Plan for today

- Propagation
- Antennas and Feed Lines
- If we have time:
  - Modulation

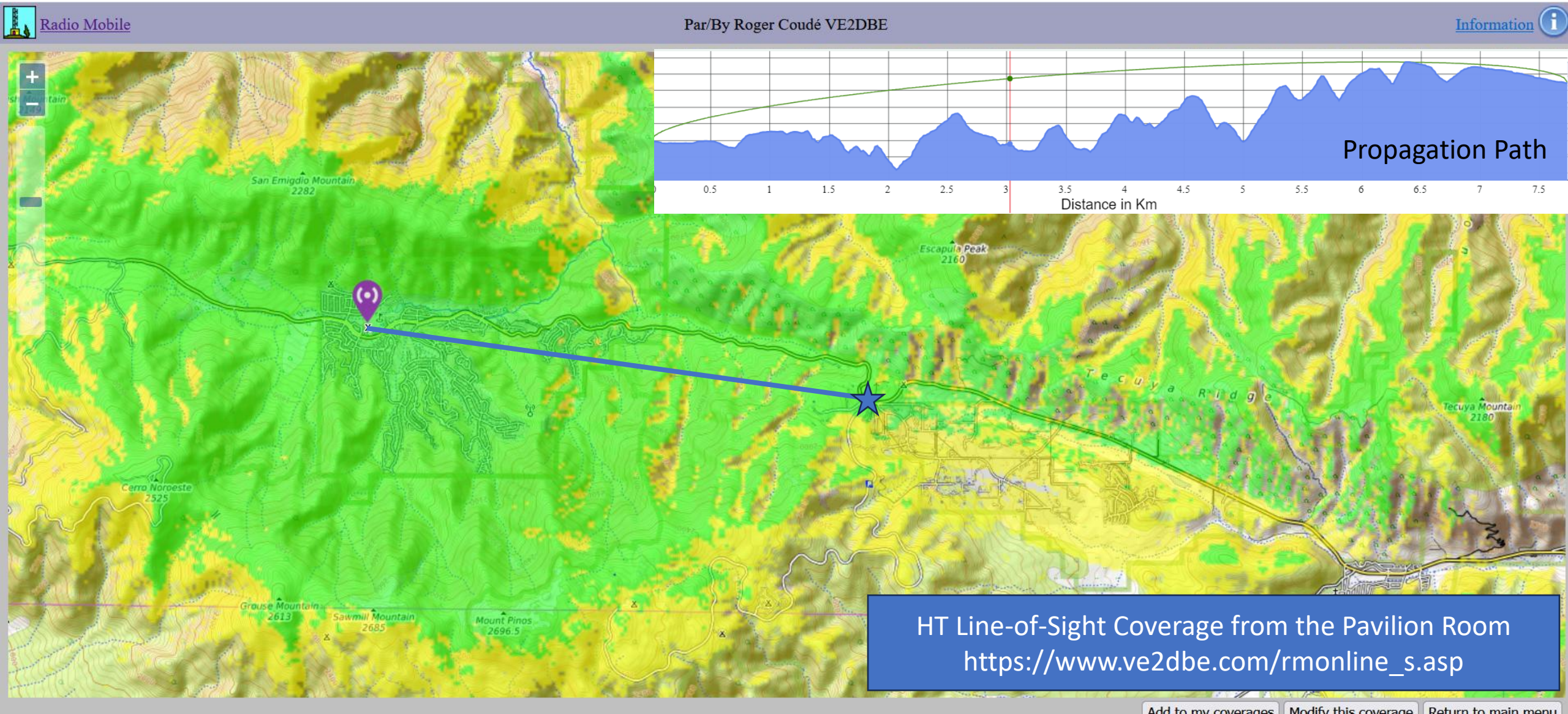
How Radio Waves Travel (“Propagation”)

- Ground Wave
  - Ground acts as a wave guide
  - Low HF and AM Radio
- Line-of-Sight (LOS)
  - Radio waves slightly refracted/reflected by atmosphere
  - FM Radio, VHF
- Sky Wave
  - Upper atmosphere bounces radio waves back to earth
  - HF, Shortwave Radio

Line-Of-Sight

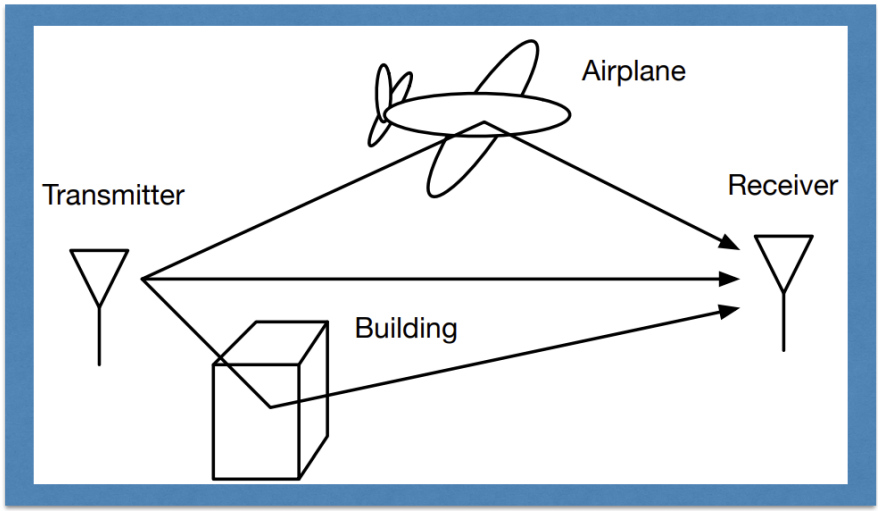
- At VHF, UHF, radio waves effectively travel in straight lines
- Limited by radio horizon
- Waves are slightly refracted by the atmosphere
  - Effective earth radius: 4/3 of the true radius
  - From a radio perspective: earth is slightly flatter than it is

VHF/UHF: Line of Sight Radio



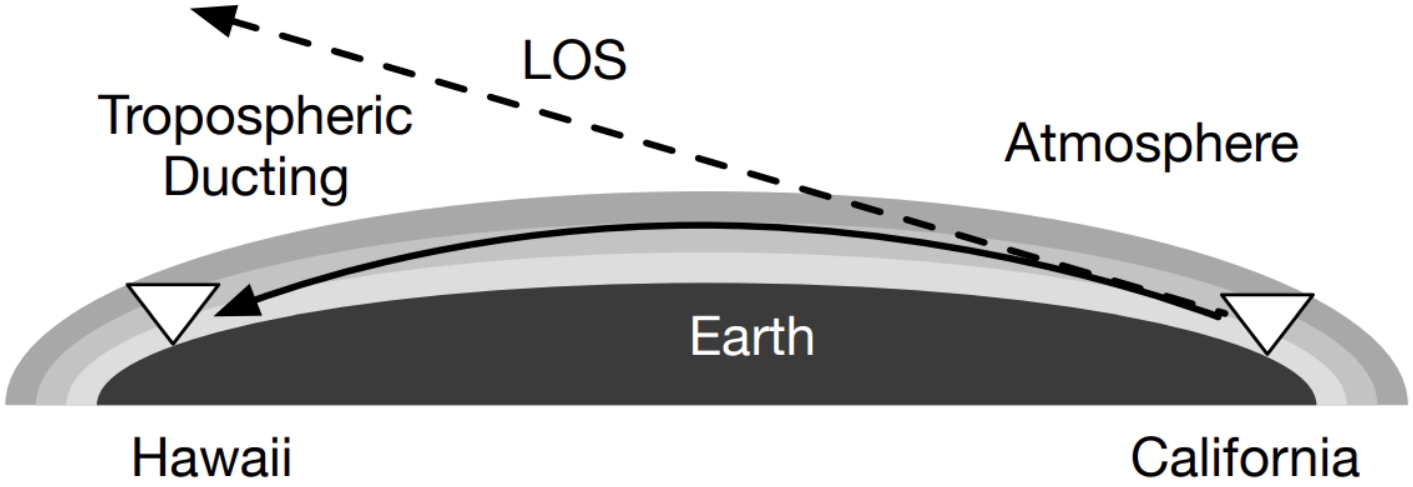
Multipath Propagation

- Radio waves often travel by multiple paths, which can interfere
  - Constructive interference – signal is louder/better
  - Destructive interference – signal is softer/more staticky
- Small changes in location can mean large changes in signal
  - “Picket Fencing” common when traveling at speed



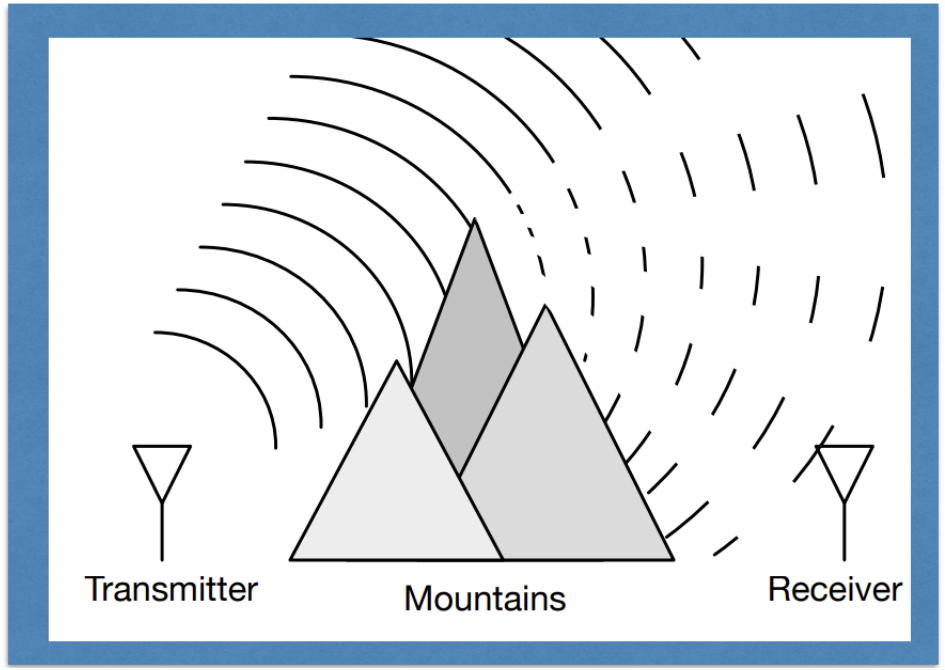
Tropospheric Ducting

- Temperature and humidity inversions can make the atmosphere act as a wave guide
- Frequently in August, VHF can be ducted from CA as far as Hawaii



