Amateur Radio Service Technician Class

Exam Preparation Class

September — October 2018

Session 2

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These slides will be uploaded to my website

https://k7ojl.com/technician-class-materials/

just before class each week.

Depending on how the class goes, they may get updated after the class.

Class Overview

- Questions?
- Reprise
  - Technician Privileges
  - Propagation
- Let's Go to Space
- Digital Communications
- Modes


Questions from Session 1?
Questions about Amateur Radio?

Technician Privileges (reprise)

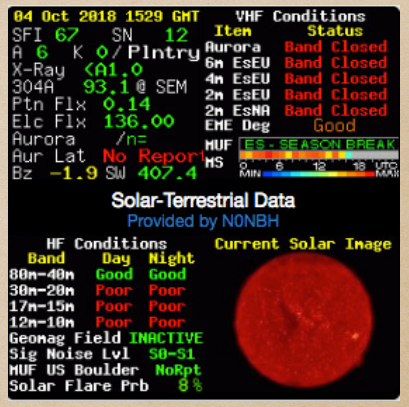
Important Factoids

- Technicians have HF phone privileges only on 10 meters
- HF has the advantage over VHF and higher frequencies of long-distance skywave propagation
- Technicians have HF RTTY (teletype) privileges on 10 meters
- The best time for long-distance 10 meter band propagation via the F layer is from dawn to shortly after sunset during periods of high sunspot activity
- "Beacons" are deployed by other amateurs around the world to help identify when communications between two points might be possible and to perform similar experimental activities

Propagation
(continued)

Propagation Forecast

- Propagation forecasts such as the one on the right are commonly available on the Internet
- Notice that on this date there were no sunspots while there was a bright spot sending solar wind which seriously degrades propagation



Space Weather Woman

- Dr. Tamitha Skov
- Produces a weekly propagation forecast published on YouTube
- https://www.youtube.com/channel/UCkXjdDQ-db0xz8f4PKgKsag

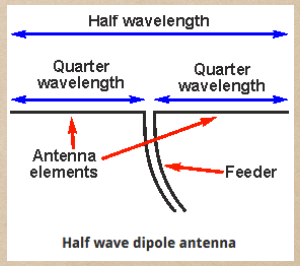
Antennas and Feed Lines

Antenna Polarization

- Antenna polarization is important at VHF and higher frequencies.
  - The position of the antenna determines the electrical polarization: vertical, horizontal, or circular
  - A signal from a horizontally polarized antenna will be significantly attenuated by a vertical receiving antenna
  - VHF and UHF FM radios are standardized around vertical polarization (including repeaters), so how you hold your HT makes a difference
  - VHF and higher SSB and Digital modes are generally horizontally polarized
- HF frequencies are usually unaffected by polarization and the ionosphere often reverses the polarization anyway

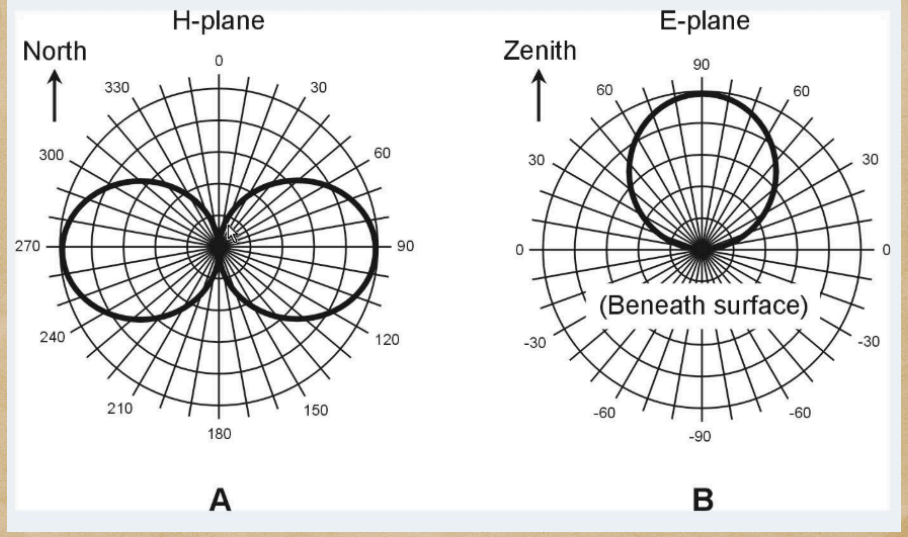
Dipole Antennas

- Most common type of antenna
- Radiates well broadside to the antenna
- Length of the antenna wire determines the resonant frequency
  - Shorten to go higher
  - Lengthen to go lower
- Height above ground affects the radiation angle
  - Works best 1/2 wavelength or more above ground



