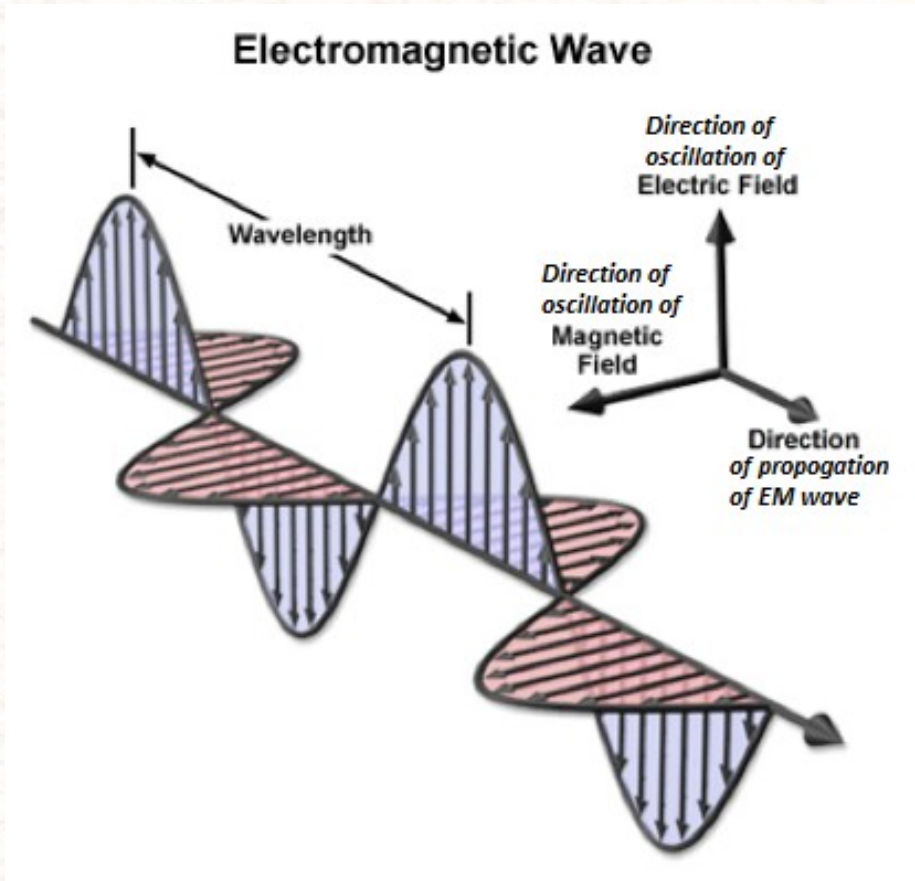


Propagation, Antennas, & Feedline

Steve Phillips – NS4P

Waves



Radio signals are transmitted by an Electromagnetic Wave

Combination of Electric and Magnetic fields

“Polarization” refers to the orientation of the Electric Field

Transmission Basics

- Transmitter creates electrical current (moving electrons) which is carried by the Transmission Line to the Antenna
- Electrical current in the antenna creates Electromagnetic Waves (radio waves) in “free space”
- Electromagnetic waves travel away from the antenna in straight lines, until they encounter physical objects
- The “wave front” expands as it travels, making the signal weaker (inverse square law)
- Higher frequency signals attenuate more quickly than lower frequency signals

