SCARS Tech License Course – Week 4

Propagation and Antennas

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Technician License Course

Chapter 4

Lesson Plan Module – 4a

Propagation

Radio Wave Propagation: Getting from Point A to Point B

- Radio waves propagate in many ways depending on…
  - Frequency of the wave
  - Characteristics of the environment
- We will discuss three basic ways:
  - Line of sight
  - Ground wave
  - Sky wave

Line-of-Sight

- Radio energy can travel in a straight line from a transmitting antenna to a receiving antenna – called the *direct path*
  - There is some attenuation of the signal as the radio wave travels due to spreading out
- This is the primary propagation mode for VHF and UHF signals.

Ground Wave

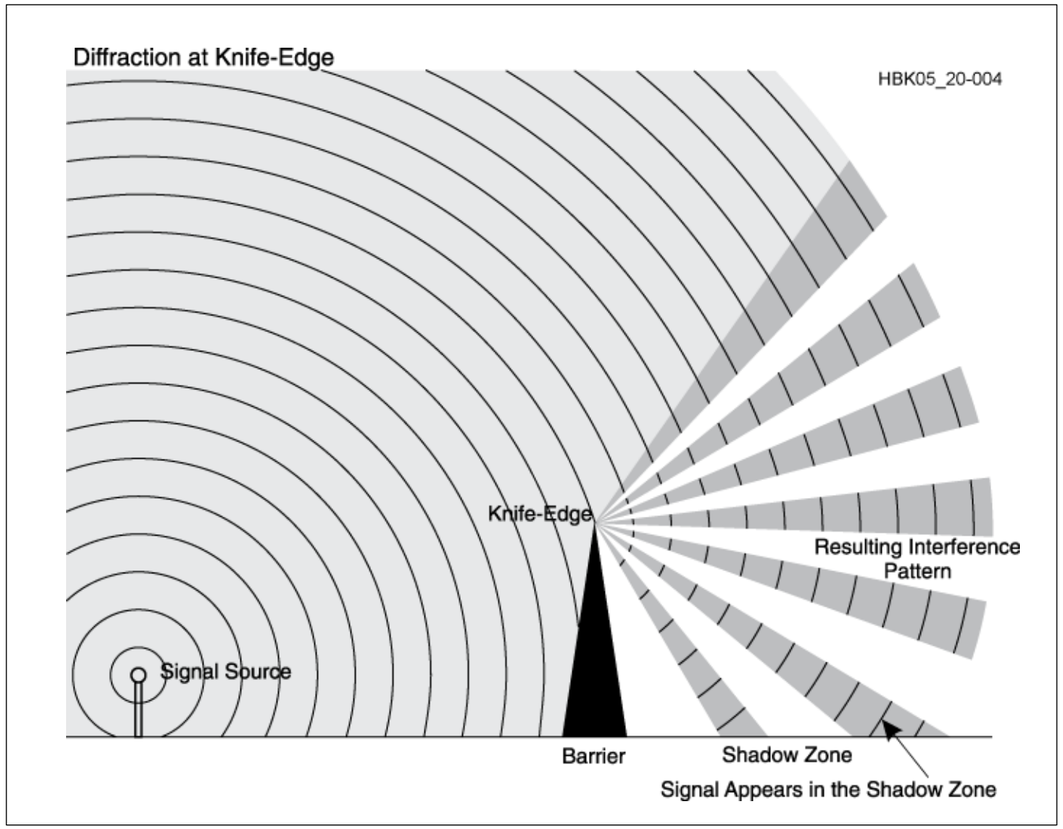
- At lower HF frequencies radio waves can follow the Earth's surface as they travel.
- These waves will travel beyond the range of line-of-sight.
- Range of a few hundred miles on bands used by amateurs.

Reflect, Refract, Diffract

- Radio waves are reflected by any conductive surface
  - Ground, water, buildings
- *Refraction* or bending occurs when waves encounter a medium having a different speed of light, such as water or an electrical feed line.

Reflect, Refract, Diffract

- Diffraction occurs when a wave encounters a sharp edge (*knife-edge propagation*) or corner



VHF and UHF Propagation

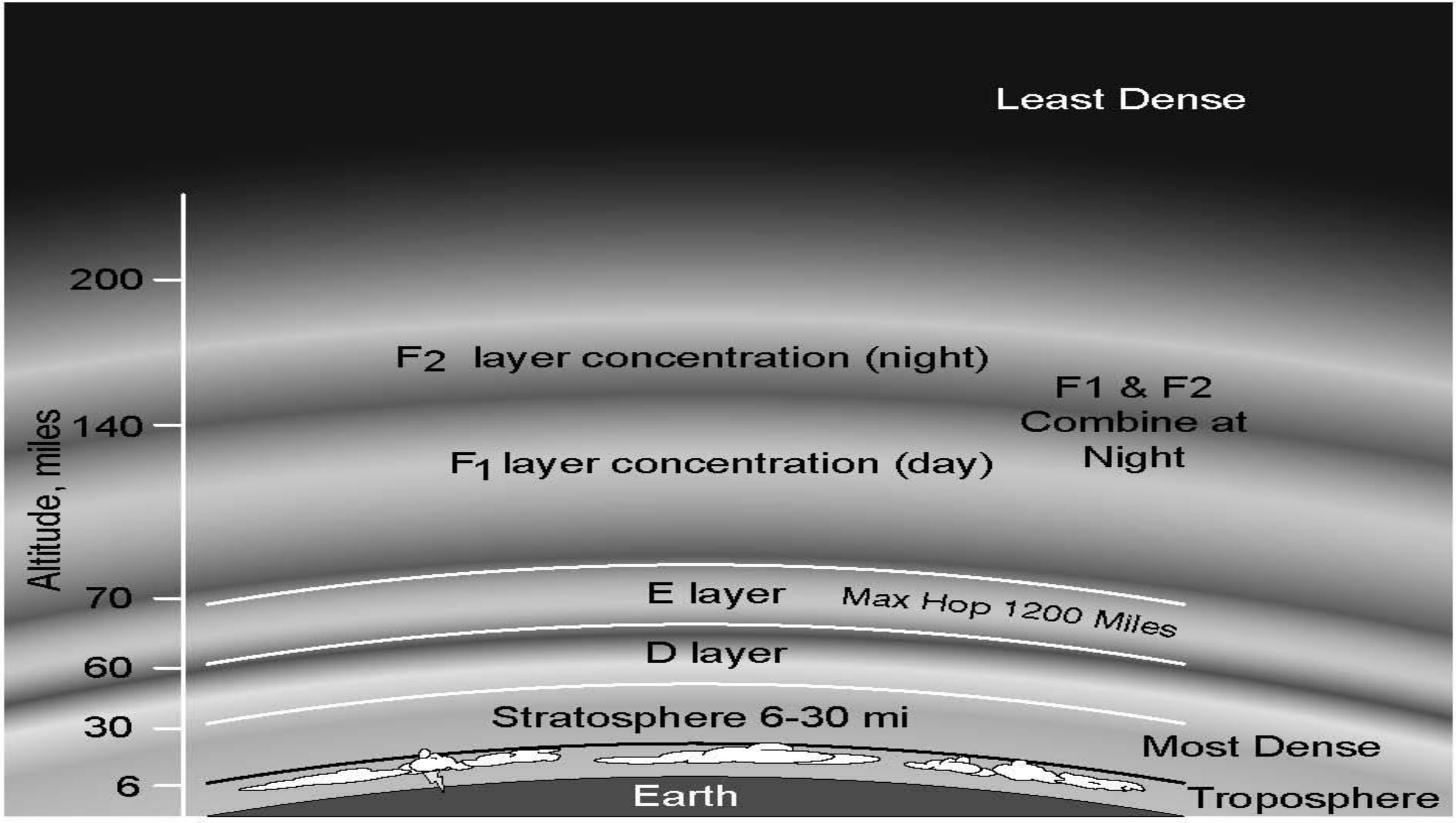
- Range is slightly better than visual line of sight due to gradual refraction (bending), creating the *radio horizon*.
- UHF signals penetrate buildings better than HF/VHF because of the shorter wavelength.
- Buildings may block line of sight, but reflected and diffracted waves can get around obstructions.