Takeoff angle

Dipole Radiation Pattern

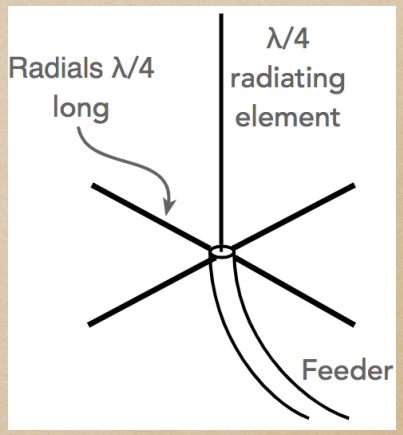


How Long Should A Dipole Be?

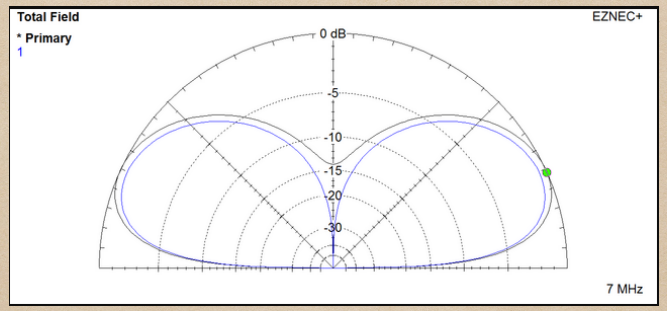
- Length in feet = 468 / frequency in MHz
  - Remember the formula to convert wavelength into frequency
- A 6 meter half-wave dipole?
  - 6 meters = 50 MHz (300/6)
  - length = 468 / 50 = 9.36 feet = 112.3 inches

Vertical Antennas

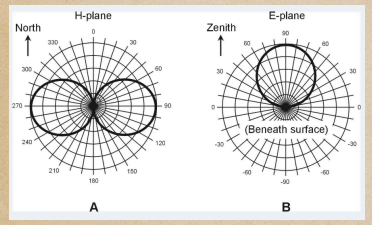
- Vertical antennas have a vertical element (1/4 wavelength) and several radials, also 1/4 wavelength, along the ground
- They have a very low takeoff angle (good for distant contacts)
- More susceptible to noise than horizontal dipoles

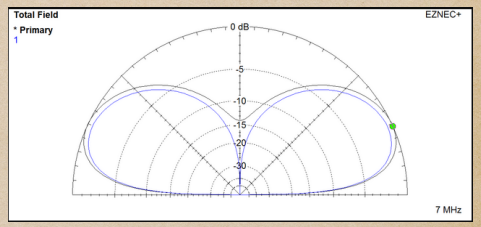


Vertical Antenna Radiation Pattern



Horizontal vs Vertical Antennas





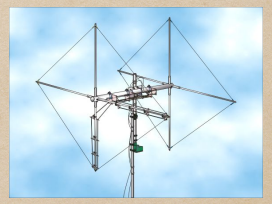
Vertical antenna has a lower take-off angle

Vertical antenna has no “lobes”

Vertical antenna has less radiation on the broadside (evenly distributed)

Directional Antennas

- Yagi, Quad, and Dish are all types of directional antennas
  - Directional means that the radiation pattern is more focused than a dipole or a vertical antenna
- Directional antennas have more "gain" and a higher "front to back ratio"

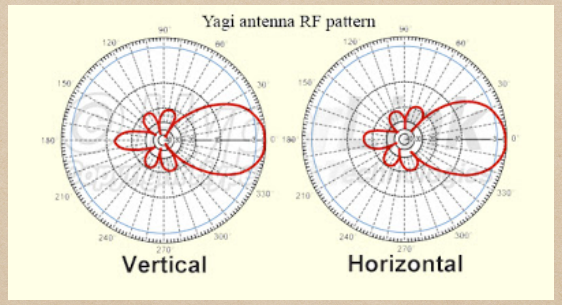


Gain: a process of taking RF energy and focusing it in an intended direction

Front to Back Ratio: The relative signal strength at the front of the antenna vs the relative signal strength at the back of the antenna