Antennas

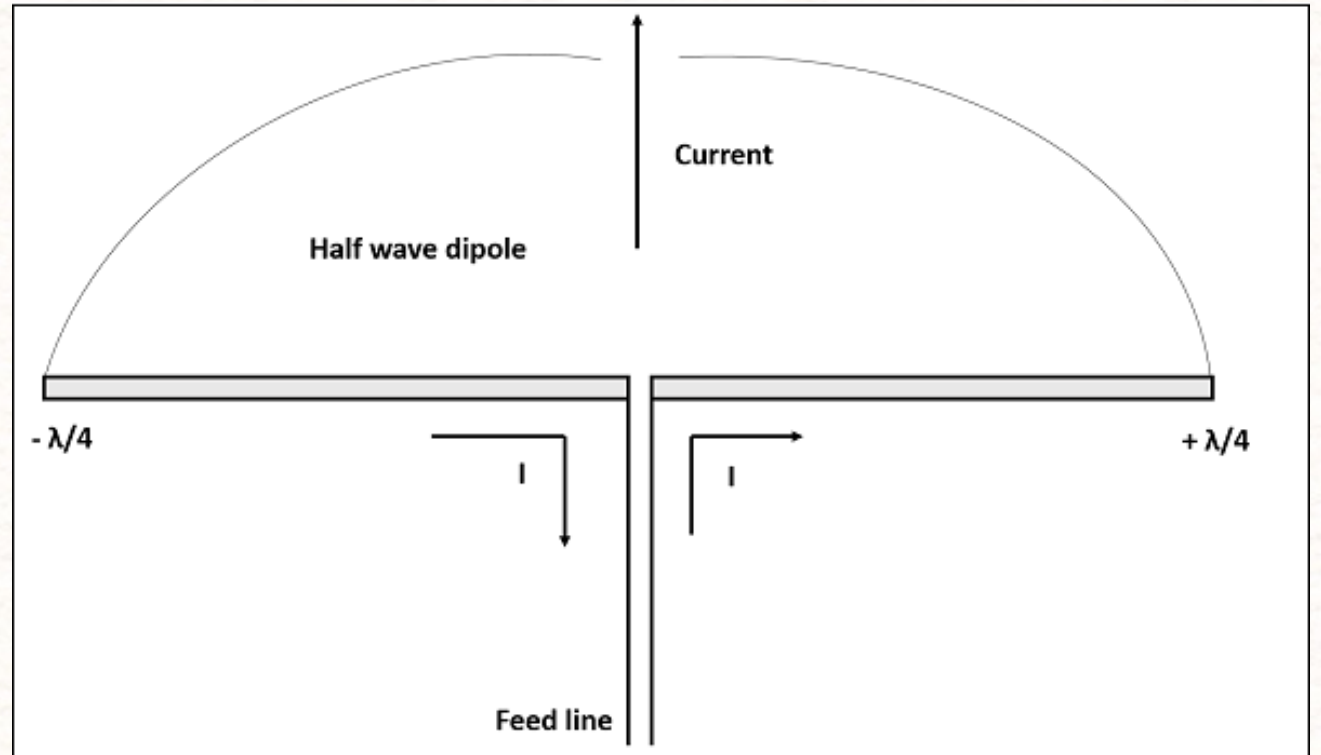
- Antennas are made of conductive material (e.g., Aluminum, Steel, Brass, Copper)
- The antenna is often considered the most critical part of a radio station
 - Good antennas improve performance on both transmit & receive
- Bigger is better
- Higher is better
- Polarization of the antenna refers to the long axis of the conductive element(s) as referenced to the earth's surface
 - For VHF FM, vertically polarized antennas are common (HTs, Cars)

Antenna Gain

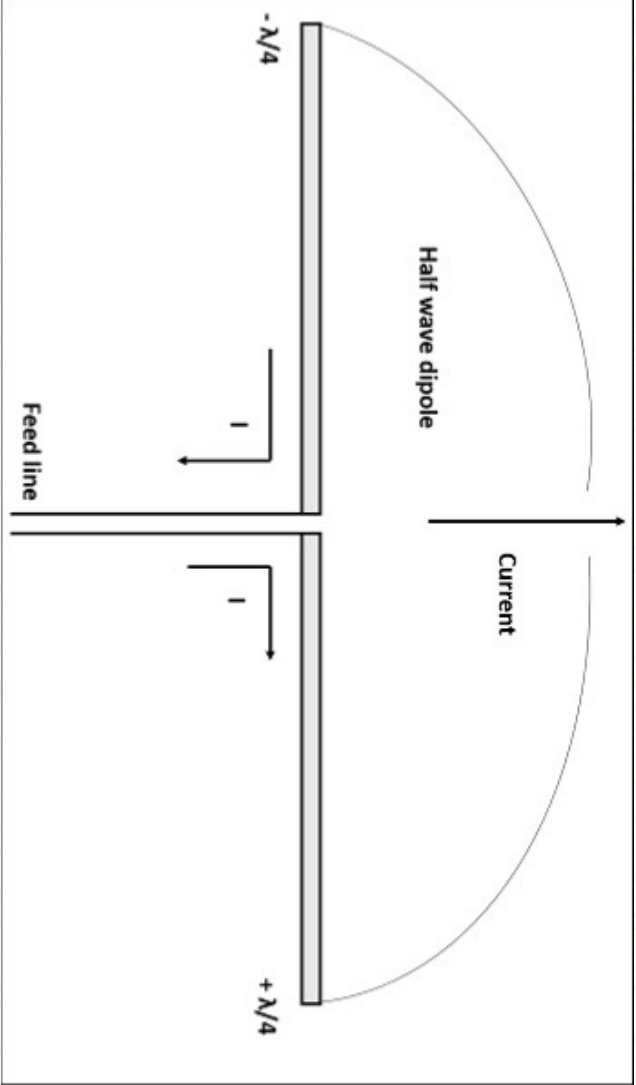
- Antennas are passive devices
- A theoretical “isotropic radiator” transmits equally in all directions (spherical wave front)
 - This antenna does not exist IRL
- Antennas can and are designed to concentrate power in specific directions
- The amount of concentration is called “gain” and is measured in Decibels (dB)