Knife-Edge Diffraction

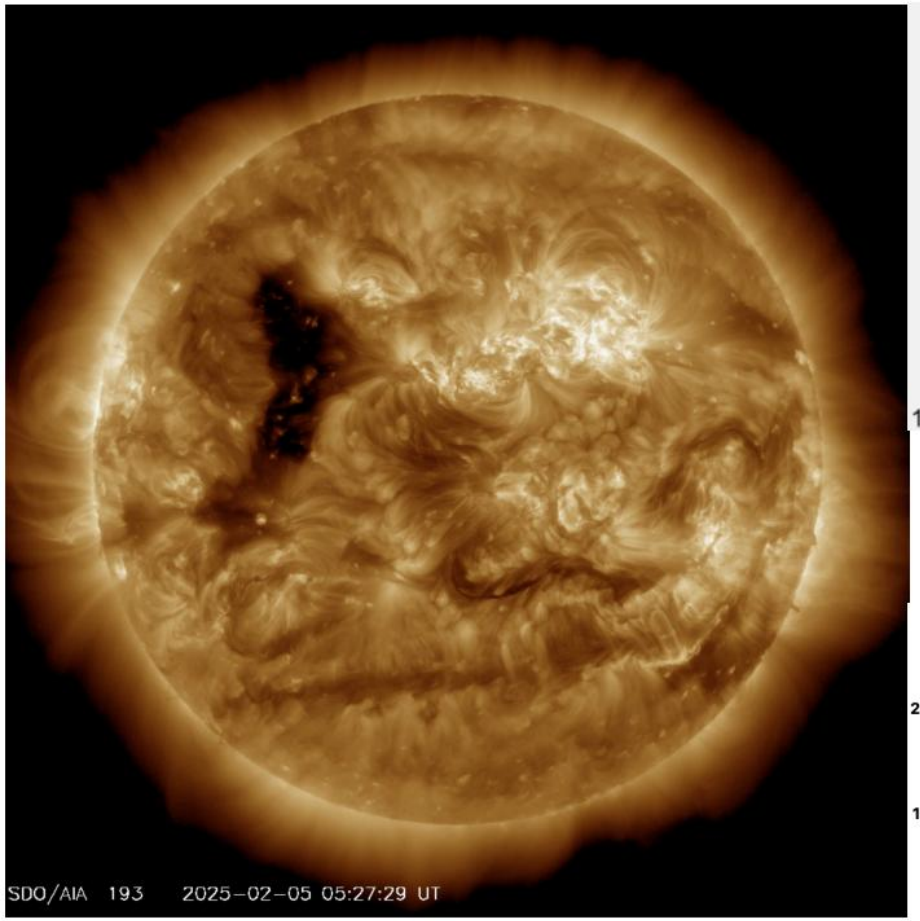
- Radio waves will diffract from sharp edges
  - Some power will be delivered behind the obstruction



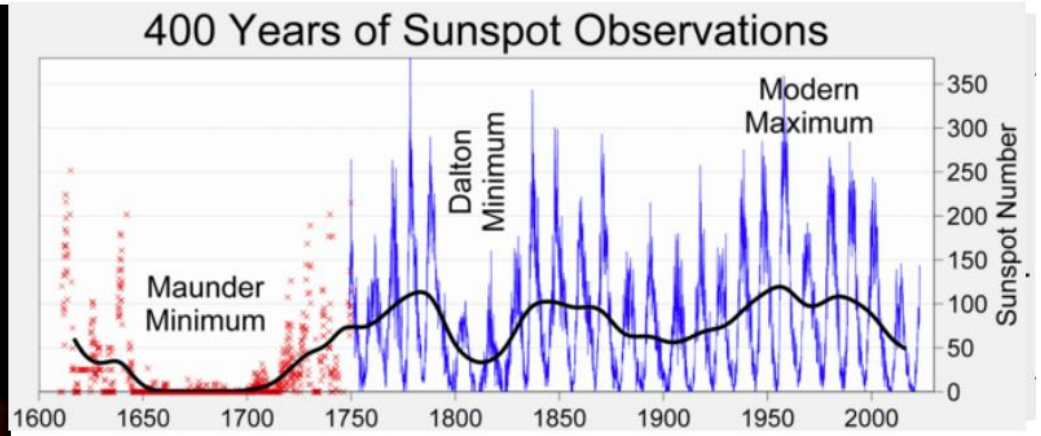
Ionospheric Propagation

- The sun ionizes the upper levels of atmosphere
- Some ionosphere layers attenuate, others refract radio waves
- Changes between day and night
- Atmospheric behavior is driven by solar activity
  - Number of sunspots, Coronal Mass Ejections (“Space Weather”)
  - Solar activity varies periodically over an 11-year / 22-year cycle
  - We are near the peak of our current solar cycle – a great time to be on HF!

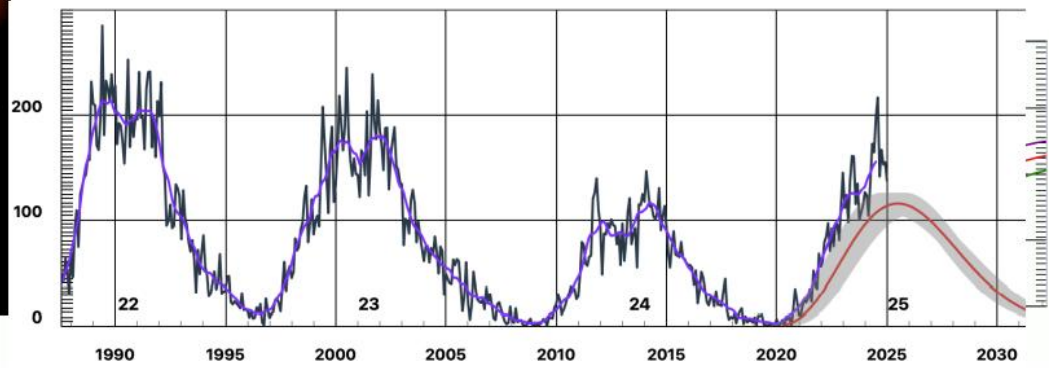
Solar Activity



Recent Solar Activity



History of Sun Spot Number



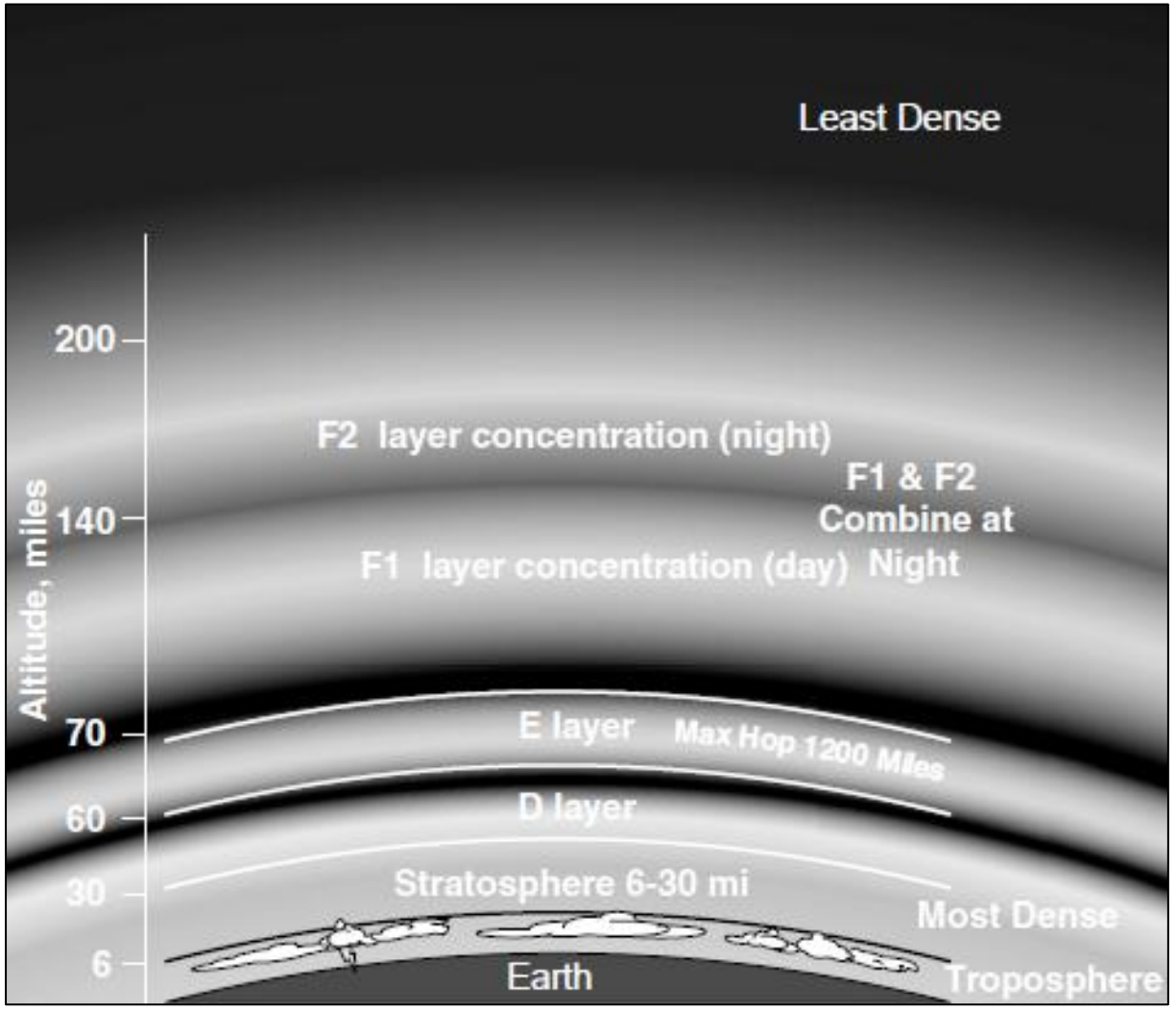
Recent Solar Cycles

Solar Weather Reports

- Tamitha Skov on Youtube
  - Updated Weekly – highly recommended!
- NOAA Space Weather Conditions
  - https://swpc.noaa.gov
  - Harder to read, but still useful

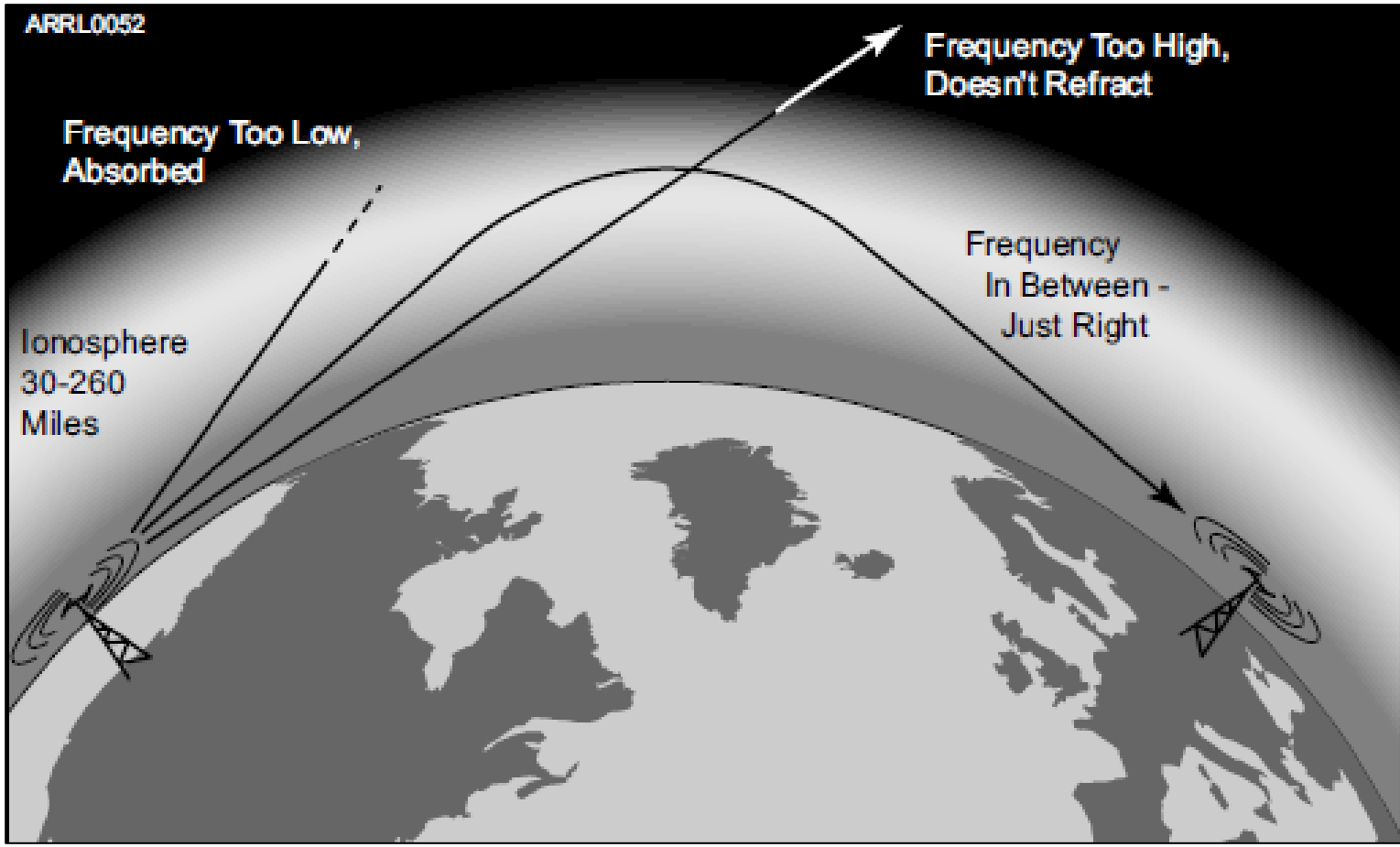
Ionosphere

- Sub ionizes atmosphere during the daytime
- Layers combine and dissipate at night
- Some layers reflect (E, F), some layers absorb (D) radio waves
- Each reflection is a *hop*