VHF and UHF Propagation

- *Multi-path* results from reflected signals arriving at the receiver by different paths and interfering with each other.
  - *Picket-fencing* is the rapid fluttering sound of multi-path from a moving transmitter

"Tropo" - Tropospheric Propagation

- The troposphere is the lower levels of the atmosphere – to about 30 miles high
- Radio waves can be reflected or *scattered* by clouds, rain, and density variations in the troposphere – range up to about 300 miles
- Temperature inversions and weather fronts can form *ducts* that trap and conduct VHF and UHF radio waves for hundreds of miles

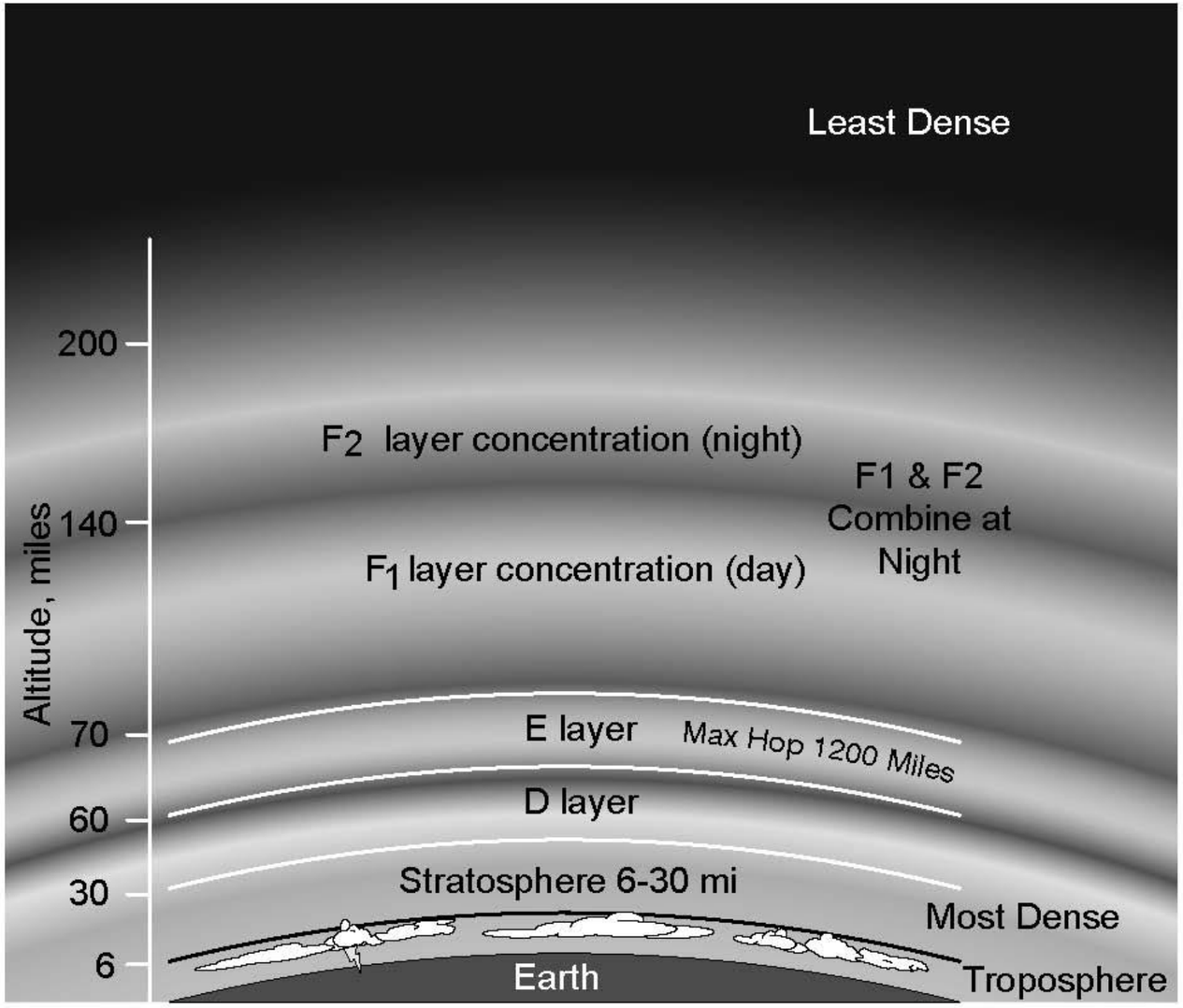

Least Dense
Altitude, miles
200
140
70
60
30
6
F2 layer concentration (night)
F1 & F2
Combine at
Night
F1 layer concentration (day)
E layer
Max Hop 1200 Miles
D layer
Stratosphere 6-30 mi
Most Dense
Earth
Troposphere

The Ionosphere

- A region from 30 to 260 miles above the surface of the Earth
- Atmosphere thin enough for atoms to be ionized by solar ultraviolet radiation
- Ions are electrically conductive

