a handheld transceiver is an **RF power amplifier***

Troubleshooting Common Problems

- Overload
- Distortion
- Feedback
- Interference

- **What can cause radio frequency interference:**
  - *Fundamental overload*
  - *Harmonics*
  - *Spurious emissions*
- Any of these can cause radio or TV interference

If someone tells you that your transmissions are causing interference, you should first ***make sure that your station is functioning properly and not causing interference to your own TV and radio***

Telephone interference

- Telephones often experience interference
- *Most likely cause of interference to a non-cordless phone from a nearby transmitter is that the* ***telephone is acting like a radio receiver***
- Logical first step to cure radio interference on a telephone *is to install an RF filter at the telephone*

Unprotected Telephone

Addressing Interference

- Useful ways to cure RF interference
  - *Snap-on ferrite chokes*
  - *Low-pass and high-pass filters*
  - *Band-reject and band-pass filters*

- **Fundamental Overload** *is interference caused by very strong signals injected into a receiver*

Part 15 Devices

This device complies with part 15 of FCC Rules. Operation is subject to the following two conditions; (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

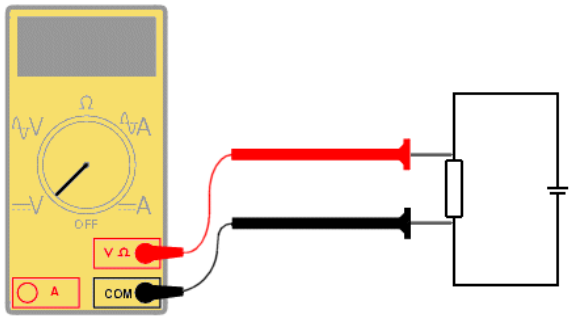
- If a neighbor's device is causing interference:
  - *Work with them to identify offending device*
  - *Politely inform them about the rules that require them to stop using the device if it causes interference*
  - *Check your station to ensure it meets standards of good amateur practice*

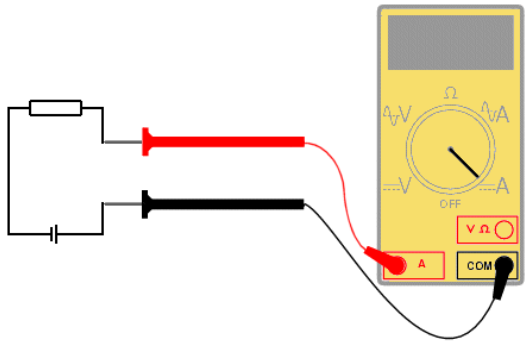
Common Problems

- **Distorted / Noisy Audio**
  - *Transmitter might be slightly off frequency*
  - *Batteries might be running low*
  - *You might be in a bad location*
- **Garbled, Distorted or Unintelligible transmission**
  - *RF Feedback*
  - Over-deviation on FM
    - *Back off the mic*
- **Noise in digital transmissions causes bit errors**
  - **BER**: *Bit error rate, the rate at which errors are occurring*
- **High pitched whine**
  - *Noise from vehicle's electrical system, usually alternator*

Using a Multimeter or DMM

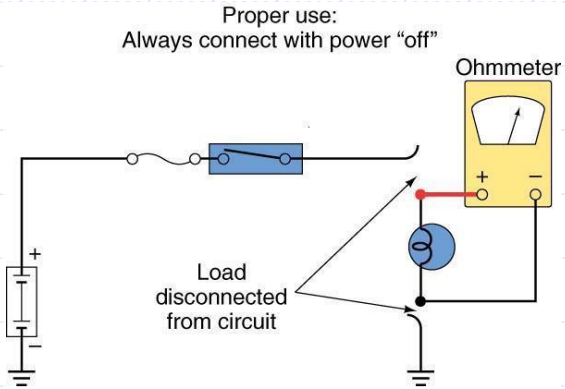
- **Multimeter** = voltmeter, ohmmeter and ammeter
- **DMM** = digital multimeter
- Measuring **voltage** and **resistance** are *common*
- *To measure **voltage**, the voltmeter is placed in parallel with the circuit*
- *To measure **current**, the ammeter is placed in series with the circuit*