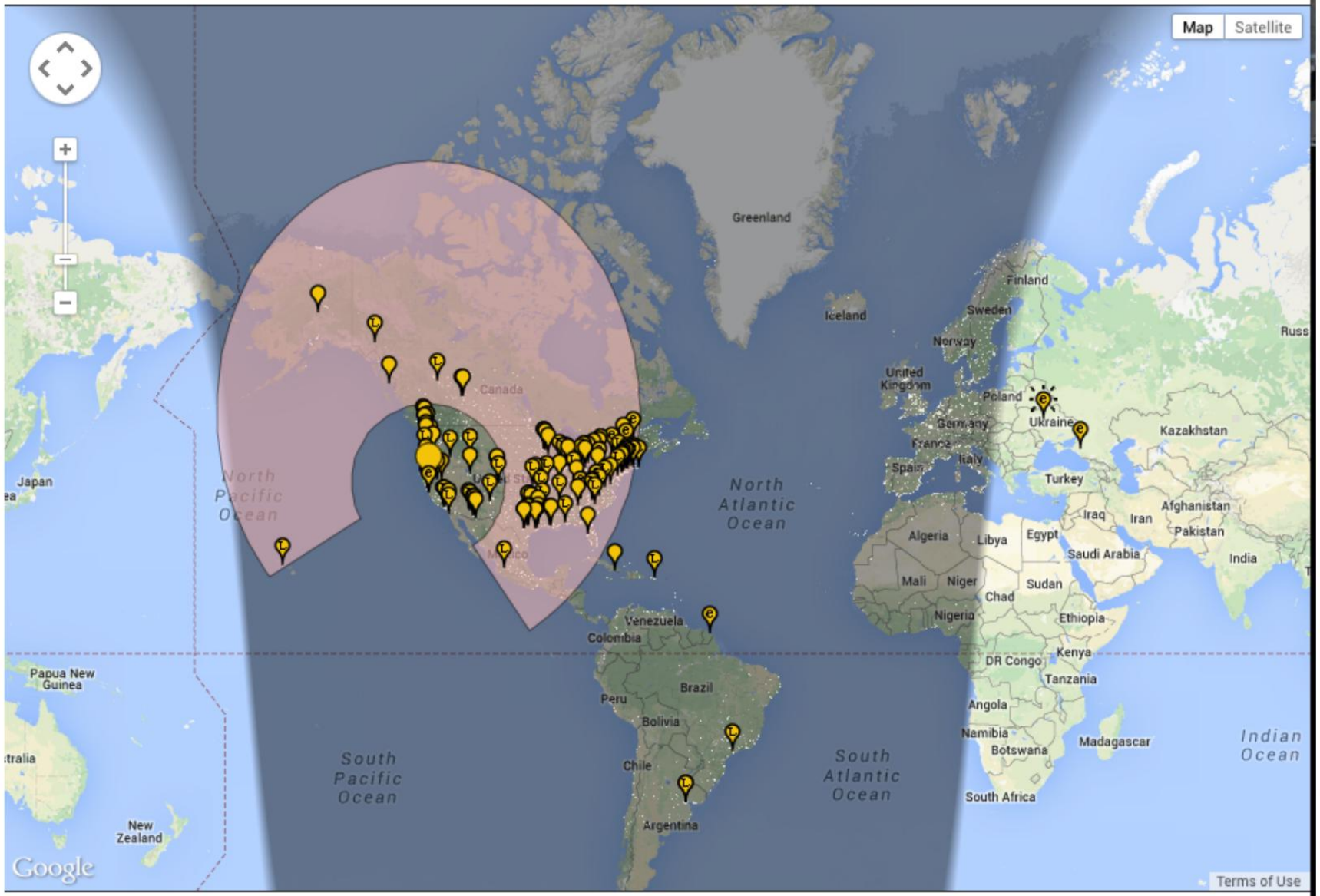
Usable Frequencies

- Lowest usable frequency (LUF): signal absorbed
- Maximum usable frequency (MUF): signal isn’t reflected
- Websites can calculate these for you



On 20m , show signals rcvd by the callsign ag6wh using all modes over the last 6 hours Go! Display options Permalink

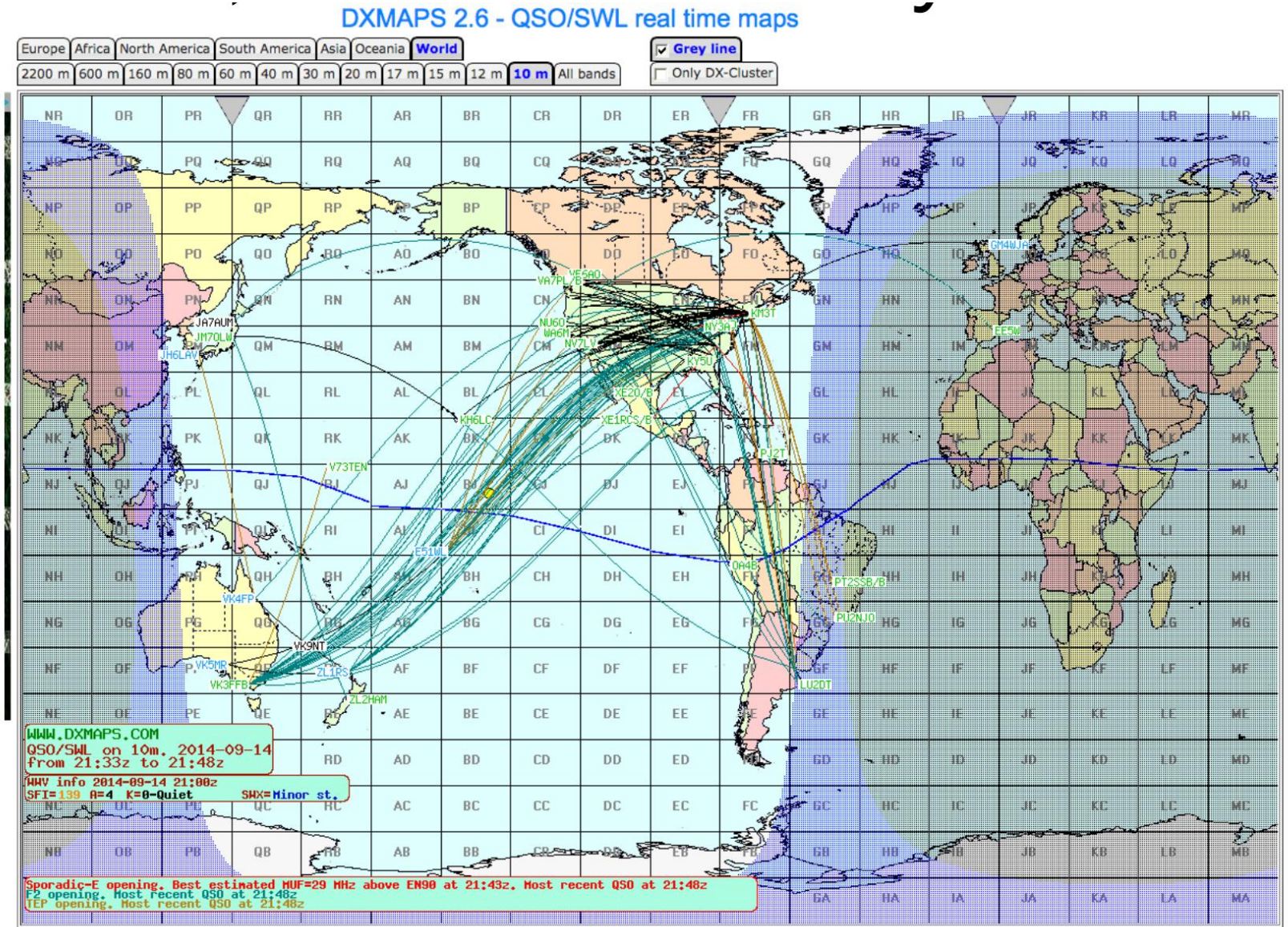
Automatic refresh in 3 minutes. Small markers are the 124 transmitters (show logbook) heard (distance chart) at AG6WH (292 reports, 22 countries last 24 hours; 629 reports, 28 countries last week).
There are 251 active monitors on 20m. Show all on all bands. Legend