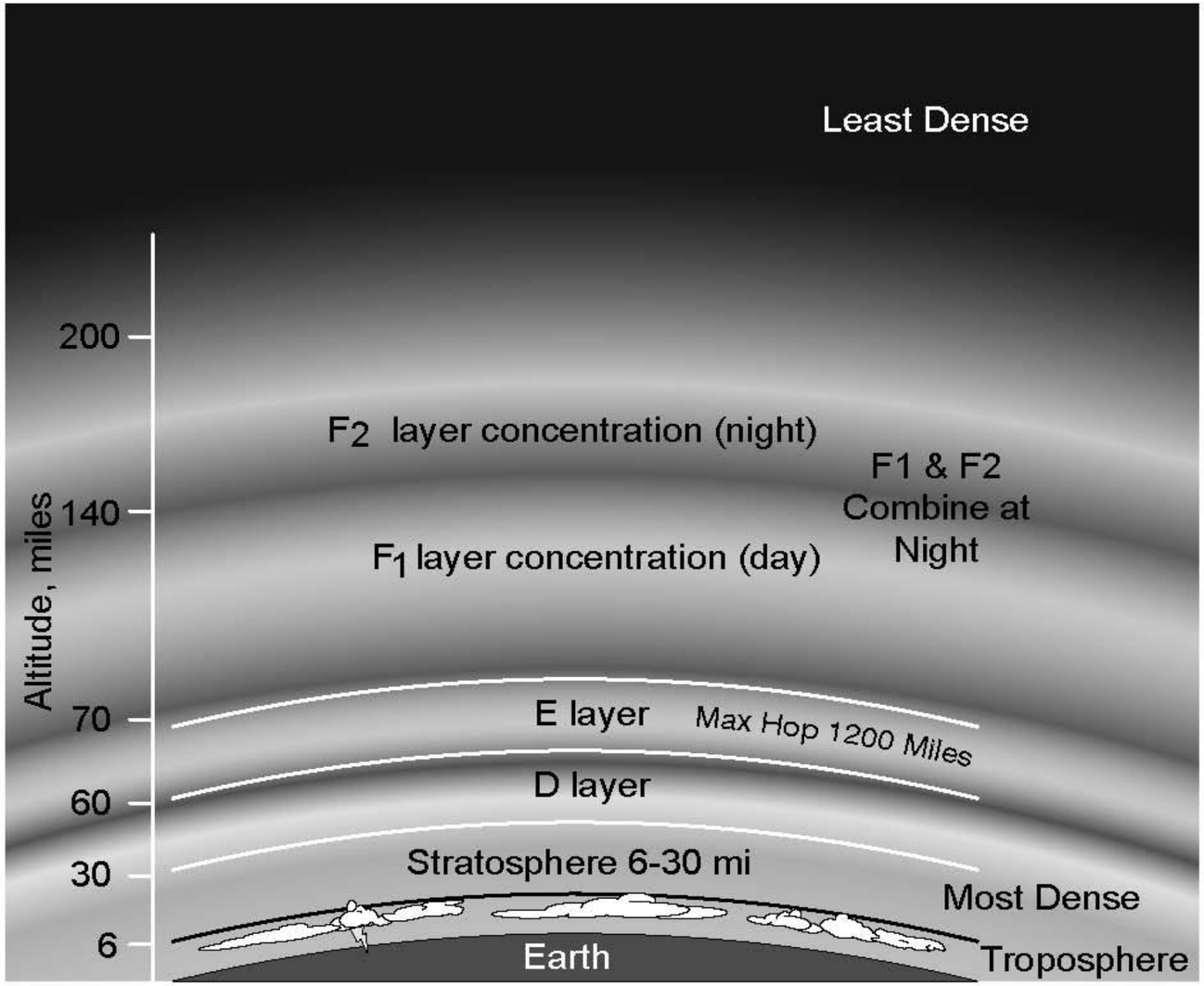
Ionospheric Levels

- Because of varying density, the ionosphere forms layers with different amounts of ionization
- Ionization varies with solar illumination (hour to hour) and intensity of solar radiation



Ionospheric Levels

- Higher ionization refracts or bends radio waves more strongly

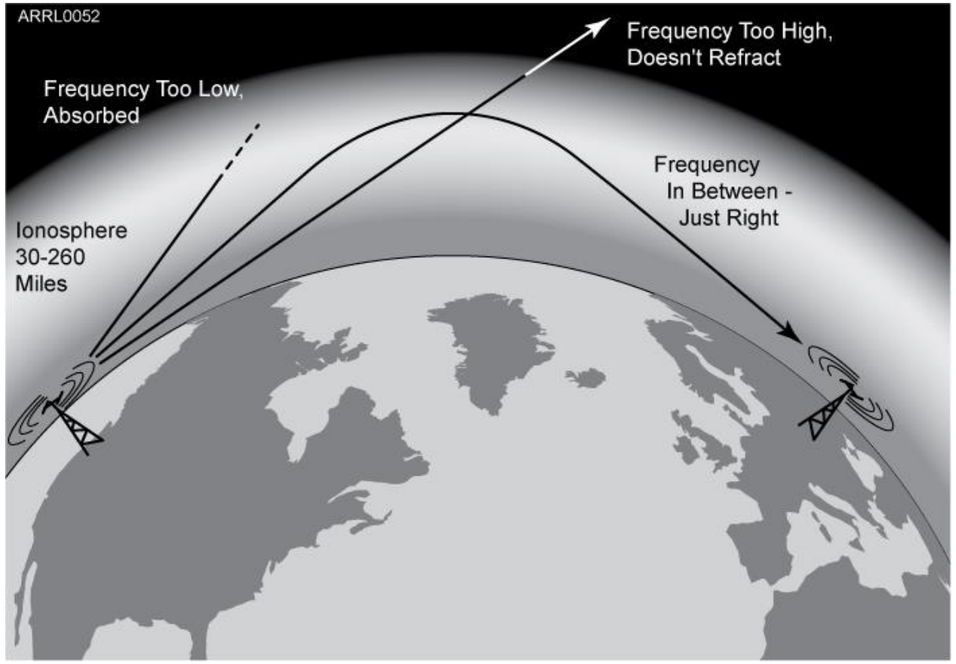


The Ionosphere – An RF Mirror

- The ionosphere can refract (bend) radio waves back to Earth – acts like reflection
- Most refraction of amateur frequencies occurs in the F layer

The Ionosphere – An RF Mirror

- Reflection depends on frequency and angle of incidence.
- Too high a frequency or angle and the waves are lost to space.



The Ionosphere – An RF Mirror

- Sky-wave or skip propagation is responsible for most over-the-horizon propagation on HF and low VHF (10 and 6 meters) during peaks of the sunspot cycle.
- Skip is very rare on the 144 MHz and higher UHF bands.
- Each ground-to-sky-to-ground trip is called a *hop*.

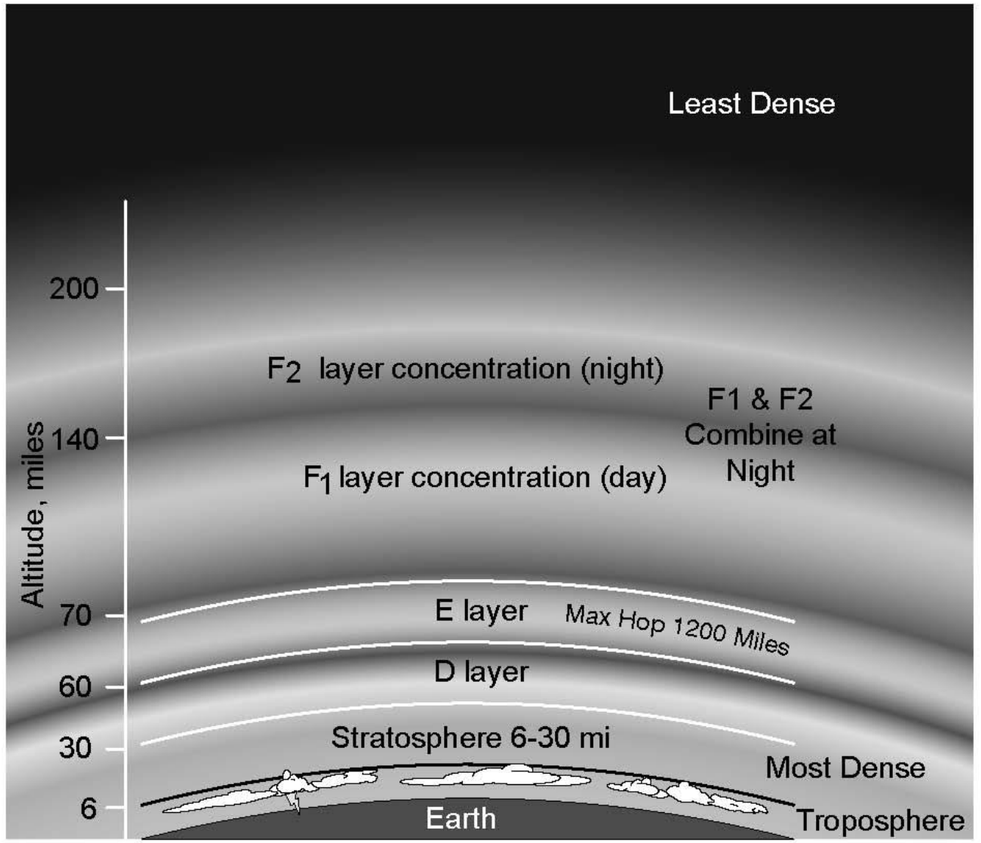
The Ionosphere – An RF Mirror

- Signals can take many paths through the ionosphere.
- Randomly combining at the receiving antenna, signals can partially cancel, creating irregular fading as the ionosphere changes.