Directional antennas a very useful for radio direction finding

Yagi Antenna Radiation Patten

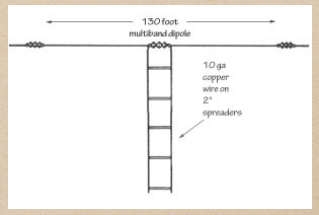


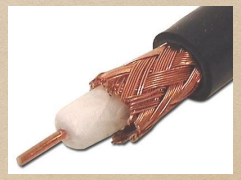
To focus the beam in the vertical: add elements to the beam

To focus the beam in the horizontal: stack another yogi

Feed Lines

- Two main types: ladder line (aka window line) and coax
  - Coax is used most often because of ease of use and no stand-off need
  - Ladder line has the lowest loss
- Each type of feed line has differing characteristic impedance

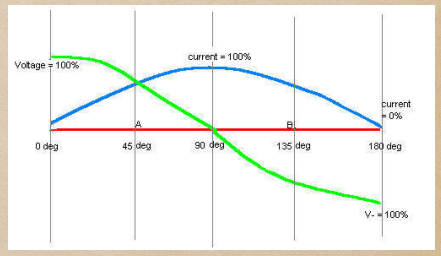




The antenna connector on the back of the transmitter / receiver expects to see an impedance (resistance) of 50 ohms
Coax generally has either 50 ohms or 75 ohms of impedance (50 ohms … amateur; 75 ohms … TV)

Antenna Impedance

- The impedance at the feed point varies across the length of the antenna
- If the impedance of the antenna at the feed point varies much from the impedance of the feed line, some of the energy is reflected back towards the transmitter rather than going into the antenna
- If the mismatch is greater than 3:1 (150 ohms at the feed point from 50 ohm coax), then the transmitter may "fold back" the power to reduce chance of damage to the final amplifier



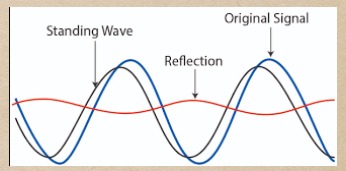
The method to address the mismatch is to insert a "transmatch" (short for transformer match) between the feed line and the antenna

Alternatively, a transmatch is often inserted between the transmitter and the feed line to be sure that the transmitter always sees 50 ohms regardless of the mismatch

Another name for the trans match is an "antenna tuner" … which doesn't tune anything

Standing Waves

- The amount of power reflected back to the transmitter varies with the mismatch
- The returning wave combines with the transmitted wave to cause a "standing wave" on the feed line. The ratio between the transmitted wave and the reflected wave is called the "Standing Wave Ratio"
- Eventually the energy not getting into the antenna goes up in heat in the coax. The greater the SWR, the more heat



Antenna / Feed Line Factoids

- A 5/8 wave vertical antenna has higher gain and a "squashed" signal pattern vs a 1/4 wave antenna
  - Often used for mobile antennas
- Inductance coils are used to electrically lengthen shorter antennas. These coils are often located in the center of the vertical antenna
- All feed lines have loss. The longer the feed line, the more loss. Coax has significantly more loss than window line but is easier to use
  - The difference between RG-8 and RG-58 is the latter has more loss than the former
- Coax must be protected against moisture incursion. The copper braid will disintegrate
- Air-insulated hardline: lowest loss, hardest to use, install, and maintain

Coax Cable Loss per 100 Feet

Coax Type	Size	Loss at HF 100 MHz	Loss at UHF 400 MHz
RG-58U	Small	4.3 dB	9.4 dB
RG-8X	Medium	3.7 dB	8.0 dB
RG-8U	Large	1.9 dB	4.1 dB
RG-213	Large	1.9 dB	4.5 dB
Hardline	Large, Rigid	0.5 dB	1.5 dB

3 dB loss is half the power (100 watts becomes 50 watts at the end)