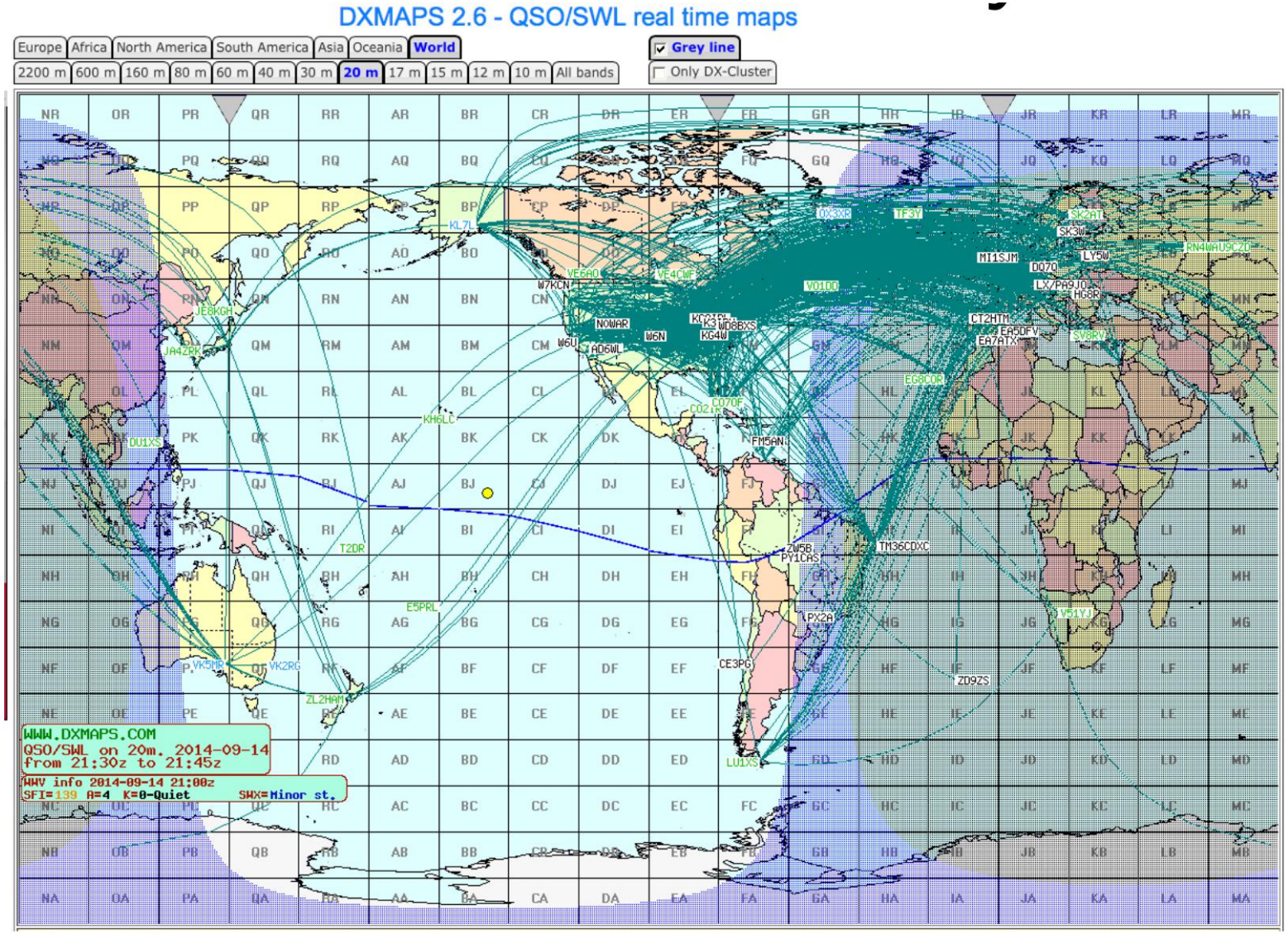
System statistics. Comments, problems etc to Philip Gladstone. Online discussion of problems/issues. Last modified: August 11, 2014 at 7:21:28 PM PDT
Reception records: 531,278,187 +1 301

PSKREPORTER.INFO

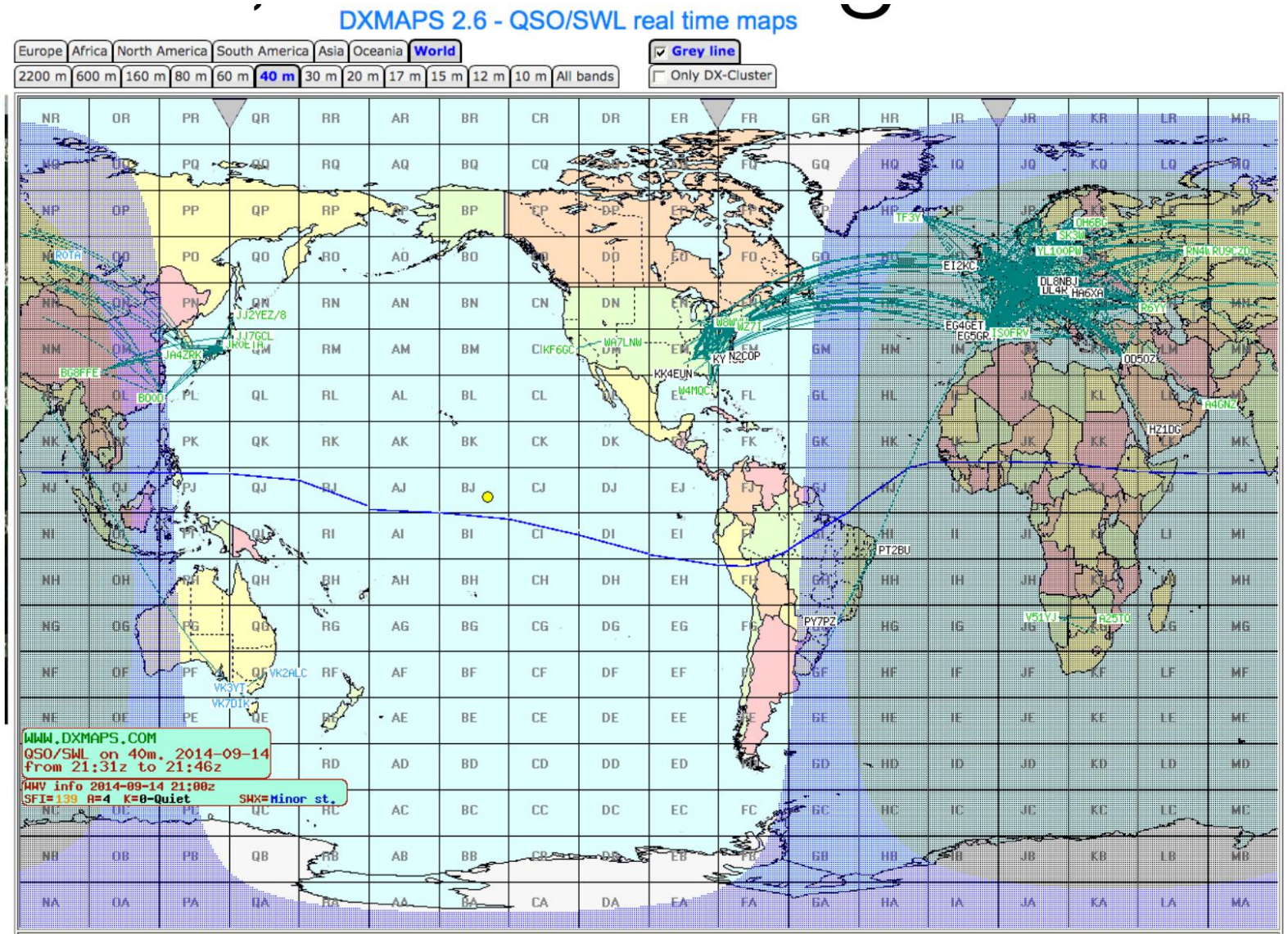
10m (28 MHz), Day



20m (14 MHz), Grayline



40m (7 MHz), Night



Many things can reflect radio waves

- Meteor trails
  - often in the F2 layer
- Aurora
  - Especially on VHF
  - Can reflect radio waves over thousands of miles
  - Signal strength usually changes quickly due to shifting aurora patterns
- Satellites
  - Side note: some satellites carry repeaters – separate topic
- Moon

Antennas

What is an Antenna?

- Unshielded piece of metal connected to your radio
- Allows your radio to emit and detect propagating waves
- Currents on the antenna elements produce electric, magnetic fields
- Antenna dimensions matter!
  - Matched to the wavelength of the wave you want to generate

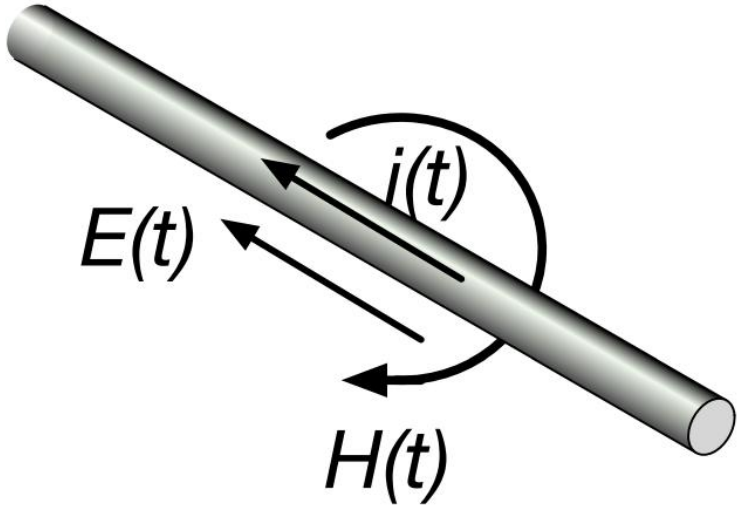
Types of Antennas

- **Omni-directional**: waves radiate equally in all directions
- **Directional/Beam**: Focuses energy in one direction

- **Gain**: how well your signal is enhanced in a direction
  - Compared to a reference antenna, measured in **decibels** (dB)
    - Decibels are a logarithmic scale
  - **dBi**: decibels relative to an isotropic antenna
    - Isotropic antenna is theoretical, radiates equally well in all directions
  - **dBb**: compared to a dipole antenna

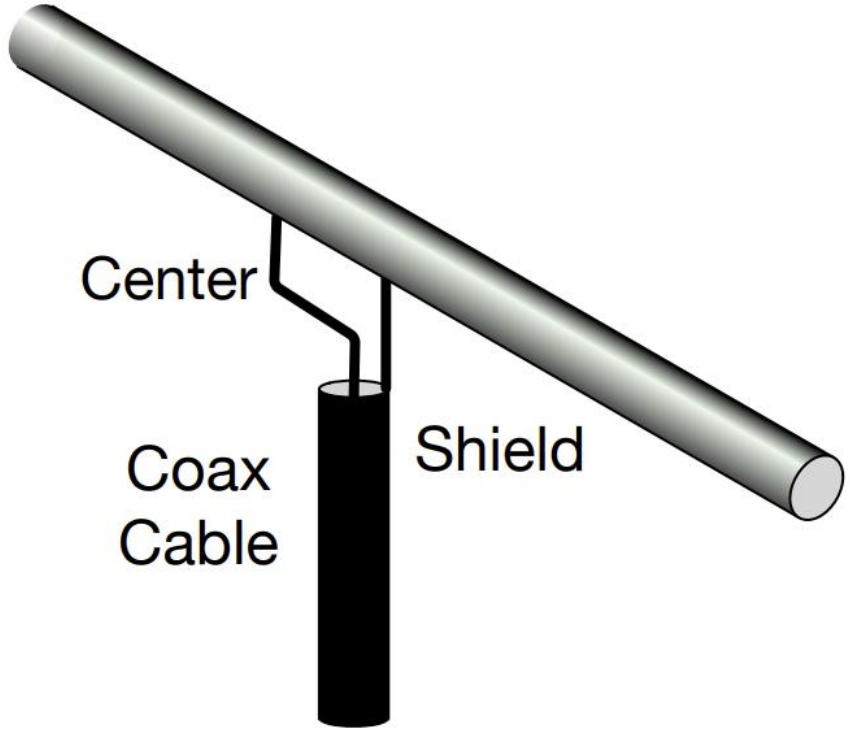
Current in a Conductor

- Current flows along a conductor
- Electric fields run parallel to the conductor
- Magnetic fields run perpendicular to the conductor