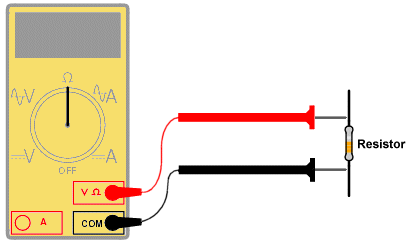




Measuring Resistance

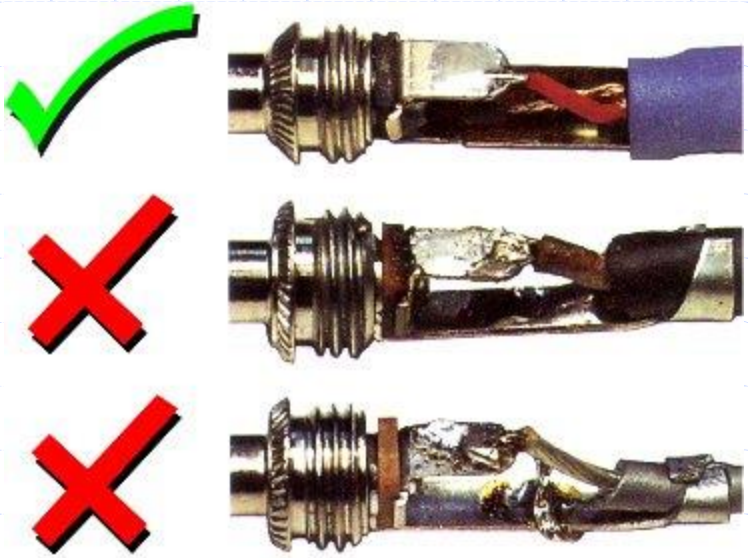
- **Ohmmeter** is used to measure *resistance*
- *Attempting to measure a voltage on the resistance setting might damage the meter*
- *When measuring **resistance**, an initial low reading that **slowing increases** means that the circuit contains a large capacitor*





Soldering

- Good skill to have!
- ***Rosin-core solder*** *is best for radio and electronic use*
- Joints should be smooth and shiny
- ***Dull*** *or* ***grainy*** *surface is characteristic appearance of a "**cold**" solder joint*



Operating Procedures

FM Operation

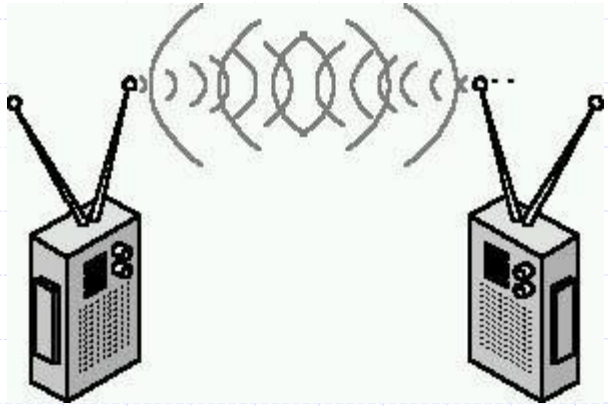
Most new Technicians start with a VHF/UHF FM transceiver

- **Repeaters**
  - Listen to you on one frequency (*Input*)
  - Re-broadcast you on another frequency (*Output*)
- **Your Radio must:**
  - Transmit on the *Input*
  - Receive on the *Output*
- **Difference** between *Input* and *Output* frequencies is called the **Split**

- **Common Repeater Splits**
  - **+/- 600kHz** for the **2m** band
  - **+/- 5MHz** for the **70cm** band

Duplex and Simplex

- Duplex Communication
  - Tx & Rx on two different frequencies
- **Simplex Communication**
  - **Tx & Rx on the same frequency**
- National simplex frequency
  - **446.000MHz on 70cm**
  - 146.520MHz on 2m



Repeater details

- **CTCSS** tones
  - *Sub-audible tone sent with your voice to open the squelch on repeater*
  - Also called PL (private line) tone
- **Reasons why you can *hear* a repeater, but can't talk on it:**
  - **Repeater req's audio tone burst for access**
  - **Repeater req's CTCSS for access**
  - **Repeater may require a DCS tone sequence for access**

Some VHF/UHF Trx Controls

- **Carrier Squelch**
  - Mutes Rx in the absence of an RF signal
- **Microphone Gain**
  - Changes the *amplitude* of the modulating signal
  - Determines the amount of **FM deviation**
  - If **deviation** is **increased**, the signal **occupies more BW**

Repeater Operation

- How to strike up a conversation…
  - CQ isn't really used
  - Say your **call sign** to indicate that you're a listening
- To call someone…
  - Say **their call sign, identify** with **your call sign.**

HF Operation

- **CQ** means *"calling any station"*
  - "CQ, CQ, CQ, this is W2AEW calling CQ"
- **Responding** to a CQ
  - *Transmit the other station's call sign, followed by yours*

Station Identification

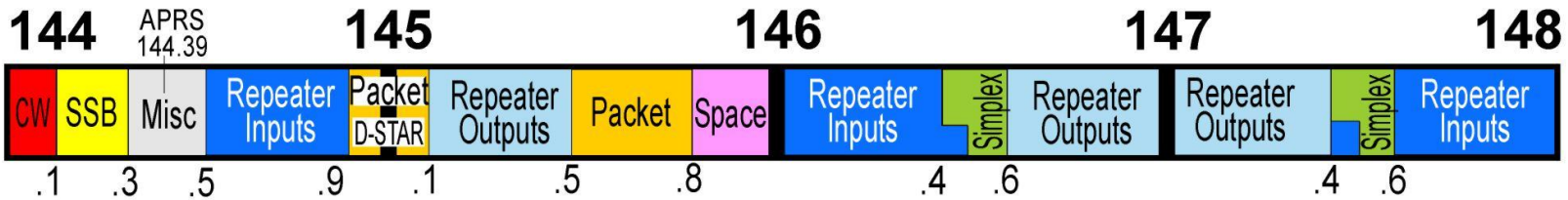
- Always **properly identify when transmitting**, even when testing
- Identify at least **every 10 minutes** of operating, and when you **end** operating