Dipole Antenna (horizontal)

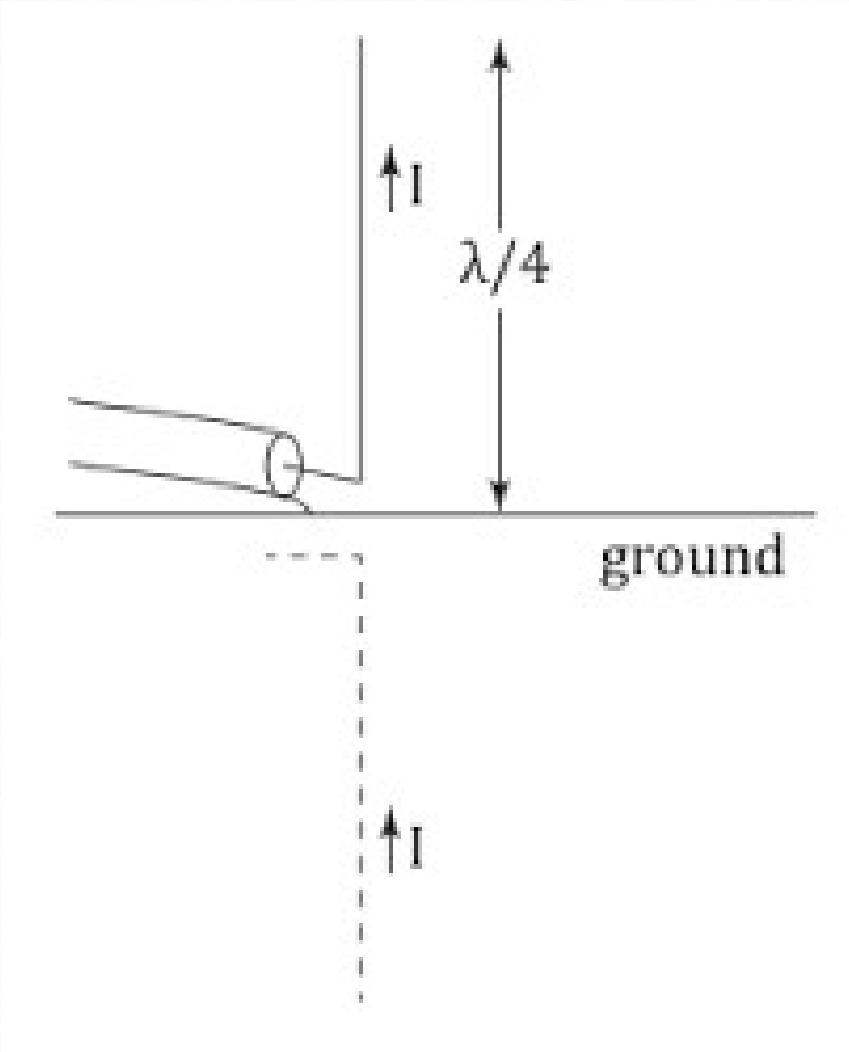
Strongest signal is broadside to the antenna



Dipole Antenna (Vertical)