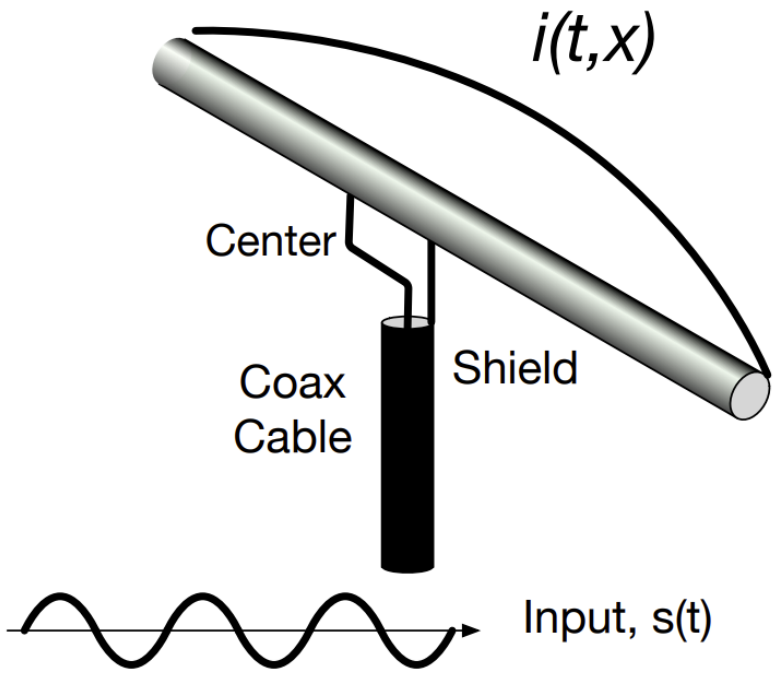
Dipole Antenna

- The antenna is driven at the center and an offset
- Dipole arm length changes the antenna impedance



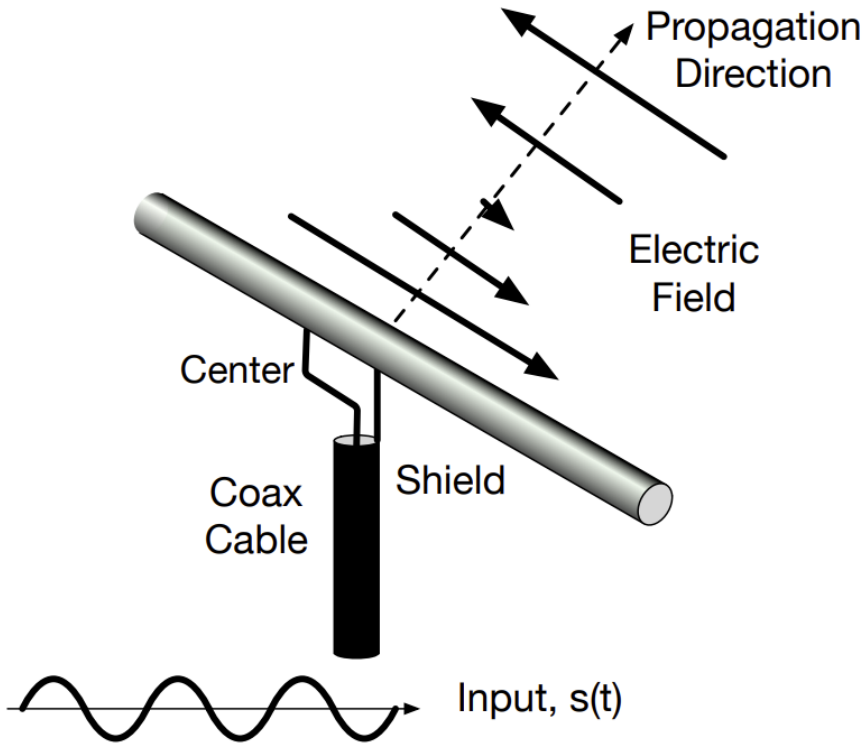
Dipole Antenna

- Sinusoidal input = half-cycle of current along antenna
- Length of the antenna should be ½ the wavelength



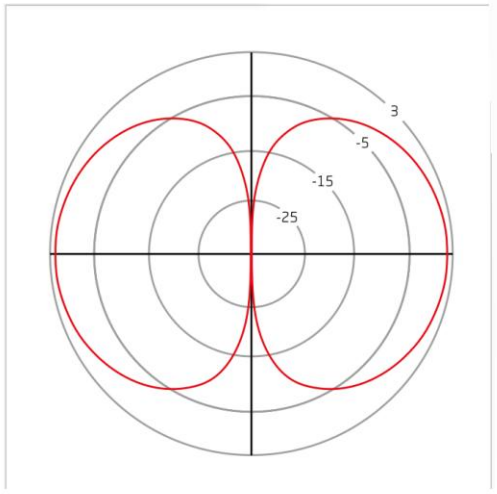
Dipole Antenna

- Oscillating electric field propagates away from the antenna

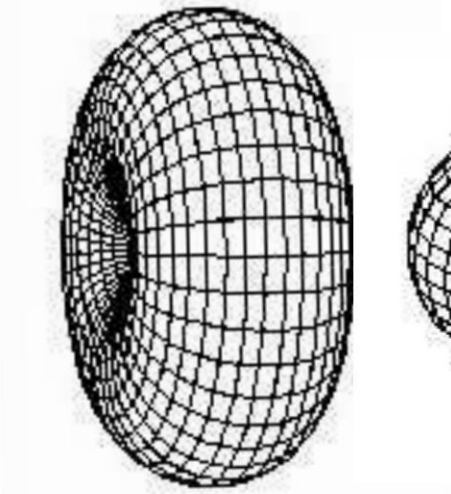


Dipole Antenna

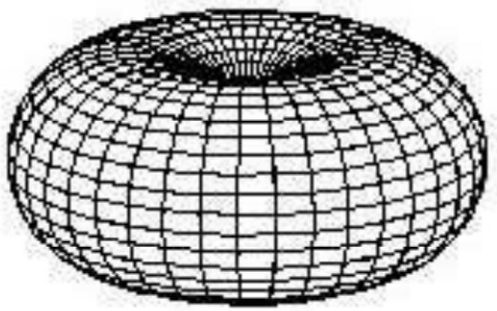
- Length is ½ the wavelength of the transmit carrier frequency
  - At 150 MHz, wavelength = 2m, so the antenna should be 1m long
  - At 450 MHz, wavelength = 67cm, so the antenna should be 33cm long
- Radiation pattern:



Horizontal



Horizontal



Vertical

Antenna Radiation Patterns

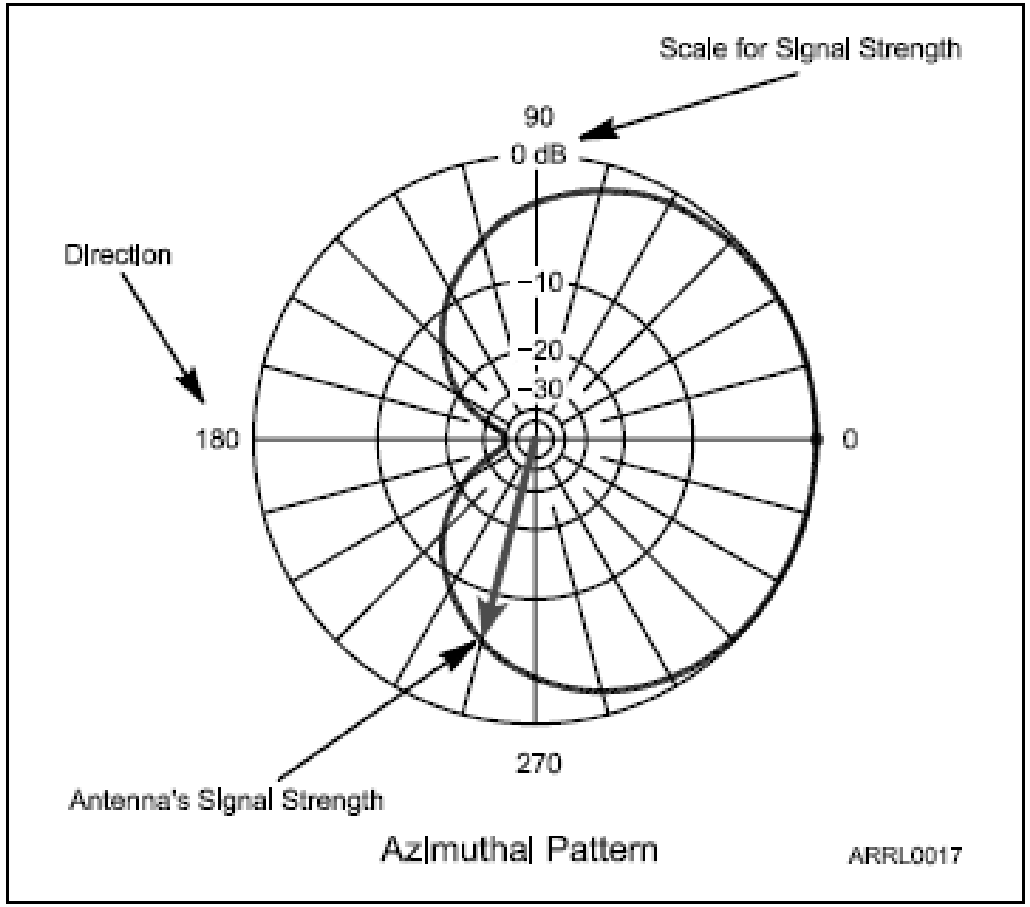


Figure 4.5 — As if looking down on the antenna from above, the azimuth radiation pattern shows how well the antenna transmits or receives in all horizontal directions. The distance from the center of the graph to the solid line is a measure of the antenna's ability to receive or transmit in that direction.