- The resulting echo and flutter distort speech and CW.
- Fading causes data errors for digital signals.

Sporadic E (Es) and Aurora

- Highly ionized patches of the E layer can reflect HF and VHF signals – best on 10, 6, and 2 meters.
- Aurora near the north and south poles can also reflect VHF and UHF waves with a distinctive distorted sound



Meteor Scatter

- Thousands of meteors enter the Earth's atmosphere every day – most quite small.
- Meteors leave trails of highly ionized gas that last for several seconds.
- Trails can reflect radio waves – called *meteor scatter*. The best band for this is 6 meters.
- Mostly in the E layer, meteor scatter and sporadic E supports contacts up to about 1500 miles.

Sunspot Cycle

- The level of ionization depends on the intensity of radiation from the Sun.
- Radiation from the Sun varies with the number of sunspots on the Sun's surface.
- High number of sunspots results in high levels of ionizing radiation emitted from the Sun.
- Sunspot activity follows an 11-year cycle.


Courtesy Dreamstime

Technician License Course

Chapter 4

Lesson Plan Module – 4b

Antenna Fundamentals
Feed Lines & SWR

The Antenna System

- Antenna: Transforms current into radio waves (transmit) and vice versa (receive).
- Feed line: Connects your station to the antenna.
- Test and matching equipment: Allows you to monitor and optimize antenna system performance.

The Antenna (Some Vocabulary)

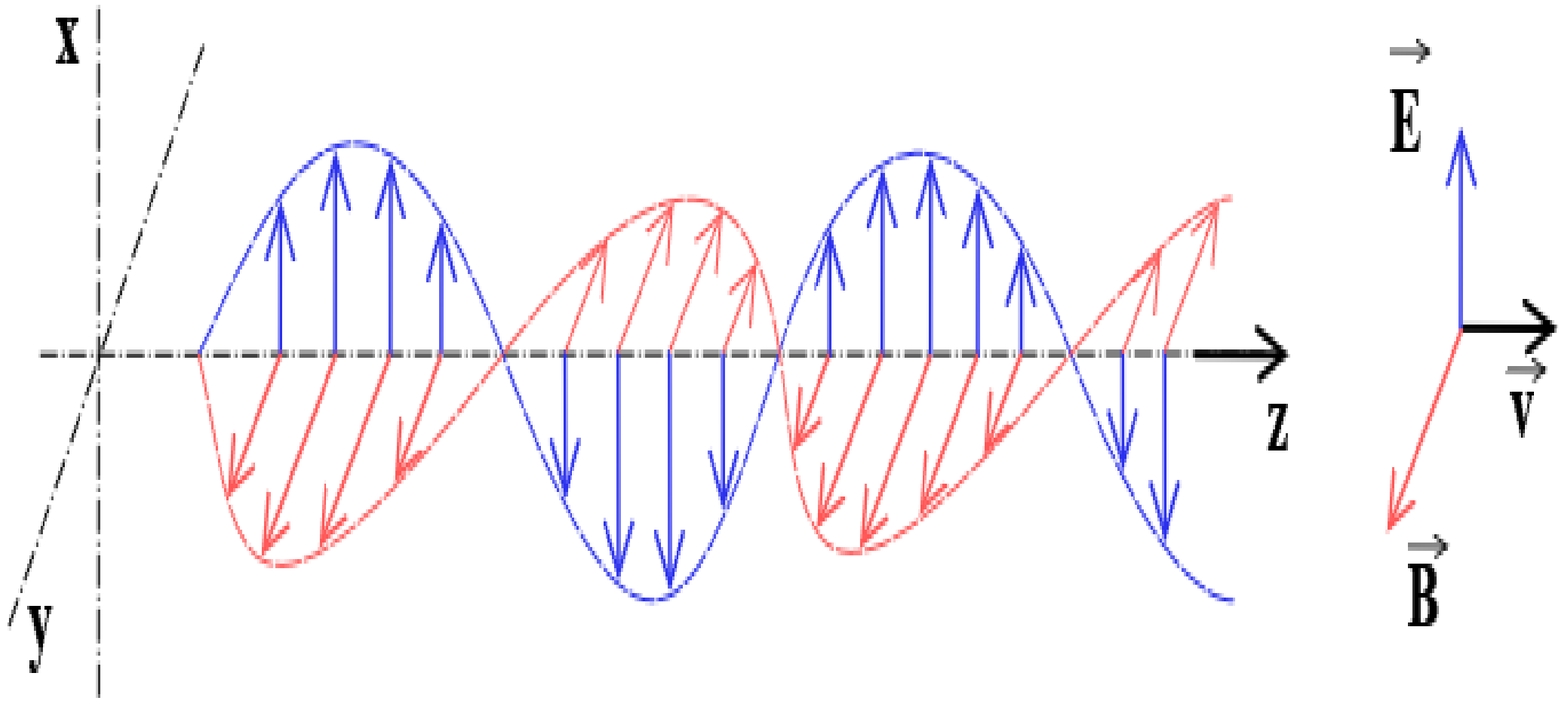
- **Element:** The conducting part or parts of an antenna designed to radiate or receive radio waves.
- **Driven element:** The element supplied directly with power from the transmitter.
- **Array:** An antenna with more than one element.

The Antenna (Some Vocabulary)

- **Parasitic element:** Elements not connected directly to a feed line.
- **Resonant:** An antenna is resonant when its feed point impedance has zero reactance.
- **Feed point:** Where the transmitted energy enters the antenna.
- **Radiation:** *NOT* radioactivity! An antenna emitting electromagnetic waves.

Electromagnetic Waves

- Radio waves are electromagnetic waves
  - Electric and magnetic fields at right angles to each other, oscillating at the wave's frequency
  - Spread out into space from the antenna
  - Created by ac current
  - Wave and current have the same frequency



Courtesy of Wikipedia

Wave Polarization

- Orientation of the wave's electric field component with respect to the surface of the Earth

- *Vertical or horizontal* – determined by elements
- Can be circular if the orientation twists as the wave spreads through space
- Combinations of polarization are called *elliptical* polarization

Cross-Polarization

- Antenna and wave polarization must match for maximum reception.
  - **Cross-polarized:** antenna elements and the wave's electric field at right angles
  - Can reduce reception by a factor of 100
- For elliptically polarized waves (such as HF sky-wave) any antenna will respond at least partially.

The Decibel (dB)

- A ratio expressed as an power of 10 to make large numbers easier to work with.