Ground Plane Antenna



Dipole Antenna Length

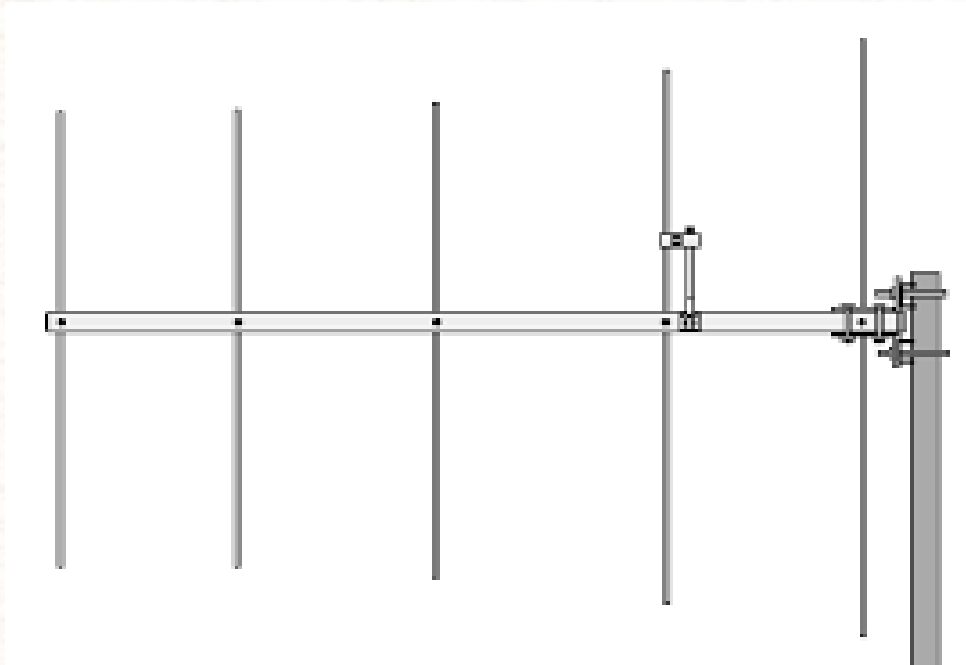
Dipoles are approximately $\frac{1}{4}$ -wavelength on each side ($\frac{1}{2}$ -wavelength total)

- Super-Nerdy Long Way
 - Traditional Approximation
 - Length (in feet) = $468 / \text{Frequency (MHz)}$
 - For “6 Meters” or 50.1MHz
 - $468/50.1 = 9.33 \text{ Ft} = 112 \text{ inches}$
- Steve’s Shortcut
 - 1 Meter = 3 Feet – 6 Meters = 18 Feet
 - $\frac{1}{2}$ wavelength = 9 feet = 108 inches
- Start with the wire too long, and trim for best SWR

5/8ths Wave Vertical

- Very popular mobile antenna
- Requires a “loading coil” at the base for proper impedance matching
- LOWER ANGLE OF RADIATION AND MORE GAIN than a $\frac{1}{4}$ wave antenna