A Few More Factoids

- An antenna analyzer can be used to measure the SWR of an antenna system
- A perfect impedance match (1:1) is achievable (??). A match of 1.5:1 and lower is considered a good match. Higher than 3:1 is a problematic match and likely will cause the transmitter to "fold back"
- Loose connections (at the transmitter, the trans match, or the feed point) will cause erratic SWR readings
  - Deteriorating coax due to water damage will also exhibit strange SWR readings
- A "dummy load" is very useful when testing a radio but don't want anything to be transmitted
  - A dummy load is simply a set of resistors giving an impedance of 50 ohms to the transmitter but sized large enough to handle the heat produced as the resistors use up the transmitted energy

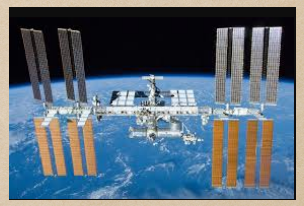
Analyzer Demo

- Device transmits a low-power signal at the designated frequency
- Device then measures the reflected power and calculates the SWR and impedance
- Device has several other functions available, including testing coax cable, determine coax velocity factor, and more


Let's Go to Space!

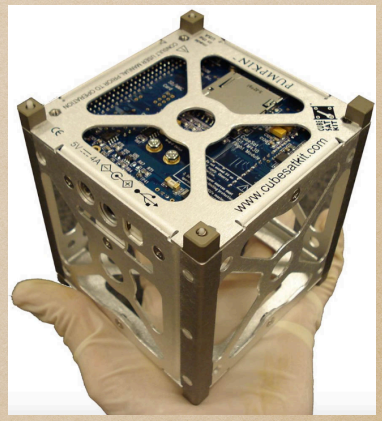
Many Amateur Radio Satellites Are Waiting for You

- A "space station" is any amateur station located 50km above the earth's surface
  - Most amateur satellites are in low earth orbit (LEO)
- In order to talk with or through a "space station" you need to know the satellite's real position, azimuth, elevation from start to finish of the pass, frequencies to use
  - The "Keplerian Elements" are the critical time, azimuth, and elevation data needed to compute the satellite's position



Satellites Continued

- Most amateur satellites have a beacon: continuous faint transmission that carries digitized telemetry about the health and status of the satellite itself
  - Anyone can receive and decode the telemetry. Once a radio signal has been transmitted it becomes public domain
- Almost all transmission modes are used, CW, Data, SSB, FM with FM being the most popular with Technicians
- Satellites usually are spinning to reduce overheating of the solar panels. The spin may cause signals to fade in and out
- As the satellite passes the frequency will change … Doppler Shift
- It is important to use the lowest power setting needed to successfully complete the transmission to or through the satellite
  - Too high power will block other users or saturate the signal to make it unintelligible
  - Your signal strength on the uplink should match the signal strength on the downlink



And Finally, Space Stations Modes

Most amateur radio satellites operate as "repeaters" … receiving a signal on one frequency and transmitting it simultaneously on another.

Since there is limited space and power, the input frequency (uplink) is on one band and the output frequency (downlink) is on a different band

The "mode" of the satellite indicates where the uplink and downlink are located. For instance, Mode U/V means uplink on the 70cm band and downlink on the 2meter band

Band	Freq Range	Mode
HF	21-30 MHz	H
VHF	144-148 MHz	V
UHF	435-438 MHz	U
L band	1.26-1.27 GHz	L
S band	2.4-2.45 GHz	S
C band	5.8 GHz	C
X band	10.4 GHz	X
K band	24 GHz	K

A Satellite Contact Video

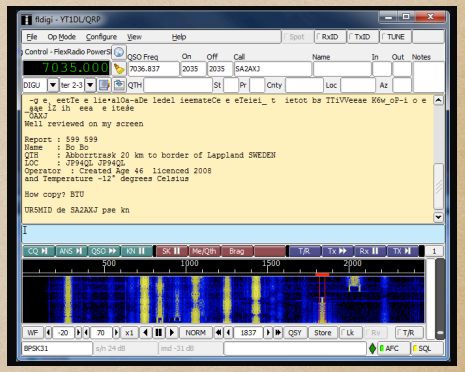
- https://www.youtube.com/watch?v=XCdvCbjK_zo&t=81s