- dB = 10 log (power ratio)

- dB = 20 log (voltage ratio)

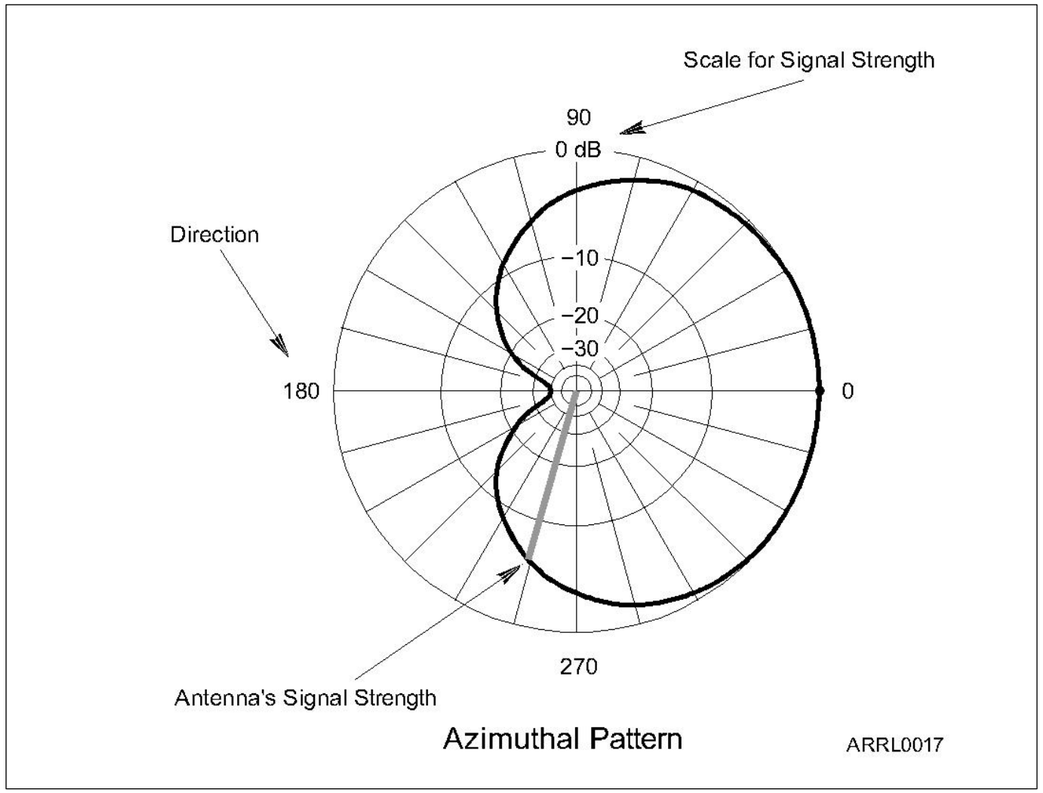
- Positive values in dB indicate ratios > 1 and negative values of dB are for ratios < 1.
- Antenna gain is discussed in terms of dB.

The Antenna (Some Vocabulary)

- **Gain:** Apparent increase in power in a particular direction by focusing radiation in that direction. Measured in decibels (dB).
- **Isotropic:** Equal radiation in all directions.
- **Omnidirectional:** No preferred horizontal direction.
- **Directional:** Antenna that focuses radiation in specific directions.

Antenna Radiation Patterns

- Radiation patterns are a way of visualizing antenna performance.
- The further the line is from the center of the graph, the stronger the signal at that point.
- Graph calibrated in dB.



Radiation Pattern Vocabulary

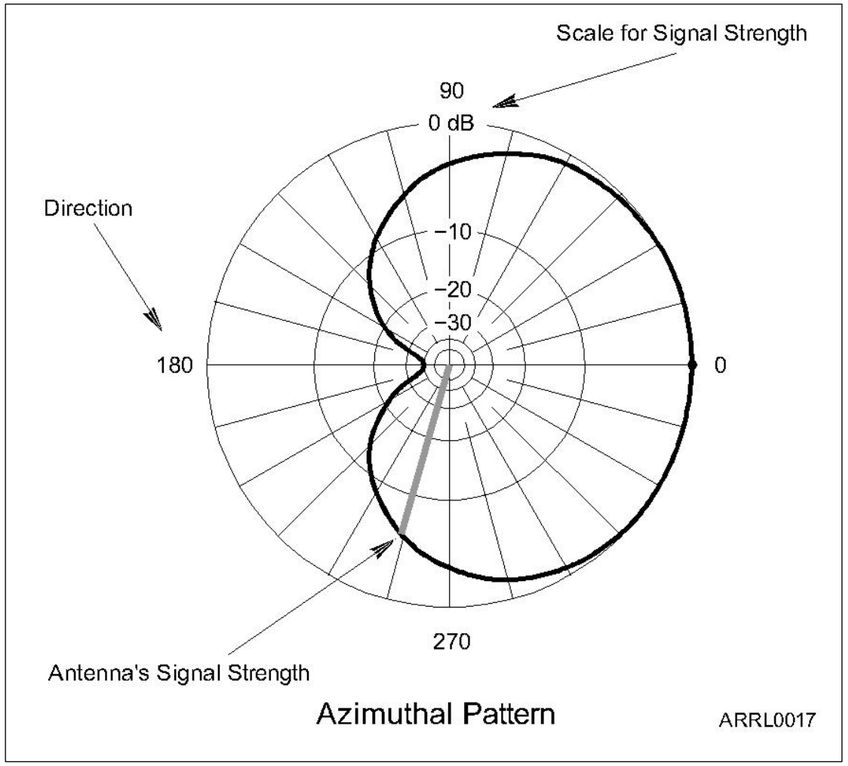
- **Nulls:** Directions of minimum gain
- **Lobes:** Regions between nulls
- **Main lobe:** Lobe with highest gain
- **Side lobe:** Any lobe other than the main lobe
- **Forward gain:** Gain in the direction assigned as forward

Radiation Pattern Vocabulary

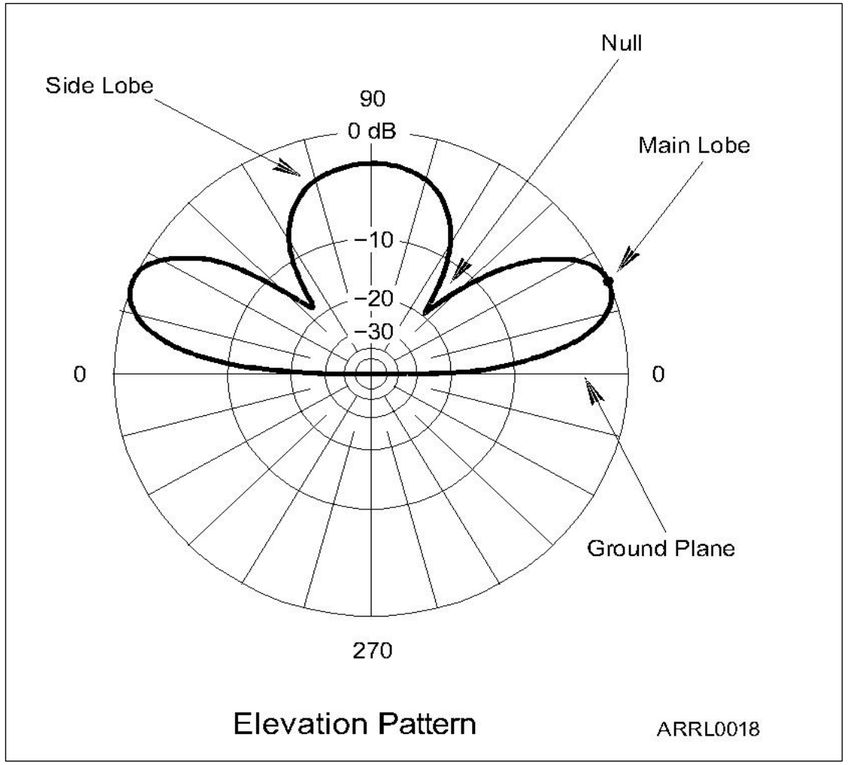
- **Azimuth pattern:** Radiation pattern showing gain in all horizontal directions around the antenna.
- **Elevation pattern:** Radiation pattern showing gain at all vertical angles from the antenna.