More HF Details

- Techs can operate CW on 80/40/15/10m
- **Q-Signals** used as shorthand
  - **QRM** indicates your getting interference from other stations
  - **QSY** indicates you are changing frequency

General Guidelines

- **Band Plan:** a voluntary guideline for different modes and activities in an amateur band
- Amateurs must use **minimum power necessary** to carry out desired communication
  - Allowed up to 1500W on VHF and above, 500W on HF



More Guidelines

- *Stay Clean*
  - If you get a report you're causing splatter or interference, **check your transmitter for off-frequency operation or spurious emissions**
  - If you unintentionally cause interference, then **properly identify yourself and move to a different frequency**
- Use of **phonetic alphabet** is encouraged by FCC
  - *Learn it, use it!*

A - ALPHA	N - NOVEMBER
B - BRAVO	O - OSCAR
C - CHARLIE	P - PAPA
D - DELTA	Q - QUEBEC
E - ECHO	R - ROME0
F - FOXTROT	S - SIERRA
G - GOLF	T - TANGO
H - HOTEL	U - UNIFORM
I - INDIA	V - VICTOR
J - JULIET	W - WHISKEY
K - KILO	X - X-RAY
L - LIMA	Y - YANKEE
M - MIKE	Z - ZULU

Public Service
Emergency & non-emergency

- Uniquely qualified to help
- **FCC Rules** still apply when using amateur radio for public service purposes

- ***May use any means necessary for essential communication when there's immediate danger to life, safety and property damage***

RACES & ARES

- RACES: **R**adio **A**mateur **C**ivil **E**mergency **S**ervice
- *Amateur stations for emergency mgmt or civil defense communications*

- ARES: **A**mateur **R**adio **E**mergency **S**ervice
- Both **RACES** & **ARES** *may provide communications during emergencies*

Common for these groups to form a network, or "*net*"

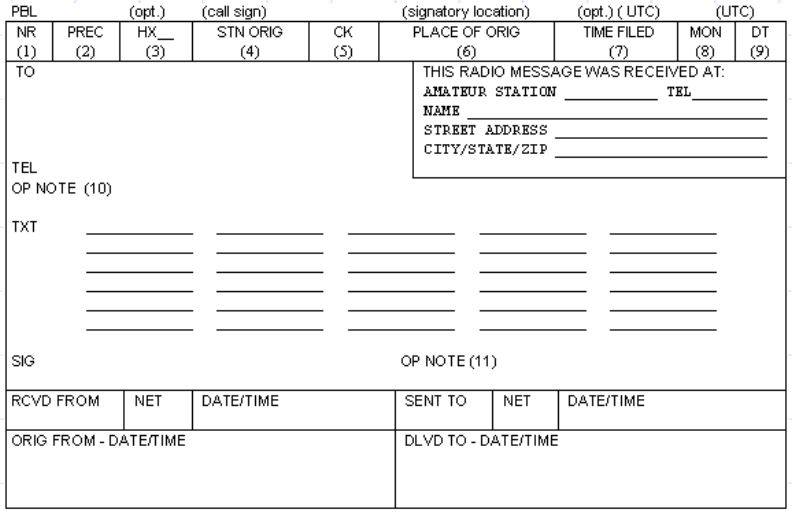
Orchestrated by a "*net control operator*"

Messages passed during these operations are called "*traffic*"

Message / Traffic handling

- Informal & Formal
- Most important: **pass messages exactly as written, spoken or received**

- Formal Messages
  - Preamble
  - Address
  - Text
  - Signature



PBL (opt.) (call sign) (signatory location) (opt.) (UTC) (UTC)

NR (1)	PREC (2)	HX__ (3)	STN ORIG (4)	CK (5)	PLACE OF ORIG (6)	TIME FILED (7)	MON (8)	DT (9)

TO

THIS RADIO MESSAGE WAS RECEIVED AT:
AMATEUR STATION _____ TEL_____
NAME _____
STREET ADDRESS _____
CITY/STATE/ZIP _____

TEL
OP NOTE (10)

TXT

SIG

OP NOTE (11)

RCVD FROM	NET	DATE/TIME	SENT TO	NET	DATE/TIME

ORIG FROM - DATE/TIME	DLVD TO - DATE/TIME

Formal Traffic Messages

- ***Preamble*** used to **track** the msg as it passes thru the amateur traffic handling system
  - The preamble **check** is the **number of words or word equivalents in the text** of the message
- *Address* is the name/address of the recipient
- *Text* is the body of the message
- *Signature* identifies the originator

Net Operation / protocol

- All communications through net control
- **Only transmit when directed by the NCS**