SO-50

Digital Communications

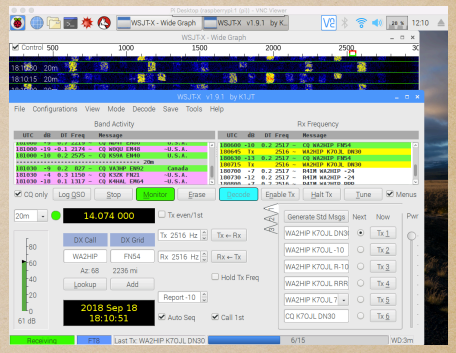
Digital Communications

- The original digital mode is CW (international morse code)
  - CW frequencies are from 50.0-40.1 MHz (10 meter band) and 144.0-144.1 MHz (2 meter band)
  - Many hams us an electronic keyer when sending CW
- A computer is used to generate and decode many other digital modes
  - The computer's sound card is used to send audio to the radio's microphone input, generate the PTT signal, and converts audio from the radio's speaker output into digital form
  - The physical connection from the radio is to the computer's microphone or line input



New Digital Modes

- Digital modes include Packet Radio, IEEE 802.11, JT65, FT8, PSK (phase shift keying), and may more
- FT8 (pictured to the right) is one of the newest enabling communications in very low signal-to-noise conditions transmitting and receiving in 15-second windows
- Joe Taylor K1JT has developed a suit of low SNR applications used for moon bounce (EME), weak-signal propagation, meteor scatter, and others
- Some modes include check sums for error detection, automatic repeat requests in case of error, header records containing metadata about the transmission
- Multipath signals will seriously degrade reception and increase error rates



Automatic Packet Reporting System

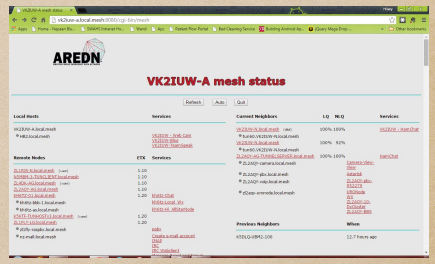
- APRS is an application capable of providing real-time tactical digital communications together with a map showing the location of stations
  - Requires a GPS receiver to provide position information to the transmitting application
- Popular mobile text messaging application
- Many amateur weather stations use APRS to send their weather information to various weather data systems
- https://aprs.fi/#!addr=salt%20lake%20city%2C%20Ut

Other RF Digital Modes

- Digital Mobile Radio (DMR)
  - Two "time multiplexed" conversations on a 12.5 kHz channel
  - Users connect to "talkgroups" which are conference rooms for like interests
  - Inexpensive cost to play
- D-Star
  - Developed in Japan, supported by ICOM, Kenwood, and Elecraft
  - Has very fast data transfer capability
- System Fusion
  - Developed by Yaesu and proprietary to Yaesu
  - Growing in popularity
- DMR, D-Star, and System Fusion are all incompatible with each other

Mesh Networking

- Commercial WIFI gear (part 90 equipment) repurposed to work on amateur frequencies (part 97)
  - Several WIFI channels are within amateur radio bands
- Makes a self-healing, multi-path routing, high-speed data network
- Amateur Radio Emergency Data Network (ARDEN) is where the firmware and additional information is available



Some Other Digital Mode Information

- PSK (phase shift keying) is a very popular keyboard to keyboard protocol as well as the ability to transfer files
- IRLP (internet radio linking project) is a technique to connect amateur radio systems, such as repeaters, using Voice Over Internet Protocol (VOIP). A popular IRLP repeater in our area is on 449.425(-) connected to the Western Reflector
  - DTMF (dual-mode multi-frequency) tones, similar to the touch tones on a phone) tones are used to connect and disconnect reflectors
- Echolink is another VOIP system. There are Echolink applications that can run on your laptop or smart phone. Registration is required before using Echolink (to prove you are a licensed amateur).
- There are online services, printed directories, and subscription services to find repeaters and VOIP services