- Often restricted to angles above horizontal

Azimuth Pattern



Elevation Pattern



Radiation Pattern Vocabulary

- **Front-to-back ratio:** Ratio of forward gain to gain in the opposite direction.
- **Front-to-side ratio:** Ratio of forward gain to gain at right angles to the forward direction.

Feed Lines

- The purpose of the feed line is to get RF power from your station to the antenna.
- Basic feed line types

- *Coaxial cable* (coax)

- *Open-wire line* (OWL) also called ladder line or window line

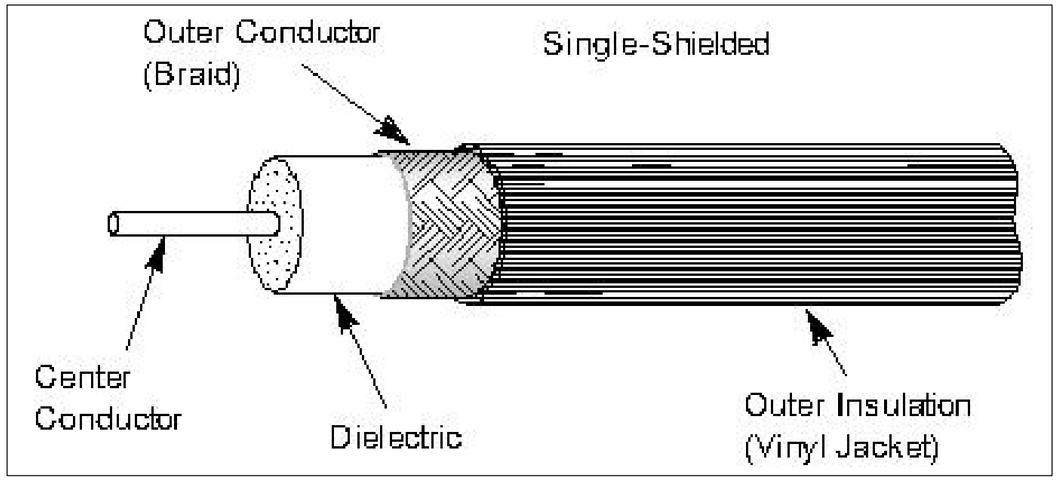
- Power lost as heat in the feed line is called loss and it increases with frequency.

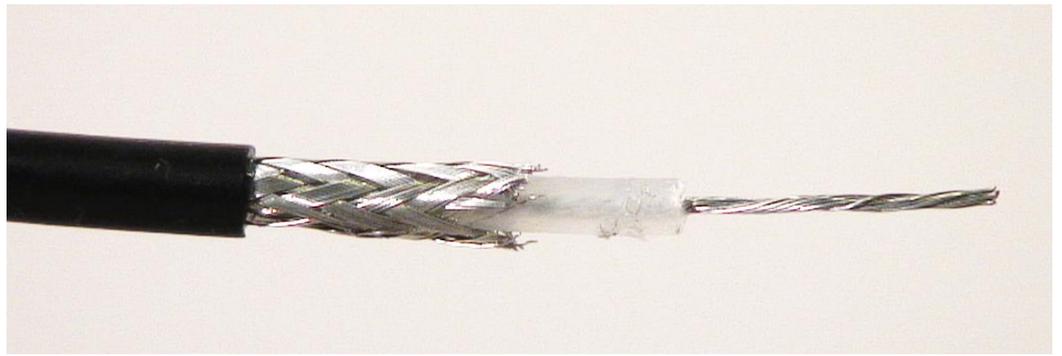
Feed Line Vocabulary

- **Center conductor:** Central wire
- **Dielectric:** Insulation surrounding center conductor
- **Shield:** Braid or foil surrounding dielectric
- **Jacket:** Protective outer plastic coating
- **Forward (reflected) power:** RF power traveling toward (away from) a load such as an antenna

Coaxial Cable

- Most common feed line
- Easy to use
- Not affected by nearby materials
- Has higher loss than open-wire line at most frequencies
- Air-insulated “hard line” has lowest loss