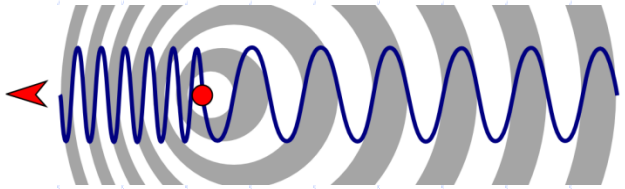
- If your emergency can't wait – get **attention** of **NCS** by begin your transmission with "**Priority**" or "**Emergency**" followed by your **call sign**

Amateur Satellites

- Repeater in space
  - Uplink & downlink frequencies
  - Often on different bands
  - **U/V mode**: *uplink* in **70cm** band, *downlink* in **2m** band
- Need license **privileges** to transmit on *uplink frequency*
  - Use minimum power necessary

- ***Talk to amateur radio operators in other countries***

More Satellite info



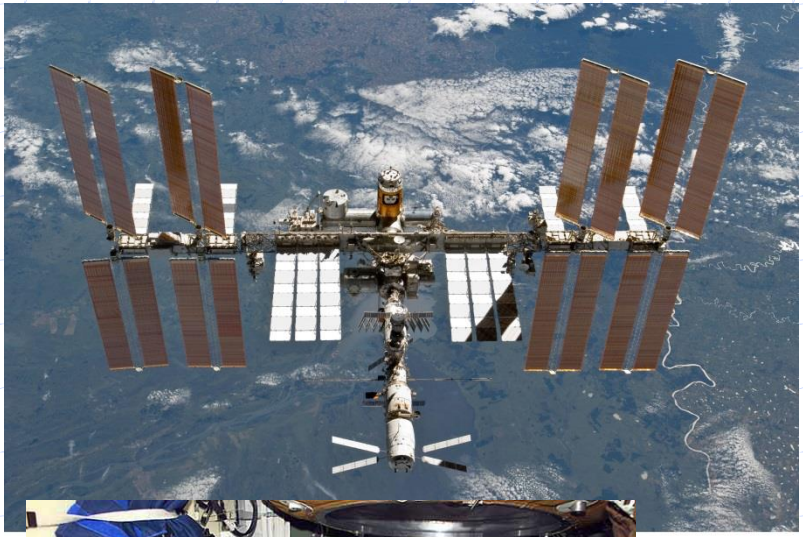
- **Satellite Beacon**:
  - Transmission from a space station/satellite that contains **info** about the satellite
- **FM Packet** is commonly used to send to/from digital satellite
- A **satellite tracking program** is often used to determine when a satellite can be accessed

Common Problems…

- **Doppler Shift**
  - Observed *change in frequency* due to relative motion between satellite and earth station
- **Spin Fading**
  - Caused by *rotation* of the satellite and its antenna

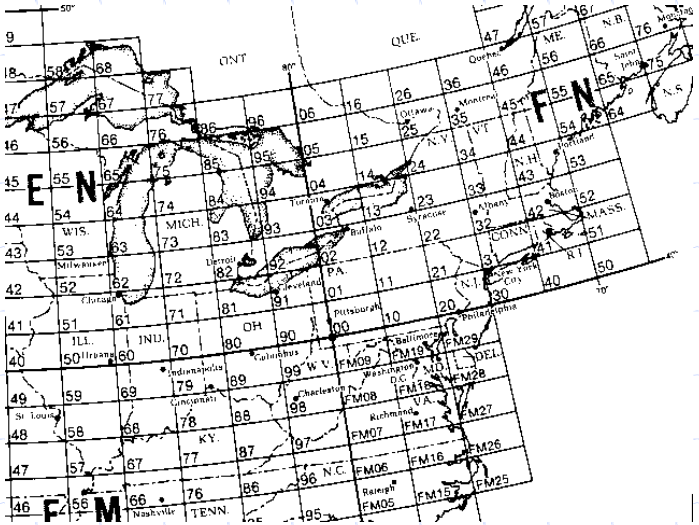
International Space Station

- Any **Technician** class can make contact to the ISS on **70cm** and **2m**
- ISS is a **L**ow **E**arth **O**rbit (**LEO**) satellite