And Finally, Amateur TV

- Slow scan tv as well as fast scan systems are available
  - Analog only at the moment. Hams are working on a non-patented digital codec
- NTSC is the standard for fast scan color analog signals
- Typically used on the 70cm band and higher frequencies.
- Fast scan tv has a bandwidth of about 6 MHz (that's why they're on the higher frequencies!)
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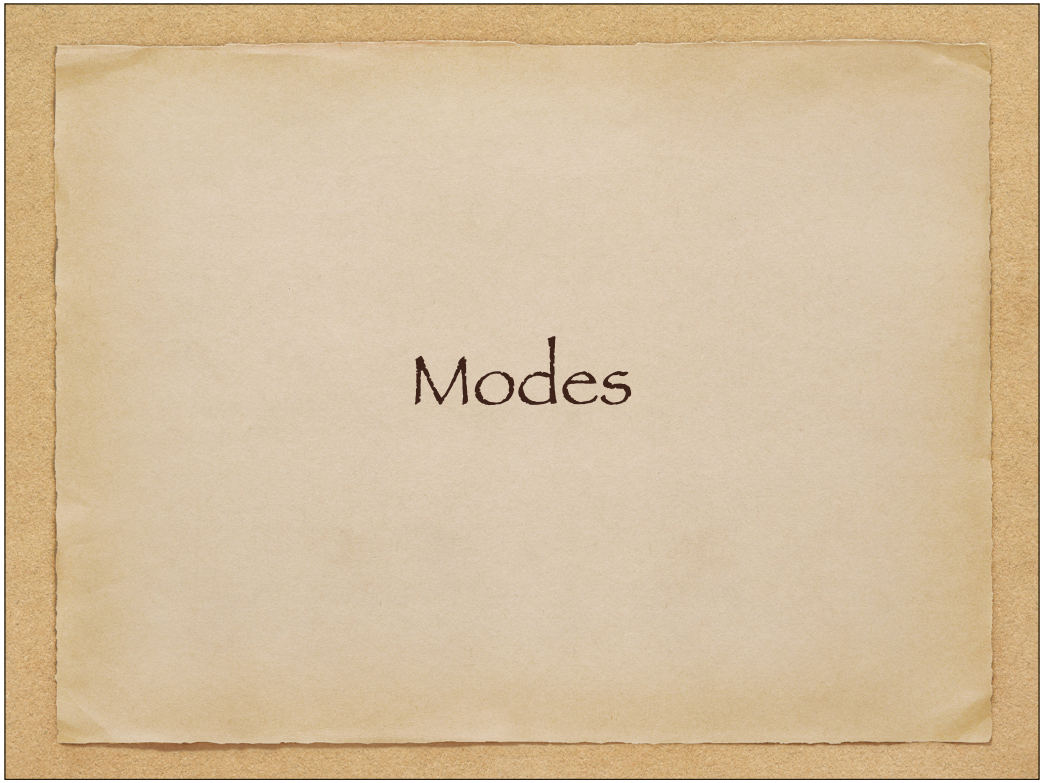
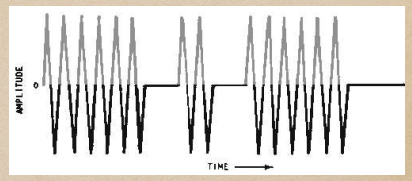

Modes

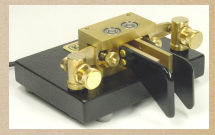
Common Transmission Modes

- Continuous Wave (CW)
  - Mode to carry morse code and several digital capabilities
- Amplitude Modulation (AM)
  - Radio stations on the AM band, for example
- Frequency Modulation (FM)
  - Radio stations on the FM band, for example
- Single Side Band
  - Either upper or lower sideband

Continuous Wave

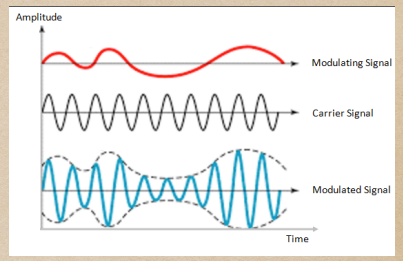
- An oscillator generates the signal
- Transmitter is either on or off … no modulation of the carrier
- Some digital modes, such as RTTY, alternate between higher amplitudes and lower amplitudes
- Very narrow bandwidth
  - CW Morse code is 150 Hz (use a 500 Hz filter)
  - Other CW modes are only slightly wider