Directional Antennas

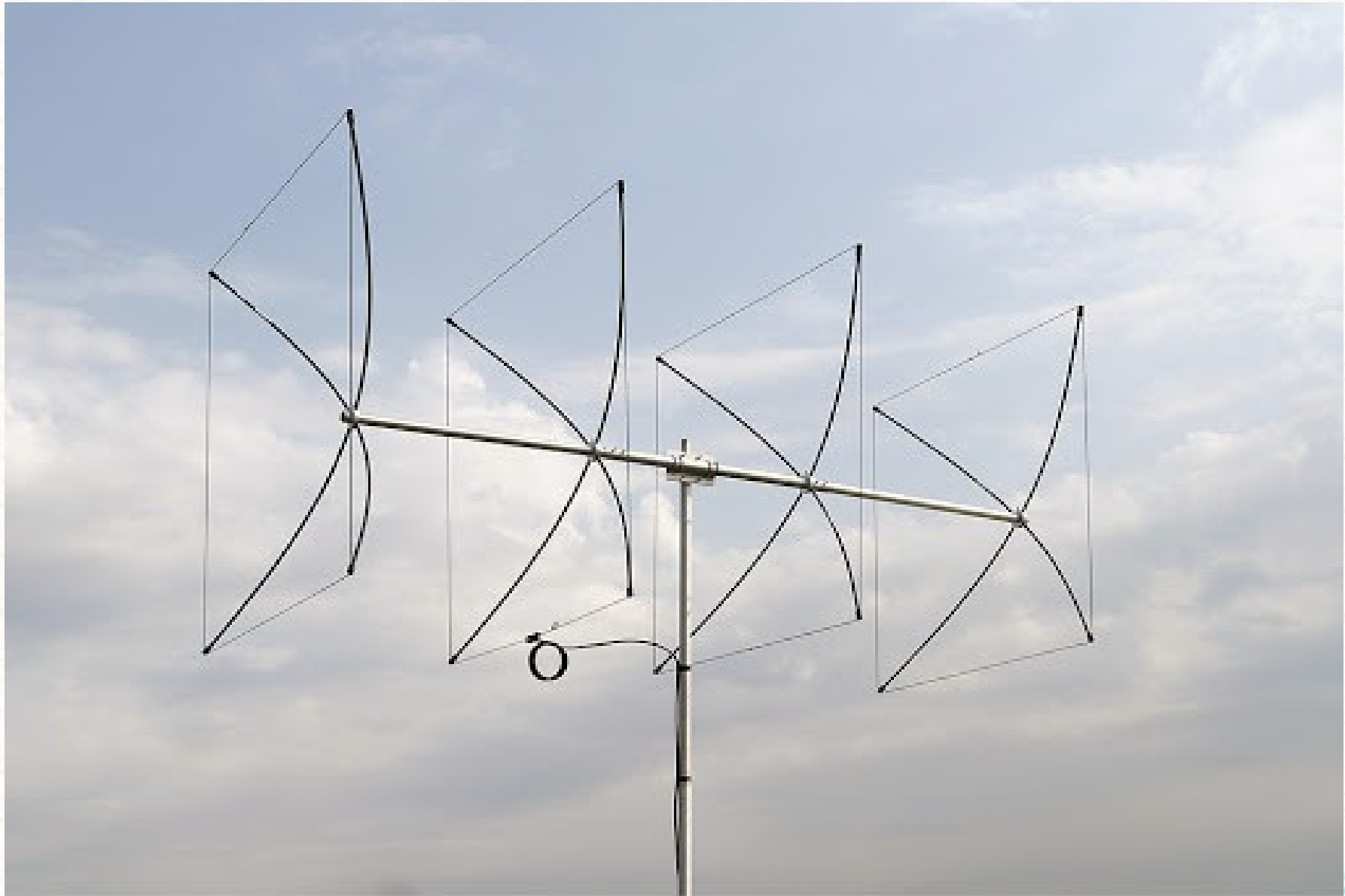


- “Directional” antennas concentrate energy in one direction
 - “Driven” element (frequently a dipole)
 - Reflectors and Directors (Parasitic elements) concentrate the power
 - Usually require a device to point the antenna toward the other station

Directional Antennas

- “Yagi” antenna
 - Invented by Shintaro Uda and Hidetsugo Yagi in 1926
 - Uda was the main guy, but the design is usually called a “Yagi”
- “Quad” antenna
 - Same idea as the Yagi, but the elements are loops instead of dipoles
- Yagis, Quads, and similar designs are frequently called “Beam” antennas
- “Dish” antennas
 - Popular at UHF and higher frequencies





Polarization Conventions

- For short range communications, you get best results if both sender and receiver use the same antenna polarization (H-H or V-V)
- For convenience, most VHF-FM (e.g., repeater) communications use vertical antennas
- Hold your HT with the antenna vertical for best performance
- By convention, most weak-signal, long-distance CW and SSB on VHF and UHF use horizontal polarization
- For line of sight communications, the best path to the other station may not be a straight line – bounce the signal off buildings or other obstructions

Feed lines & SWR

- Feed Line AKA Transmission line
 - Connects the transceiver to the antenna
 - Connects station components
 - Can be used as part of an antenna
- Feed Line Components
 - Two Conductors
 - Insulating Material
 - Several Types
 - Ladder Line
 - Coax
 - Hardline

Ladder Line

- Also called Window Line
 - Two parallel conductors, separated by insulating spacers
 - Wide spacing between conductors and small amount of insulation mean low loss
 - Not shielded, so proximity to other conductors affects transmission
 - Susceptible to noise



Coaxial Cable or “Coax”

- Wire Center Conductor
- Insulation or Dielectric
- Tubular shield of braided wire and/or foil
- Outer plastic jacket
- By far the most popular transmission line for amateur radio use
 - Easy to run – no conduit needed
 - Self-shielded, so relatively low noise
 - Not affected by nearby conductors
 - Comes in a variety of sizes



Hardline

- Special type of coax
 - Outer jacket is solid copper
 - Much less flexible than coax
 - Lower loss, especially at VHF & UHF
 - Special (expensive) connectors required



Characteristic Impedance (Z_0)

- Feedlines have inherent capacitance and inductance in addition to DC resistance
- Z_0 is determined by the size and physical arrangement of the conductors
- Z_0 is measured in Ohms
- Common values of Z_0
 - Ham radio coax & hardline – 50 Ohms
 - Cable TV coax – 75 Ohms
 - Ladder line – 300 to 600 Ohms
- The feedline you use should match the impedance of the transceiver and antenna