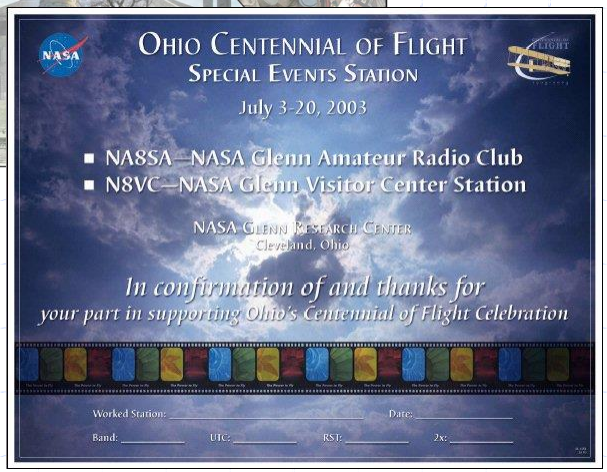
Fun activities

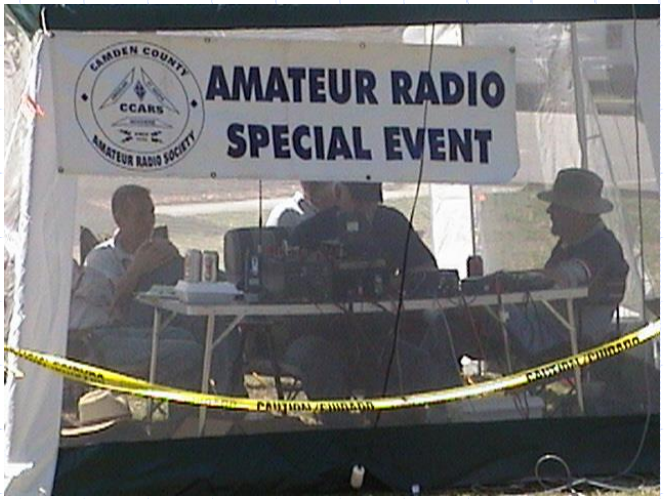
- **Contesting**
  - Make many contacts in a *specific time period*
  - Good practice: send only **minimum amount of info req'd** for ID and contest exchange
  - Be mindful of others on the band
- **VHF/UHF Contests**
  - Often use grid locators: **letter-number designation** for geographic location



More Fun Activities

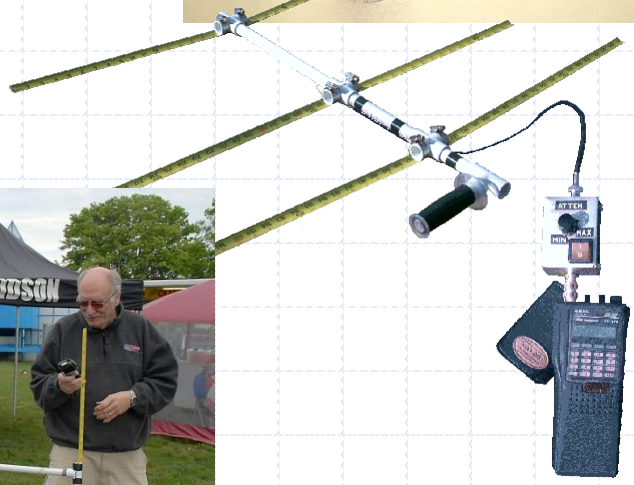
- **Special Event Stations**
  - 1x1 call signs
  - Often for events of **special significance** to amateur community





Even more fun…

- **Radio Direction Finding** (Fox Hunting)
  - Fun contest
  - Good skill for **interference** and **jammer** hunting
  - Uses a **directional** antenna to hunt for a hidden transmitter

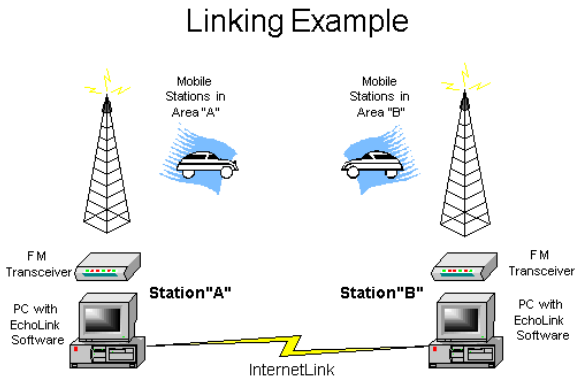


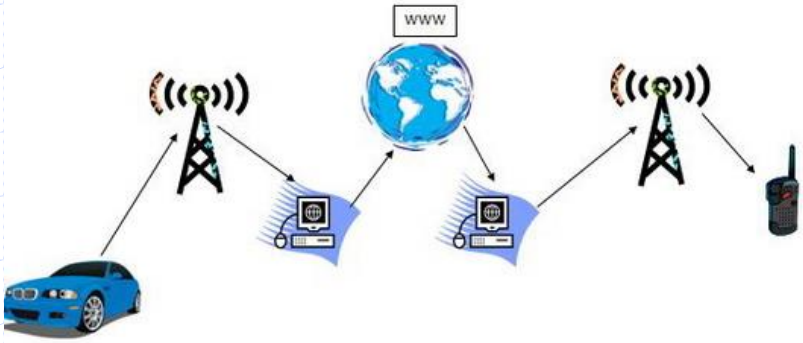
Still more fun activities

- Remote Control (**RC**) Models
  - Planes, Boats, Cars
  - **1 Watt** maximum
- Identification
  - via **label** or **flag** attached to the RC transmitter antenna
  - **Name, call, address**