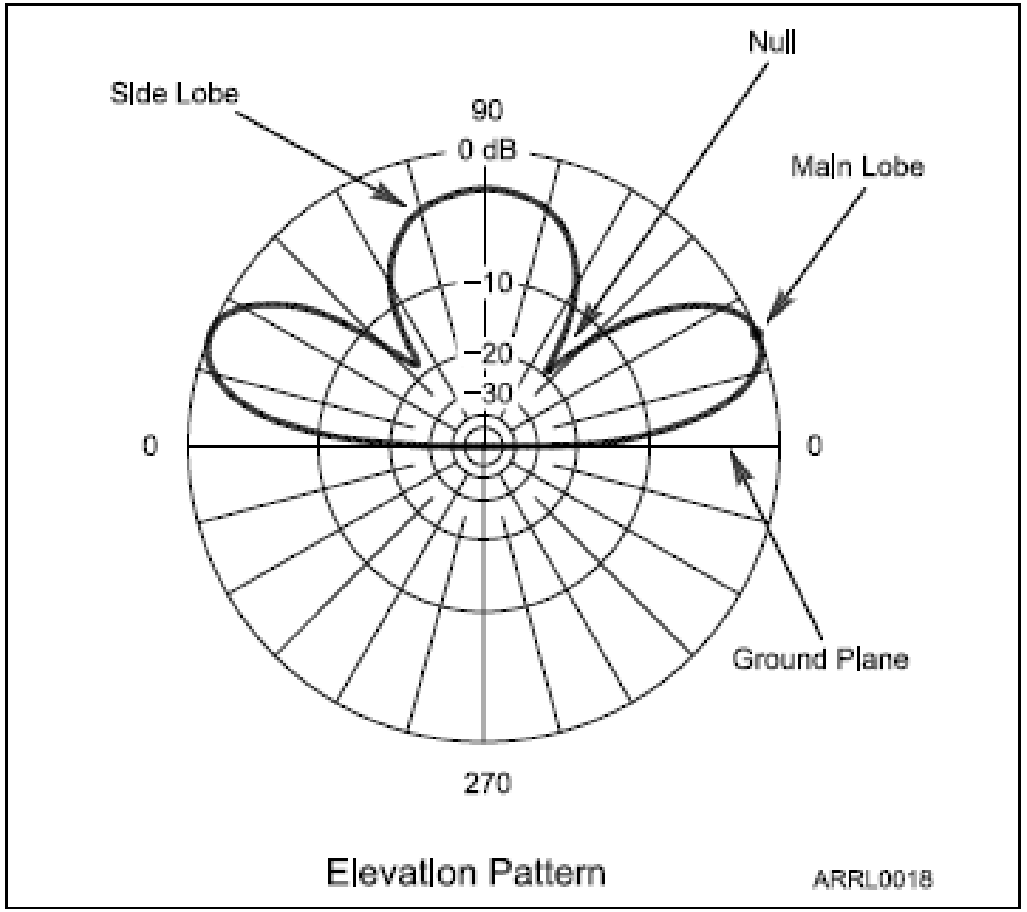


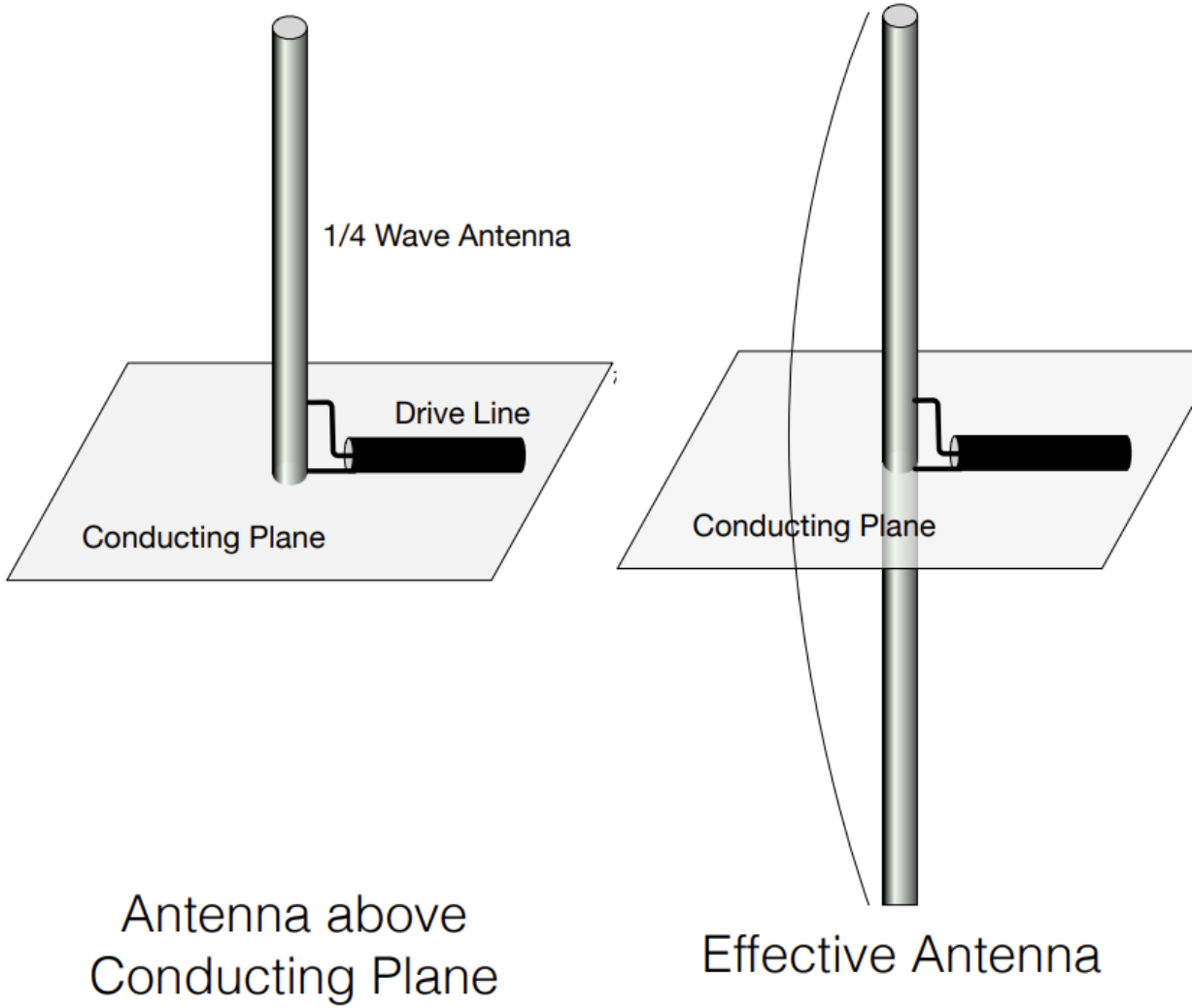
Figure 4.6 — The elevation pattern looks at the antenna from the side to see how well it receives and transmits at different angles above a horizontal plane.

Polarization

- Polarization = direction of the electric field
  - Horizontal, vertical, circular
- Horizontal dipole has horizontal polarization
- Vertical dipole has vertical polarization
- If transmitting and receiving antennas have different polarizations
  - Very large signal loss!

¼ Wave Vertical Antennas

- Conducting surfaces act as a current mirror
  - “Ground plane”
- You get the second half of the antenna for free!



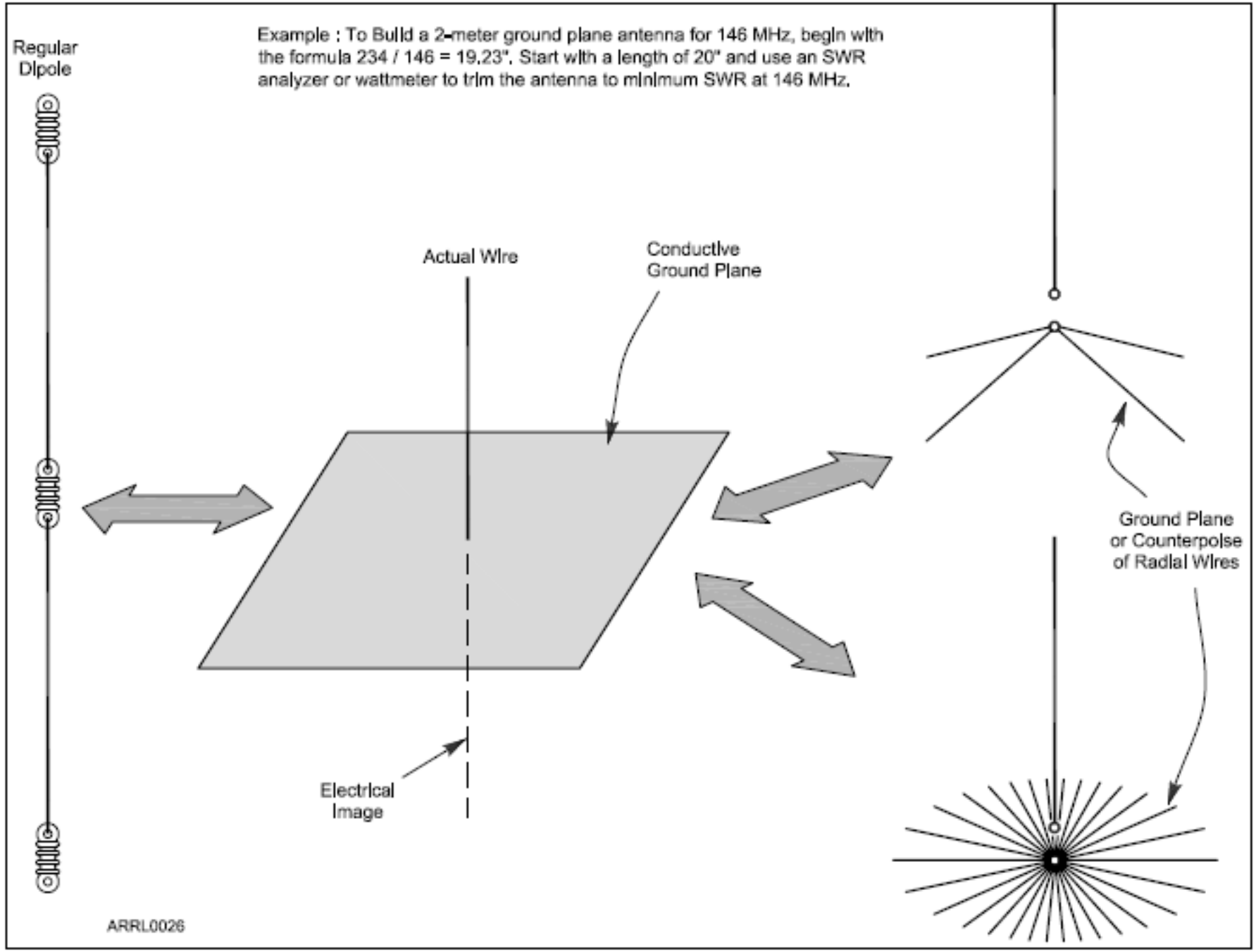
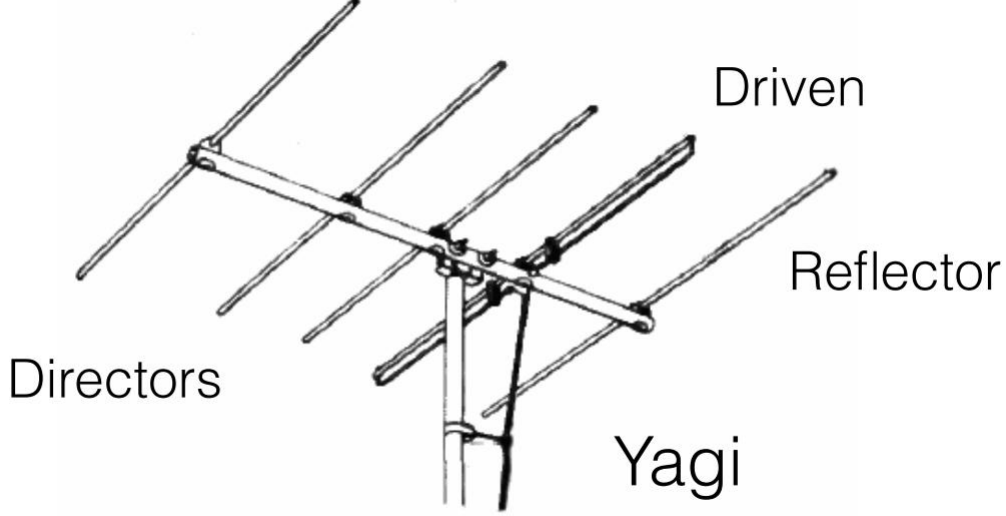
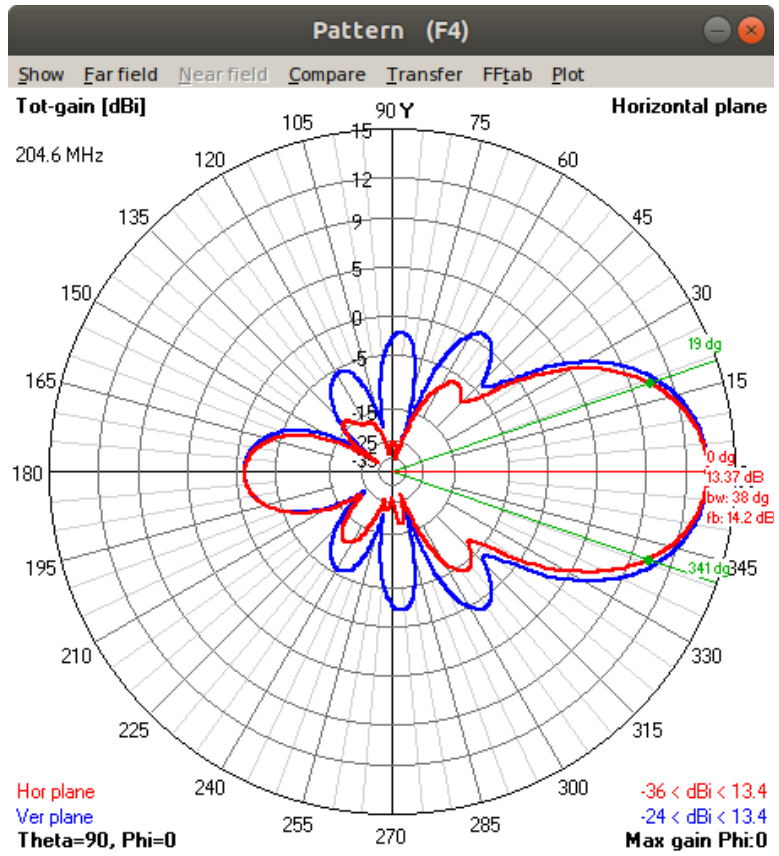


Figure 4.10 — A *ground-plane* makes up an electrical mirror that creates an image of the missing half of a ground-plane antenna. The result is an antenna that acts very much like a dipole. The ground plane can be made up of a screen of wires (often used at HF) or a metal surface at VHF and UHF. For VHF and UHF antennas mounted on masts, a counterpoise of a few wires serves the same purpose.