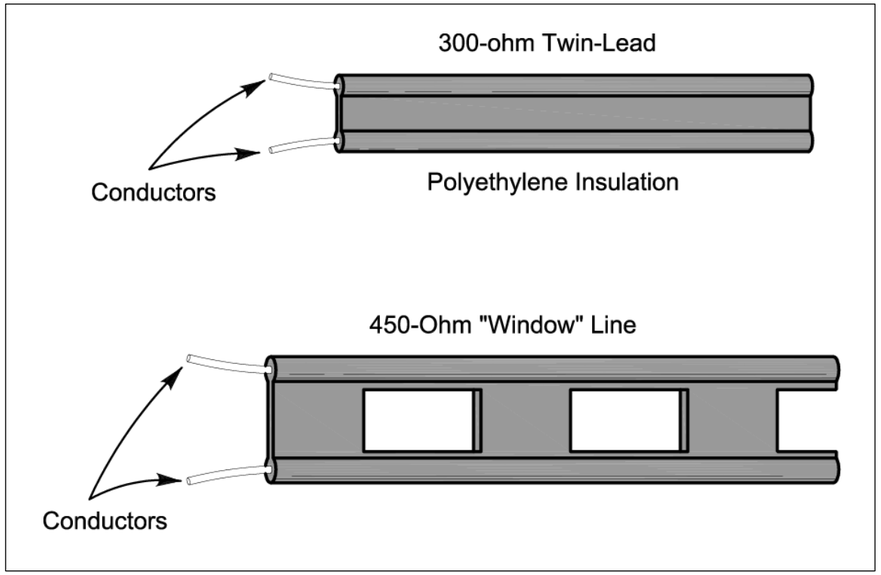




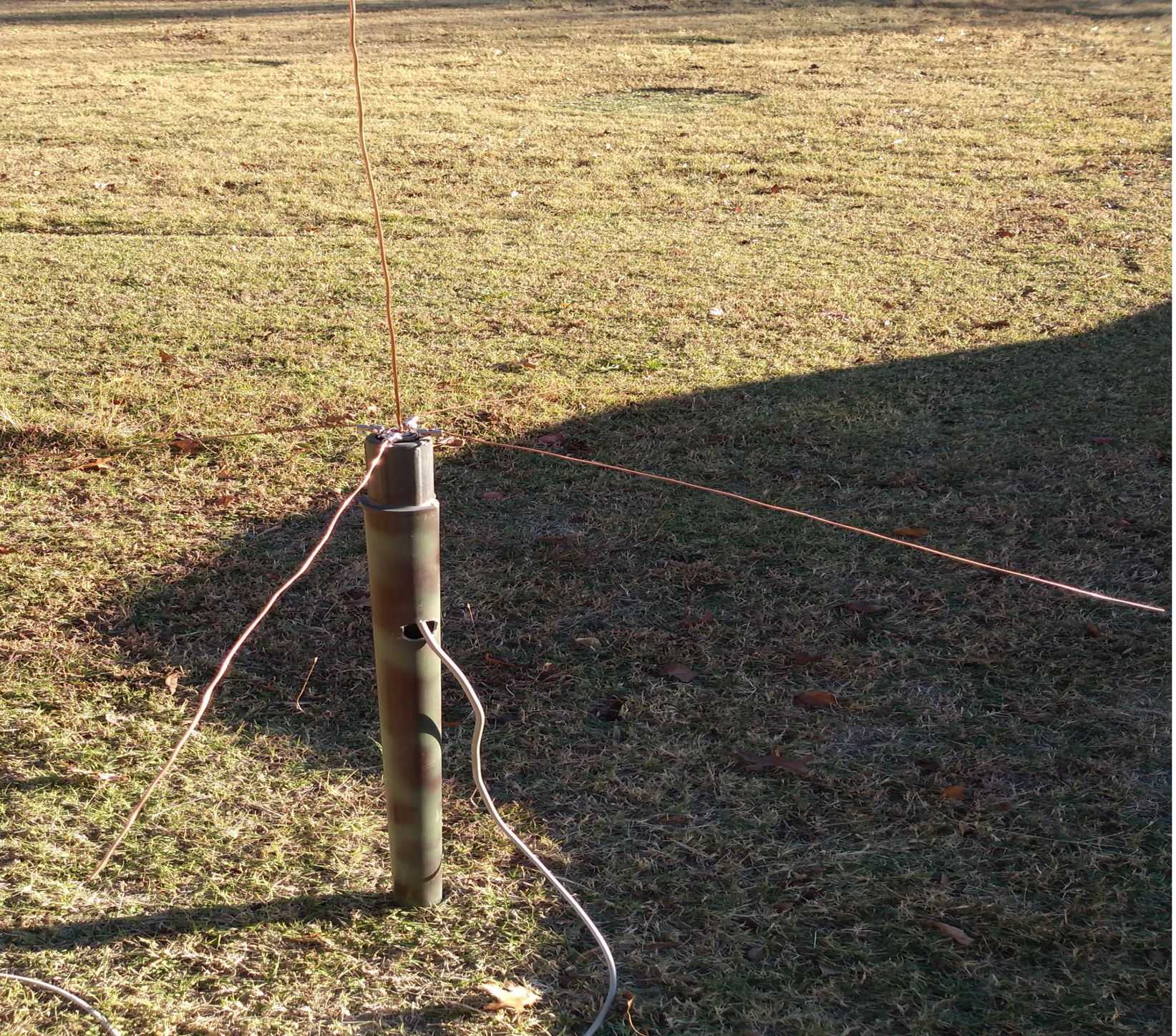

RAMFLEX RG-8/X FOAM 95% SHIELD

Open-Wire Line

- Lighter and less expensive than coax
- Has lower loss than coax at most frequencies
- More difficult to use since it is affected by nearby materials
- Requires impedance matching equipment to use with most transceivers




MODEL CN-620B
ANT.
TR.
FREQ.RANGE : 1.8-150MHz
MAX.POWER : 2kW
INPUT IMP. : 50Ω
DAIWA INDUSTRY CO.,LTD. JAPAN
Distributed in USA by
J.W. MILLER DIV.
BELL INDUSTRIES
19070 Reyes Avenue
P.O. Box 5825
Compton, Ca. 90221
No. F 50066



Characteristic Impedance

- The impedance presented to a wave traveling through a feed line
- Given in ohms (Ω), symbolized as Z_0
- Depends on how the feed line is constructed and what materials are used

- Coax: 50 and 75 Ω
- OWL: 300, 450, and 600 Ω

Standing Wave Ratio (SWR)

- If the antenna feed point and feed line impedances are not identical, some RF power is reflected back toward the transmitter.

- Called a *mismatch*

- Forward and reflected waves create a pattern of *standing waves* of voltage and current in the line

- SWR is the ratio of standing wave max to min

- Measured with an *SWR meter* or *SWR bridge*

Standing Wave Ratio (SWR)

- Reflected power is re-reflected at the transmitter and bounces back and forth.

- Some RF power is lost as heat on each trip back and forth through the feed line

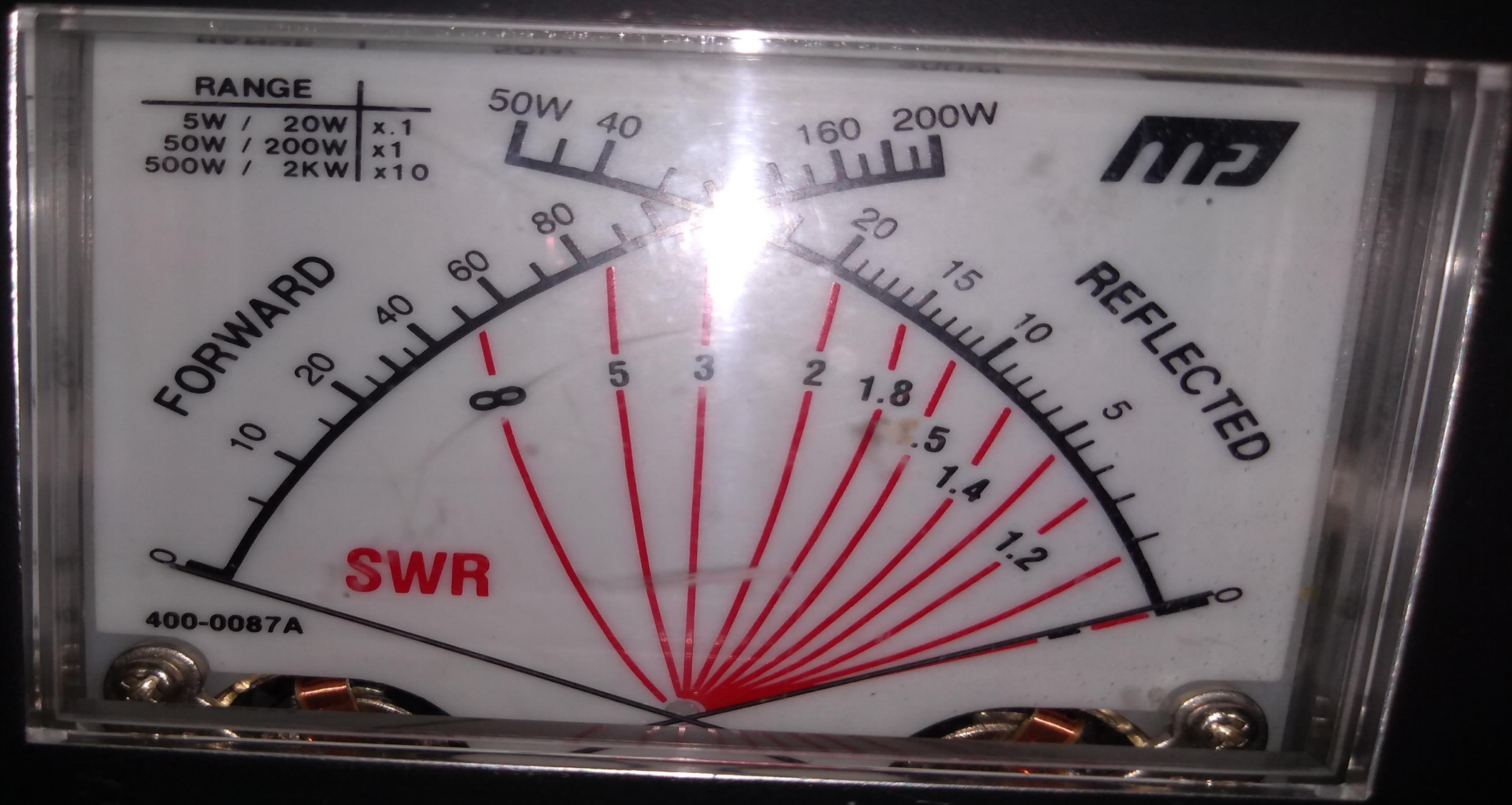
- All RF power is eventually lost as heat or transferred to the antenna or load

- High SWR means more reflections and more loss of RF power (less transferred to the antenna or load).