Add a scoop of Internet…

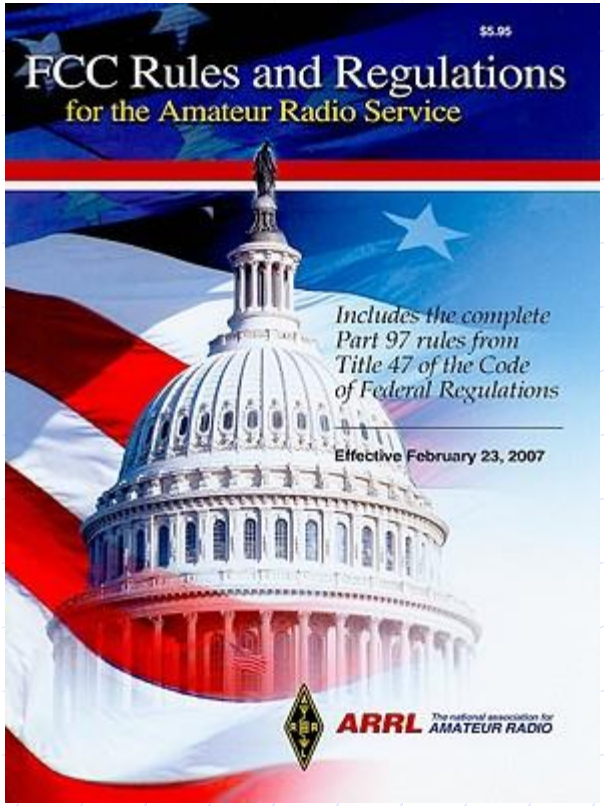
- **IRLP**: **I**nternet **R**epeater **L**inking **P**roject
  - Uses **VOIP** – voice over internet protocol
  - Repeater **directory** will list active nodes
  - **Keypad** on radio used to dial up a node
- **Echolink**
  - Radio or Computer links
- A **Gateway** is the name of a station that links to other stations via Internet





Rules & Regulations

- **Amateur Radio Service** – for persons who are interested in radio technique solely with a **personal aim** and **without pecuniary interest**
- Regulated and enforced by **FCC**
- **Part 97** applies to Amateur Radio



Part 97 defines an amateur radio station as a station in an Amateur Radio Service consisting of the apparatus necessary for carrying on radio communications

More FCC Part 97 Definitions

- **Space Station**
  - an amateur station located **>50km** above earth
- **Telecommand**
  - 1-way transmission to **initiate**, **modify** or **terminate** functions of a device at a distance
- **Telemetry**
  - 1-way transmission of **measurements** at a distance from the measuring instrument

Repeaters…

- **Repeater**
  - Amateur station that simultaneously retransmits the signal of another amateur station on a different channel(s)
- **Auxiliary Station**
  - A station that transmits signals over the air from a remote receive site to a repeater for retransmission
- **Frequency Coordinator**
  - Entity that recommends transmit/receive frequencies for repeaters and auxiliary stations
  - Serves eligible amateurs in a local/regional area

Interference

- **Harmful Interference**
  - …that which seriously degrades, obstructs, or repeatedly interrupts a radio communication service operating in accordance with the Radio Regulations
- Intentionally causing interference is grounds for:
  - Revocation of license
  - Fines
  - Prison

The ITU (International Telecommunications Union)

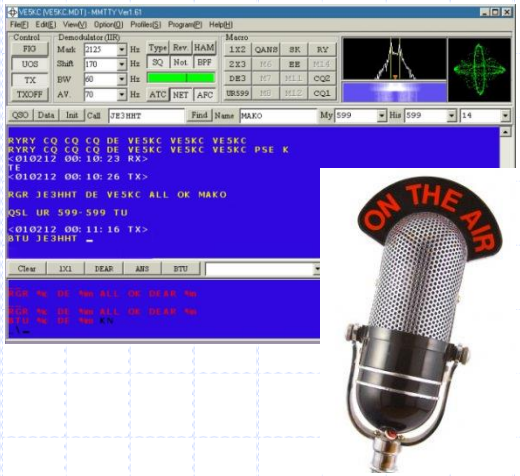
- ***ITU is a United Nations agency for information and communication technology issues***
- Three **ITU Regions**
  - North American radio stations are in **region 2**

- ITU deals with worldwide amateur radio issues
- FCC deals with US only, within ITU framework

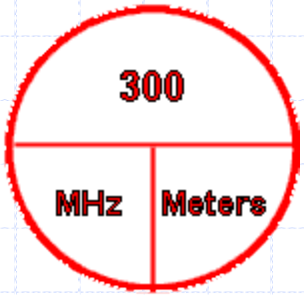
Frequency / Mode Allocations

Band	Frequencies (In MHz)	Modes You Can Use
80 meters	3.525 – 3.600	CW
40 meters	7.025 – 7.125	CW
15 meters	21.025 – 21.200	CW
10 meters	28.000 – 28.300 28.300 – 28.500	CW, RTTY/data, 200 watts PEP maximum power CW, phone, 200 watts PEP maximum power
Above 50 MHz	All amateur privileges	

CW = Morse code; PEP = peak envelope power; RTTY = radioteletype.