Feed Line Selection & Maintenance

- Use the correct impedance cable
- Consider feedline loss
 - All feedlines have loss (measured in dB/100ft)
 - Remember 3dB is half your power
 - Feedline losses are converted to heat
 - As frequency increases, so do losses (for a given cable type)
 - Better shielding and “fatter” cable means lower loss, but
 - Less flexibility
 - Higher cost
- Get the correct jacket
 - UV resistance
 - Direct Burial

Feedline Selection & Maintenance

- Get the correct insulator/dielectric
 - Air Core or Open Cell Foam has lower loss, but is more susceptible to water intrusion
- Consider the application
 - Skinny/flexible cable for connections in the shack
 - Fatter cable/better shield for UHF
 - High power needs fatter cable
- Proper installation
 - No sharp bends
 - No cuts or nicks (water water everywhere)
 - Watch out for landscapers!
- Use the proper connectors, properly installed
 - Most popular connector is the PL-259 or “UHF” connector
 - The “UHF” connector actually doesn’t do very well on UHF
 - Use the “N” connector above 400 MHz

Soldering

- Soldering is a method of joining two or more items by melting and placing a filler metal (solder) into the joint
- This technique is over 5000 years old
- Soldering requires a “flux” which prevents corrosion and acts as a wetting agent
- For electrical work “rosin-core” solder is recommended
- A good solder joint will have a smooth, shiny finish
- A “cold” solder joint will have a grainy or dull surface



Standing Wave Ratio - SWR

- The objective is to transfer the maximum amount of power from the transmitter to the load (antenna)
 - Feedline and antenna impedance should be identical, or “match”
 - If the impedances do not match, some power is reflected by the load
 - Worst case – open or short – 100% is reflected – not good for feedline or transmitter
 - Forward power and reflected power travel in opposite directions on the feedline
 - This creates a “standing wave” interference pattern
 - The reflected power creates losses (heat) - Excessive heat can melt the coax
 - Excessive reflected power can damage the transmitter
 - Modern solid-state transmitters can protect themselves (most of the time)
 - Relative values of forward and reflected power can be measured and are reported as the “Standing Wave Ratio”
 - 1:1 (One to One) is perfect – There is no reflected power
 - Values up to 2:1 are considered acceptable in most cases

Causes of High SWR

- Wrong feedline
- Antenna not tuned (too long or too short)
- Faulty feedline (cuts or shorts), water intrusion
- Faulty connectors
- Erratic or jumpy SWR can be caused by a loose connection somewhere

Cool video

- <https://techchannel.att.com/playvideo/2011/03/07/AT&T-Archives-Similarities-of-Wave-Behavior>

How to Measure SWR

- Use an SWR meter!
 - SWR meter
 - Wattmeter (can measure forward and reverse)
 - Directional wattmeter
 - Need a chart to convert to SWR
 - SWR meter is placed in series between the transmitter and the load
 - Usually at the transmitter end of the feedline



How to measure SWR

- SWR meters require a transmitter to work
- SWR meter can be combined with a very low power transmitter to create an “Antenna Analyzer”
 - Can be used to tune the antenna when it is in a convenient location
 - Reduces interference
 - Analyzers often contain advance features