Nothing Is Perfect

- SWR equals the ratio of feed point (or *load*) and feed line impedance, whichever is greater than 1 (SWR always greater than 1:1).
- What is an acceptable SWR?

- 1:1 SWR is perfect – no power reflected
- Up to 2:1 SWR is normal
- Modern radios lower transmitter output power for protection when SWR is above 2:1


RANGE
5W / 20W x.1
50W / 200W x1
500W / 2KW x10
50W
40
160
200W
FORWARD
10
20
40
60
80
REFLECTED
20
15
10
5
0
SWR
8
5
3
2
1.8
1.5
1.4
1.2
400-0087A

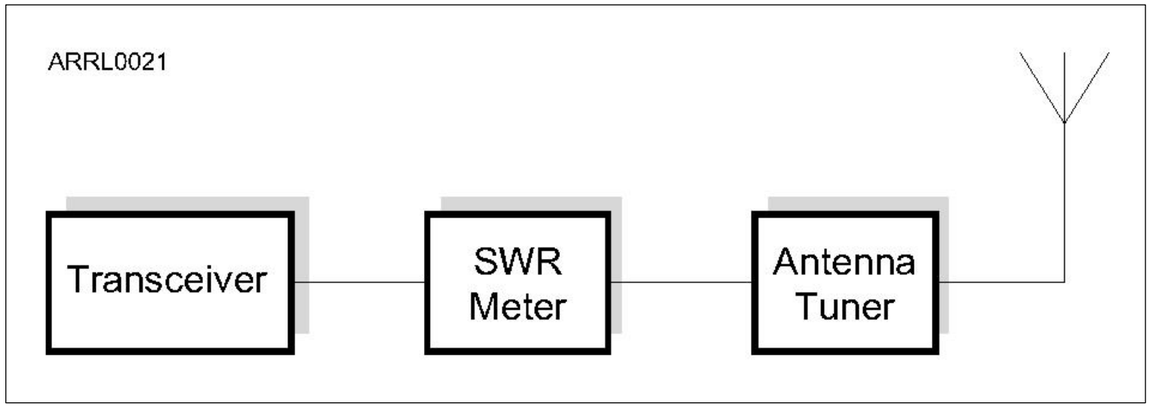
Nothing Is Perfect

- SWR above 3:1 is considered high in most cases.
- Erratic SWR readings may indicate a faulty feed line, faulty feed line connectors, or a faulty antenna.
- High SWR can be corrected by

- Tuning or adjusting the antenna
- With impedance matching equipment at the transmitter
    - Called an *antenna tuner* or *transmatch*
    - Does not change SWR in the feed line

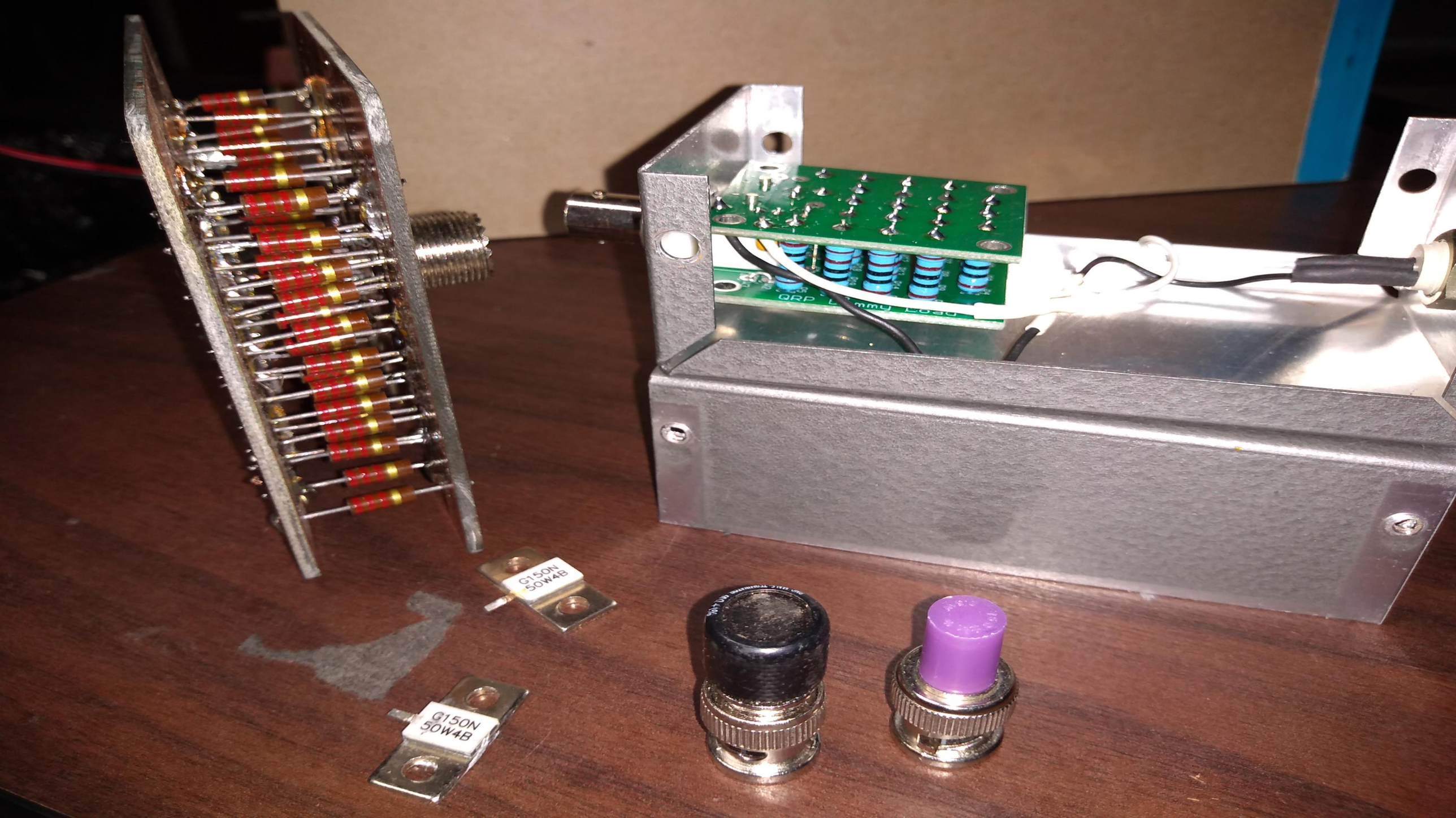
Adjusting SWR

- An SWR meter is inserted in the feed line and indicates the mismatch at that point.
- Either adjust the antenna to minimize the reflected power or adjust the antenna tuner for minimum SWR at the transceiver.



Dummy Loads

- A dummy load is a resistor and a heat sink
- Used to replace an antenna or other piece of equipment during testing.
- Dummy loads dissipate signals in the feed line as heat
- Allows transmitter testing without sending a signal over the air
- Helpful in troubleshooting an antenna system


G150N
50W4B
G150N
50W4B

End of Week 4

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