Qs on Frequencies/Bands



- **52.525 MHz** is within the 6 meter band
- The **2 meter band** is what you're using when your station is transmitting on 146.52 MHz
- **443.350 MHz** is in the 70 cm band, authorized for use by Technicians in ITU Region 2
- **1296 MHz** is a 23 cm frequency that Techs can use
- The **1.25 meter band** is what your using when your station is transmitting on 223.50 MHz.

Primary and Secondary users

- Amateur radio shares some bands with other radio services
  - Sometimes we're the primary users, like 70 cm band
  - Sometimes we're the secondary users, like 23 cm band
- When we're secondary users of a band…
  - **…must not cause harmful interference to primary users**
  - Example: *If you learn that your 23 cm operation is interfering with a radiolocation service outside the US, you must **stop operating** or **take actions** to eliminate the interference*

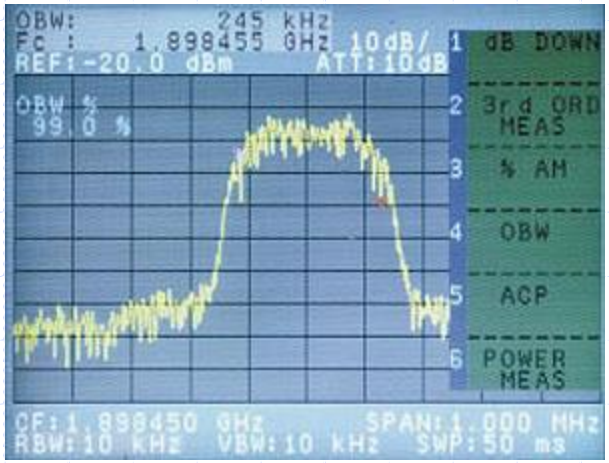
Sub-bands

- **FCC** defines sub-bands for specific operating modes
  - **CW only** is allowed in these mode-restricted sub-bands:
    - **50.0 to 50.1 MHz**
    - **144.0 to 144.1 MHz**
- **Mode-restricted** sub-bands for the Technician are found on…
  - **6 meters**
  - **2 meters**
  - **1.25 meters**

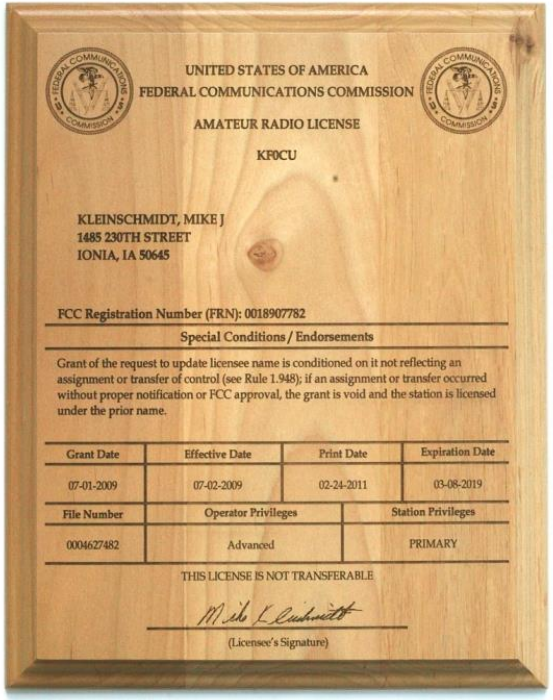
Frequency selection

- Don’t operate right at the band or sub-band edge!

- **Reasons why**:
  - To allow for calibration error of the transmitter frequency display
  - So that modulation sidebands do not extend beyond the band edge
  - To allow for transmitter frequency drift



Licenses and Operating



UNITED STATES OF AMERICA
FEDERAL COMMUNICATIONS COMMISSION

AMATEUR RADIO LICENSE

KF0CU

KLEINSCHMIDT, MIKE J
1485 230TH STREET
IONIA, IA 50645

FCC Registration Number (FRN): 0018907782

Special Conditions / Endorsements

Grant of the request to update licensee name is conditioned on it not reflecting an assignment or transfer of control (see Rule 1.948); if an assignment or transfer occurred without proper notification or FCC approval, the grant is void and the station is licensed under the prior name.

Grant Date	Effective Date	Print Date	Expiration Date
07-01-2009	07-02-2009	02-24-2011	03-08-2019

File Number	Operator Privileges	Station Privileges
0004627482	Advanced	PRIMARY

THIS LICENSE IS NOT TRANSFERABLE

(Licensee's Signature)

Call Signs in the US

- Consist of one or two letters…
  …followed by a single number…
  …followed by one, two or three letters
  - 1x2, 2x1, 1x3, 2x3
- **W2ABC** is an example of a valid US call sign
- **Special event** call signs are typically **1x1**
  - W8C is an example of a special event call sign
- **Clubs** can apply for a call sign
  - *must have **at least four members***

Records and Operating

- Logging is no longer required
- You **must** keep your mailing address current
  - *Failure to do so can result in suspension or revocation!*
  - *FCC will take action if correspondence is returned due to incorrect address*

Operating outside the US

- You can operate in a foreign country, **when the foreign country authorizes it**
  - Sometimes with reciprocal licensing agreements
  - Example: I can operate in Germany as DL/W2AEW
  - Different countries have different restrictions
- Shipboard in international waters – OK **provided the ship is documented or registered in the United States**, as well as places where FCC regulates communications

When can I operate???