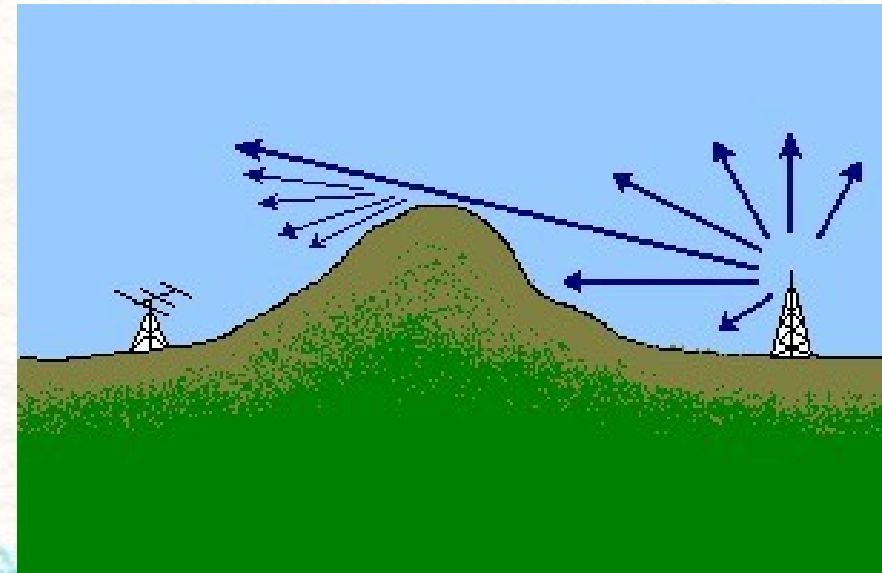


Antenna Tuners

- Antenna tuners do NOT tune the antenna
- The tuner matches the impedance of the antenna/feedline system to that of the transmitter output
- Usually, part of or located next to the transceiver
- Less often, located remotely - close to the antenna
- Can be manual or automatic

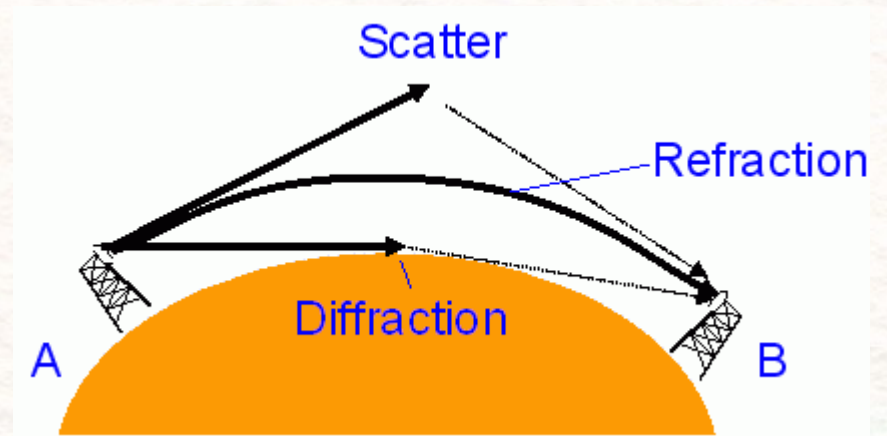
Propagation – How to get from here to there

- In “free space” radio waves travel in straight lines
 - Radio waves travel forever, but eventually get too weak to receive
 - Voyager 2 is currently 11.6 Billion miles from Earth
 - Transmitting with about 20 Watts, we can still hear it (with a really big ground station)
- Radio waves can be reflected
 - Buildings
 - Hills
 - Temperature changes in the atmosphere
- Radio wave knife-edge diffraction



Weird Propagation

- Refraction
 - Bending of radio waves to follow the curvature of the Earth
 - Caused by change in refractive index with altitude
 - Allows communication beyond visual range
- Scatter
 - Reflection of radio waves off solid objects
 - Meteor ionization trails
 - Airplanes



Weird Propagation

- Tropospheric Ducting
 - Troposphere is the lowest region of the atmosphere (surface to about 30,000 feet)
 - Weather fronts or temperature inversions create “ducts” in the troposphere that guide VHF and UHF signals
 - Can enable VHF & UHF Communications over about 300 miles
- Multipath
 - Radio signals can bounce their way along different paths.
 - Different paths=Different distances=Different times=Different Phases
 - Mixing of different phases can cause weak or distorted signals
 - The different phases can cancel each other out – move a few feet and try again

Loss of signal

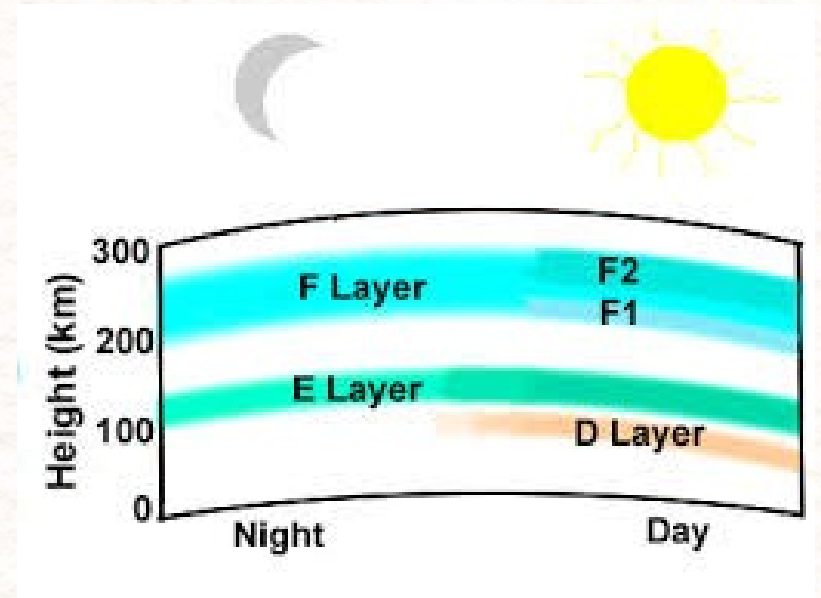
- Building and hills can create radio “shadows”
- Vegetation and leaves can absorb RF
 - (better propagation in the Winter, up North anyway)
- Rain and fog can absorb on high UHF and microwave frequencies