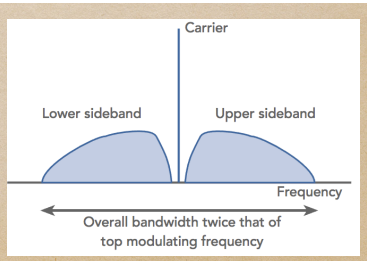




Amplitude Modulation

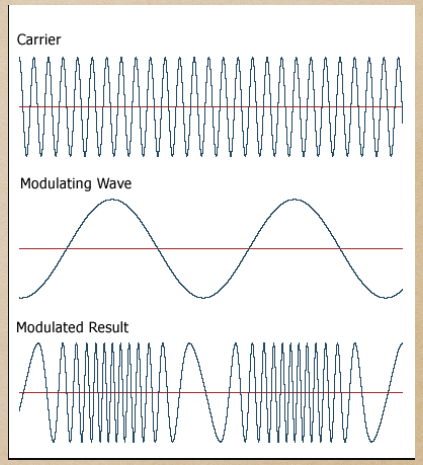
- An Oscillator generates a carrier signal
- A microphone or similar generates a modulating signal
- A mixer combines the modulating signal and the carrier
- The amplitude of the resulting wave form varies in time with the modulating signal
- AM signals are about 6 kHz wide and have a center carrier with an upper and a lower sideband





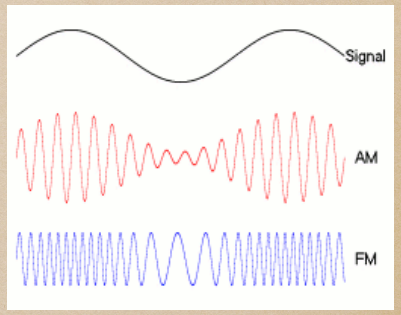
Frequency Modulation

- An oscillator generates a carrier
- A microphone or similar creates a modulating wave
- A modulator varies the carrier frequency over time with the modulating wave
- FM voice signals have a bandwidth of 25 kHz
- When using a repeater, the strongest FM signal wins



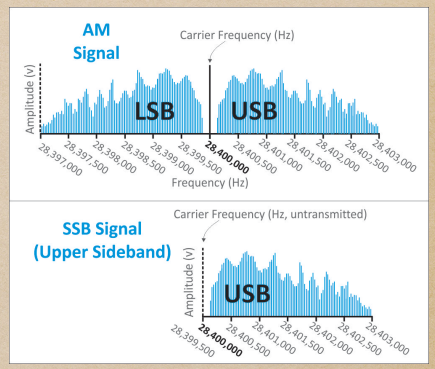
AM vs FM

- In AM modulation, the amplitude of the signal varies. Low signal means lower amplitude
- In FM modulation, the frequency of the signal expands or contracts based on the modulating signal



Single Side Band

- A form of amplitude modulation
- An oscillator generates a carrier
- A microphone or similar creates the modulating wave
- A mixer combines the carrier and the modulating signal
- A filter strips the center carrier and unwanted sideband
- SSB signals have about a 3 kHz bandwidth (use a 2.4 kHz filter)
- Convention for SSB voice is to use lower sideband on 40 meters and below and to use upper sideband on 60 meters and above
- Digital modes using single sideband as the carrier are always upper sideband regardless of the frequency



Multi-mode Transceiver

- A transmitter and receiver in the same box with a method to switch the receiver out of the circuit when the transmitter is operating
  - Multiple bands and modes
  - Switching modes switches in the proper filter
- Most include a Receiver Incremental Tuning (RIT) control to manage the pitch of a SSB signal
- Usually have multiple bandwidth choices to reduce noise or interference
- The ability of the receiver to pull out weak signals is the receiver's sensitivity
- The selectivity of the receiver is its ability to discriminate between multiple signals

Some Important Definitions

- Oscillator: a circuit that generates a signal at a specific frequency
- Mixer: a non-linear device that takes two radio signals and creates the sum and difference frequencies of the two input frequencies
- Automatic Gain Control (AGC): Used to (somewhat) level out the huge variations in signal strength making the audio relatively constant. The AGC speed can often be set
- Transverter: A device that converts the RF input and output of a transceiver to another band. Often used for microwave and very low frequency systems
- RF Preamplifier: If needed (and rarely is needed) is placed between the antenna and the receiver to boost weak signals
- Modulation: the process of combining speech with an RF carrier


That's All for Today!