- Operate **as soon as your name and call sign appear in FCC's ULS database**
- License good for **10 years**
- Renewal grace period is **2 years**
- **Can't transmit until renewal** shows in the database

Operating outside of the US

- Allowed **if the foreign country allows it**
  - *Some countries have reciprocal agreements*
  - *Ex: Germany, operate as DL/W2AEW*
  - *Check local restrictions*
- International waters
  - Any vessel **documented or registered in US**

Authorized & Prohibited

- Prohibited Transmissions
  - **Obscene** or **indecent** words or language
  - **Music**
    - *Except when incidental to an authorized retransmission of manned spaceflight communications*
  - Unpublished **codes** or **ciphers**
    - *Except when transmitting control commands to space stations or radio controlled crafts*
- Permitted only with other Amateurs, except:
  - Emergencies
  - Armed Forces Day Communications Test

More Prohibited

- No communications with **any country whose administration has notified the ITU that it objects to such communications**
- Can not use station to make money or be compensated, except
  - Operation in **incidental to classroom** instruction
  - Occasional notification of **equipment for sale**
- **No broadcasting**
  - *Defined as transmissions intended for reception by general public*
  - *Exception:* **only where such communications directly relate to the immediate safety of human life or protection of property**

What is allowed?

- Communications incidental to the purposes of the amateur service and remarks of a personal character
- Brief transmissions for the purposes of making adjustments

Control Operator & Types

- Who can be a Control Operator?
  - Only a person for whom an amateur operator/primary station license grant appears in the FCC database or who is authorized for alien reciprocal operation
  - Usually the **station licensee**
- License class of Control Operator determines transmitting privileges
  - Ex: Technician can't be control operator in Extra class portion of band

Control Operator / Point

- Required **only** for **transmitting**
- **Designated** by Station Licensee
- **BOTH** are equally responsible
- Operator or originating station responsible when using repeater

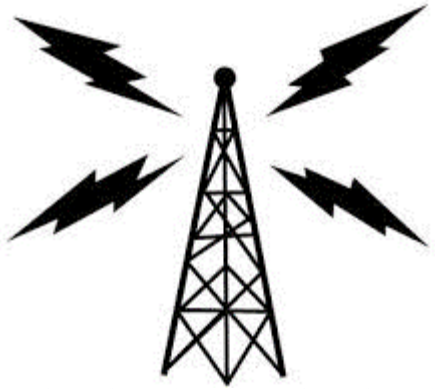
- **Control Point**: location at which the control operator function is performed

Control Type

- **Local Control**
  - Such as transmitting using a handheld radio
- **Remote Control**
  - Control operator is not at the station location but can indirectly manipulate the operating adjustments of a station
- **Automatic Control**
  - Repeater when the control operator is not present at a control point
  - Only type permissible for the control operator to be at a location other than the control point

Station Identification

- Every 10 minutes & at end of contact
- Using English
- Voice (phone) or CW (Morse) emission



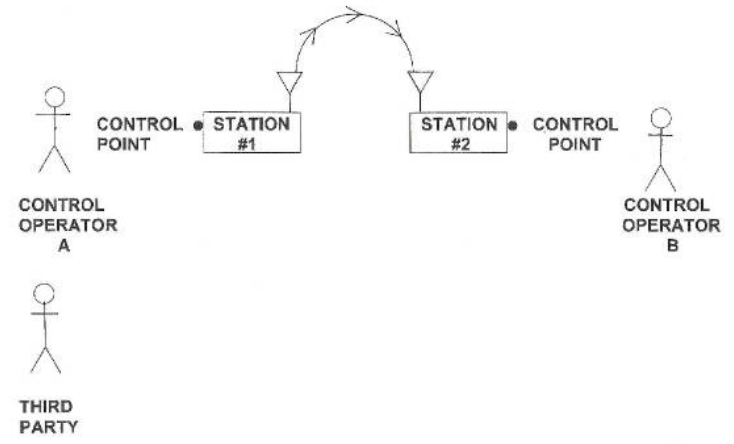
- Tactical call, like "Race Operator" OK
  - *But must still ID with call sign every 10 minutes*

More Station Identification

- Self-assigned Identifiers
  - Examples: “/3”, “mobile”, “QRP”
  - All of these are correct
    - W2AEW stroke W3
    - W2AEW slant W3
    - W2AEW slash W3
  - Must not conflict with other FCC identifiers or foreign country call sign prefixes

Third Party Communications

- On behalf of someone other than licensee
  - For example – a friend using your station
- Legal in US
  - May have restrictions communicating outside of US
  - Authorized by FCC with any station whose government permits such communications



Station Records

- Station records must be made available for inspection by FCC representative at any time

Are you ready???

- Questions?
- What topics are fuzzy to you?

- Practice Exams…