The Ionosphere

- The ionosphere is the ionized part of Earth's upper atmosphere
 - From 30 mi to 260 (or more) miles in altitude
 - Electrons dislodged from a neutral gas atom or molecule by solar radiation to form “ions” and electrons
 - Amount of ionization depends on the sun and it's activity, as well as:
 - Time of day
 - Solar Cycle
 - Season (which way the Earth is tilted)
 - Geographical position
 - The electrically charged particles can refract radio waves back toward the Earth, enabling communication beyond visual range – “Sky Wave” propagation
 - The Earth is also electrically conductive and can reflect signals back toward the ionosphere
 - Multiple hops enables propagation over hundreds or thousands of miles

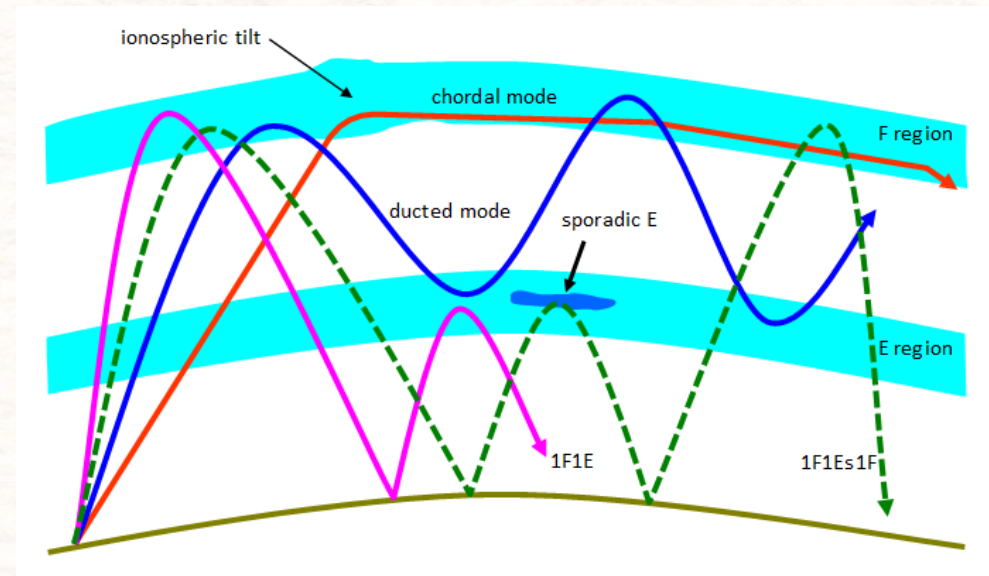
Ionosphere Layers

- D, E, F1, & F2 layers
- D layer (present during the day) absorbs lower frequencies (e.g., 40 meters and below)
- E layer (Stronger during the day) refracts lower frequencies. “Sporadic E” occasionally enables skip on 10M, 6M and 2M (summer and mid-winter)
- F layers – F1 occurs during summer daytime. F1 & F2 combine at night
- Not all frequencies refract
 - VHF and higher frequencies usually pass through to space (UHF repeaters are rarely heard beyond the radio horizon)



Ionospheric Propagation

- Multiple layers means multiple possible paths for signals
 - As with VHF, signals arriving at different times can cause distortion and irregular fading
 - For digital modes, error rates are likely to increase
- When signals are refracted, polarization is changed to “elliptical” so that H & V antennas can play well together



Decibels

- What is the approximate amount of change, measured in decibels (dB), of a power decrease from 12 Watts to 3 Watts?