Beam Antennas

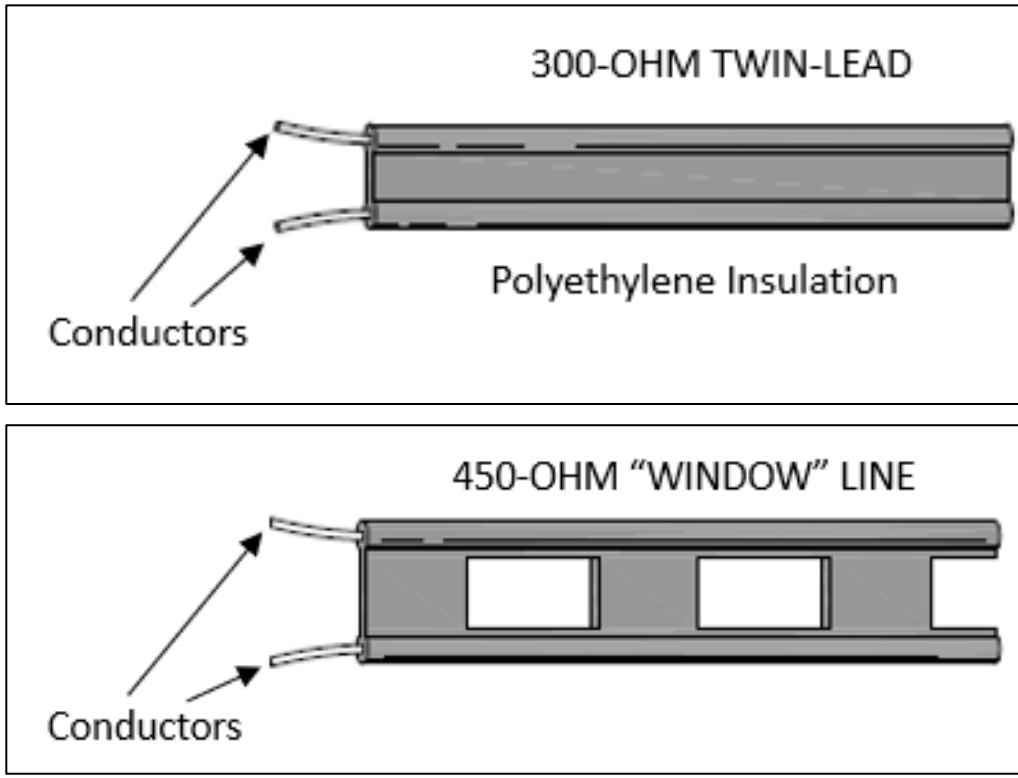
- Generally 1 driven element
- Directors focus energy forward
- Reflectors cancel out the pattern to the rear
- Higher gain in 1 direction
  - Power isn't created
  - Waves are manipulated to amplify or cancel out in different directions





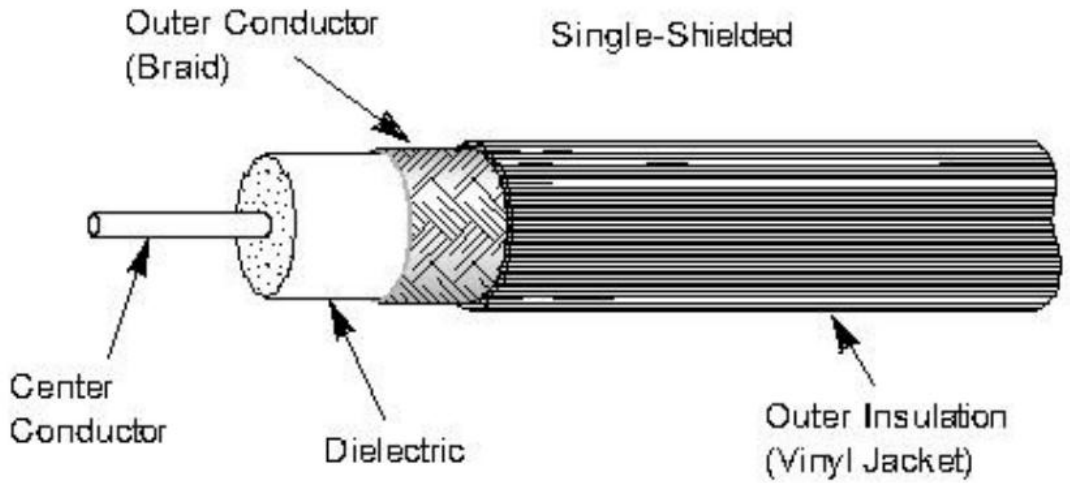
Feed Lines

- How your radio is connected to your antenna
- Responsible for delivering electrical energy
- Common types:
  - Coaxial
    - Convenient
    - Can have multiple cables next to each other
  - Open-wire line / “Ladder Line”
    - Very low loss
    - Can’t be near other lines

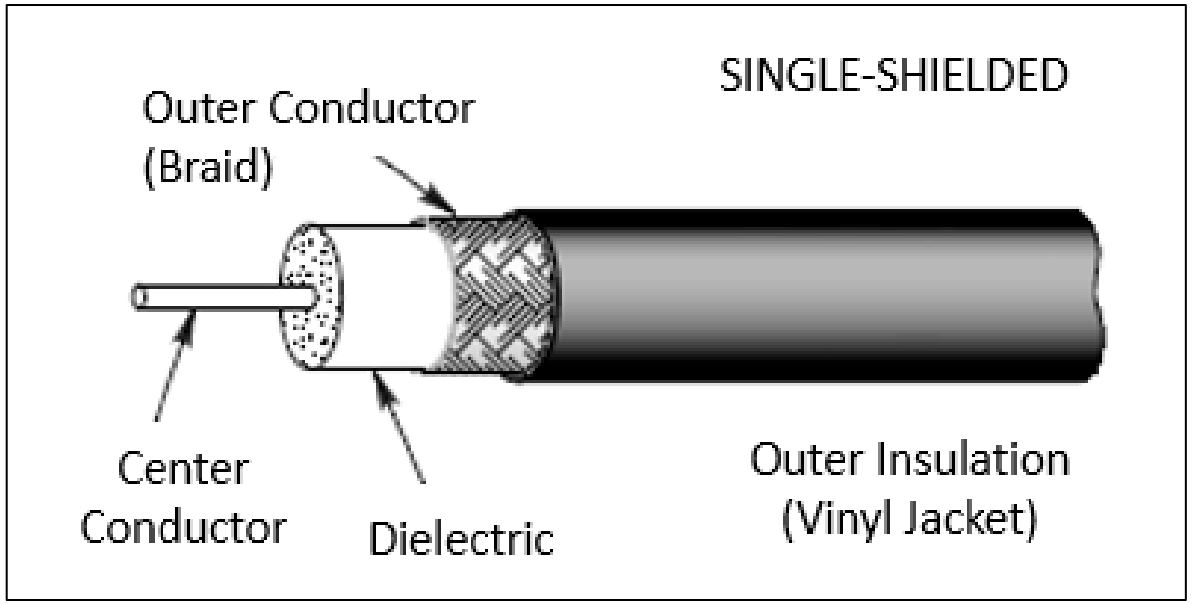


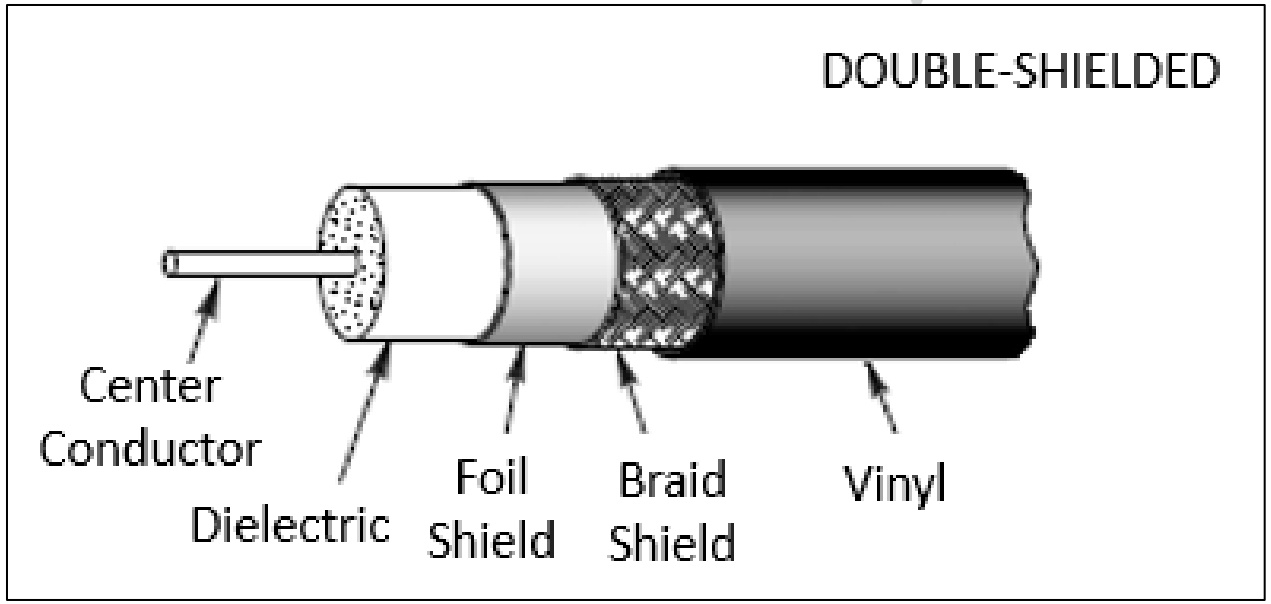
Coaxial Cable (“Coax”)

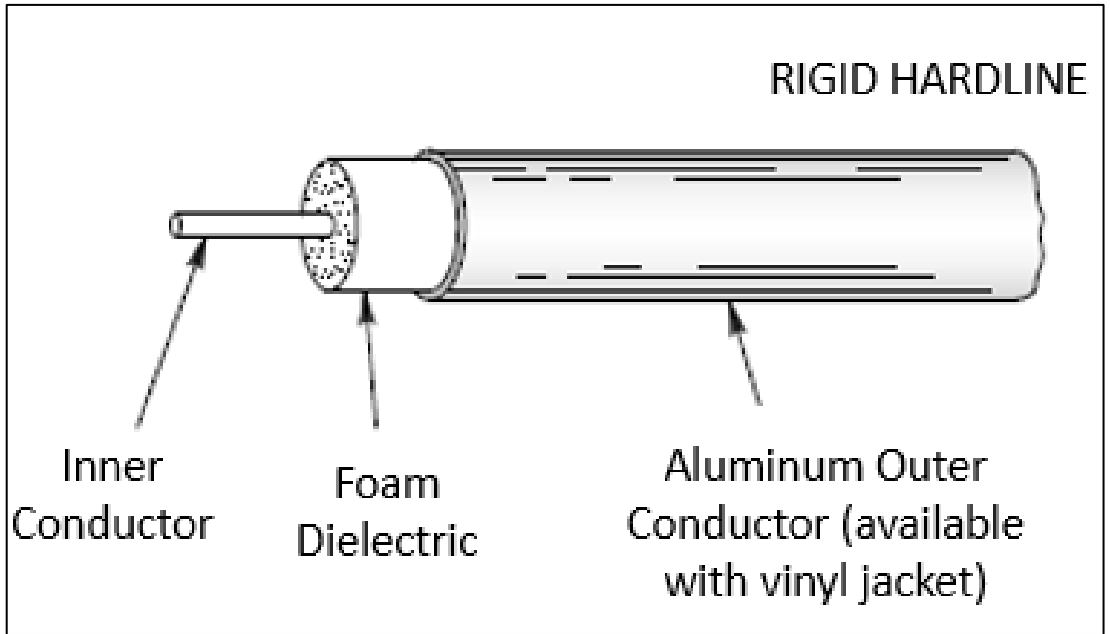
- Most common feedlines
- Commonly 50-Ohm impedence
  - Cable service coax is usually 75-Ohm
  - Other impedances exist too
- Loss depends on the frequency, cable properties

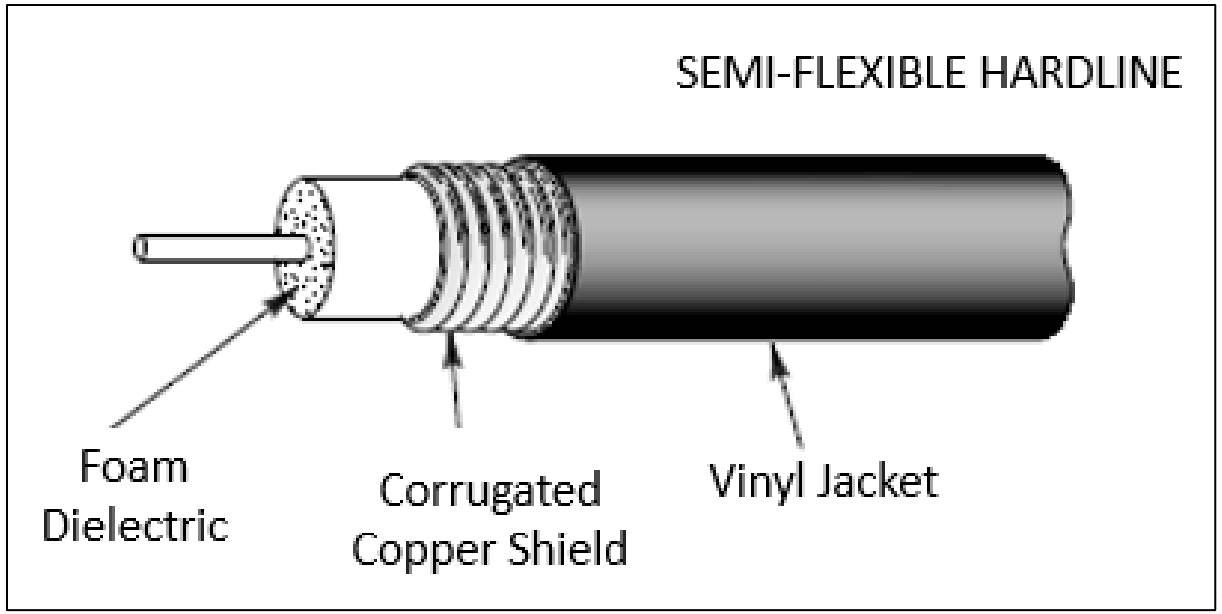


Coaxial Cable









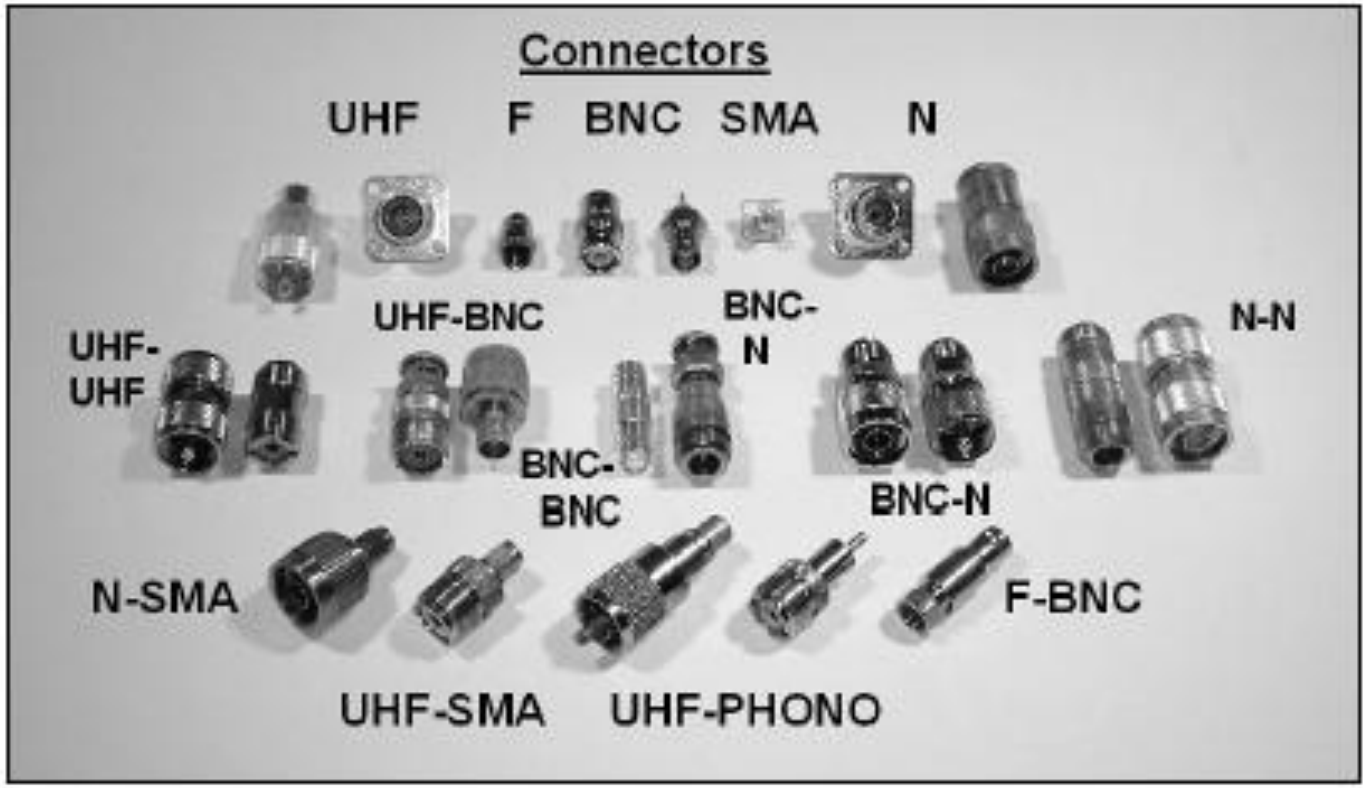
Coax Cable Loss (dB/100’)

TYPE	IMPEDANCE	Loss Per 100’ @ 30 MHz	Loss Per 100’ @ 150 MHz
RG-6	75	1.4	33
RG-8	50	1.1	2.5
RG-8X	50	2.0	4.5
RG-58	50	2.5	5.6
RG-59	75	1.8	4.1
RG-174	50	4.6	10.3
RG-213	50	1.1	2.5
LMR-400	50	0.7	1.5

Online calculator: www.timesmicrowave.com/calculator

Connectors

- SO-259 / PL-239 / “UHF” common for HF, also seen in VHF/UHF
- N common above 400 MHz
- BNC up to GHz
- SMA GHz and above
  - Also on many HTs



Connectors

UHF
HF, low VHF

BNC
up to 1 GHz

SMA
1 GHz and up

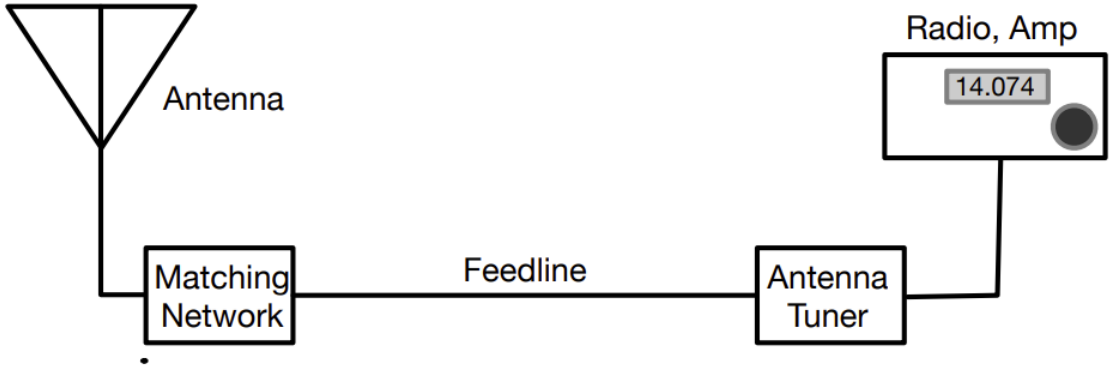
Connection to the Antenna

- Ideally, all power from the feedline gets to the antenna
- Feedline impedance, antenna input impedance should match
- If impedances mismatched, some power reflected back to amplifier
  - Reduces transmit power
  - Increases line losses (released as heat)
  - Reduces amplifier output
  - Can damage the amplifier if too much power reflected!

Standing Wave Ratio (SWR)

- Ratio of total power : forward power
- Always in the form X:1
- Perfect SWR is 1:1
- Semiconductor amplifiers have troubles at SWR > 2:1

Antenna Matching



- Matching network: part of the antenna
  - Makes sure the antenna can accept the power from the feedline
- Antenna tuner: adjustable matching network
  - Doesn’t really tune the antenna
  - Makes the amplifier happy
  - You still have a standing wave in the feedline

Antenna Tuners / “Transmatch”

- Many radios (esp. on HF) have an OK tuner built-in

Measuring Antenna Matching

- Antenna Analyzer: measure antenna input impedance, freq. response
- SWR meter: measure SWR, forward power, reflected power
- Recommended tool: NanoVNA

Questions?

- Next week: overlap with EP Town Hall (12-2pm)
  - Reschedule to later in the day? 3pm?

- Proposed schedule – 1 additional day
  - March 9: Radio Equipment Communicating (read ch.5, ch.6)
  - March 16: Regulations (read ch.7, ch.8)
  - March 25: Safety and Preparing For the Exam (ch.9)

END OF MODULE 5

ARRL The National Association for Amateur Radio®
225 Main St, Newington, CT 06111-1400 USA
www.arrl.org