Amateur Radio Technician Exam Preparation Course

ARRL
The National Association for Amateur Radio®

Amateur Radio Technician Exam Prep Course

Module 4

Propagation, Antennas, and Feed Lines

4.1 Propagation
4.2 Antenna and Radio Wave Basics
4.3 Feed Lines and SWR
4.4 Practical Antenna Systems

Propagation

- 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
- Radio waves can be reflected by any sudden change in the path they are traveling, such as a building, hill, or even weather-related changes in the atmosphere
- Vegetation can also absorb VHF and UHF radio waves
- Precipitation such as fog and rain can absorb microwave and UHF radio waves although it has little effect at HF and on the lower VHF Bands

Ground Wave

- At lower HF frequencies radio waves can follow the Earth's surface
- These waves will travel beyond the range of line-of-sight
- Range of a few hundred miles

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
- By bending signals slightly back towards the ground, refraction counteracts the curvature of the Earth and allows signals to be received at distances beyond the visual horizon
- *Knife edge diffraction*: Diffraction as waves travel past sharp edges of large objects

Multipath

- Radio signals arriving at a receiver after taking different paths from the transmitter
- Results in irregular fading, even when reception is generally good
- Because "dead spots" from multipath are usually spaced about ½-wavelength apart, VHF or UHF signals from a station in motion can take on a rapid variation in strength known as *mobile flutter* or *picket-fencing*
- Distortion caused by multipath can also cause VHF and UHF digital data signals to be received with a higher error rate, even though the signal may be strong

Tropospheric Propagation

- Propagation at and above VHF frequencies are assisted by variations in the atmosphere
- Variations such as weather fronts or temperature inversions create layers of air next to each other that have different characteristics
- The layers form structures called ducts that can guide even microwave signals for long distances
- Regularly used by amateurs to make VHF and UHF contacts that would otherwise be impossible by line-of-sight propagation (300 miles or more)

PRACTICE QUESTIONS

Why do VHF signal strengths sometimes vary greatly when the antenna is moved only a few feet?

A. The signal path encounters different concentrations of water vapor
B. VHF ionospheric propagation is very sensitive to path length
C. Multipath propagation cancels or reinforces signals
D. All these choices are correct

T3A01 C 4-1

What is the effect of vegetation on UHF and microwave signals?

A. Knife-edge diffraction
B. Absorption
C. Amplification
D. Polarization rotation

T3A02 B 4-1

What is the meaning of the term "picket fencing"?

A. Alternating transmissions during a net operation
B. Rapid flutter on mobile signals due to multipath propagation
C. A type of ground system used with vertical antennas
D. Local vs long-distance communications

T3A06 B 4-1

What weather condition might decrease range at microwave frequencies?

A. High winds
B. Low barometric pressure
C. Precipitation
D. Colder temperatures

T3A07 C 4-1

What is a likely cause of irregular fading of signals propagated by the ionosphere?

A. Frequency shift due to Faraday rotation
B. Interference from thunderstorms
C. Intermodulation distortion
D. Random combining of signals arriving via different paths

T3A08 D 4-1

What effect does multi-path propagation have on data transmissions?

A. Transmission rates must be increased by a factor equal to the number of separate paths observed

B. Transmission rates must be decreased by a factor equal to the number of separate paths observed

C. No significant changes will occur if the signals are transmitted using FM

D. Error rates are likely to increase

T3A10 D 4-1

What is the effect of fog and rain on signals in the 10 meter and 6 meter bands?

A. Absorption
B. There is little effect
C. Deflection
D. Range increase

T3A12 B 4-1

Which of the following effects may allow radio signals to travel beyond obstructions between the transmitting and receiving stations?

A. Knife-edge diffraction
B. Faraday rotation
C. Quantum tunneling
D. Doppler shift

T3C05 A 4-1

What type of propagation is responsible for allowing over-the-horizon VHF and UHF communications to ranges of approximately 300 miles on a regular basis?

A. Tropospheric ducting
B. D region refraction
C. F2 region refraction
D. Faraday rotation

T3C06 A 4-1

What causes tropospheric ducting?

A. Discharges of lightning during electrical storms
B. Sunspots and solar flares
C. Updrafts from hurricanes and tornadoes
D. Temperature inversions in the atmosphere

T3C08 D 4-2

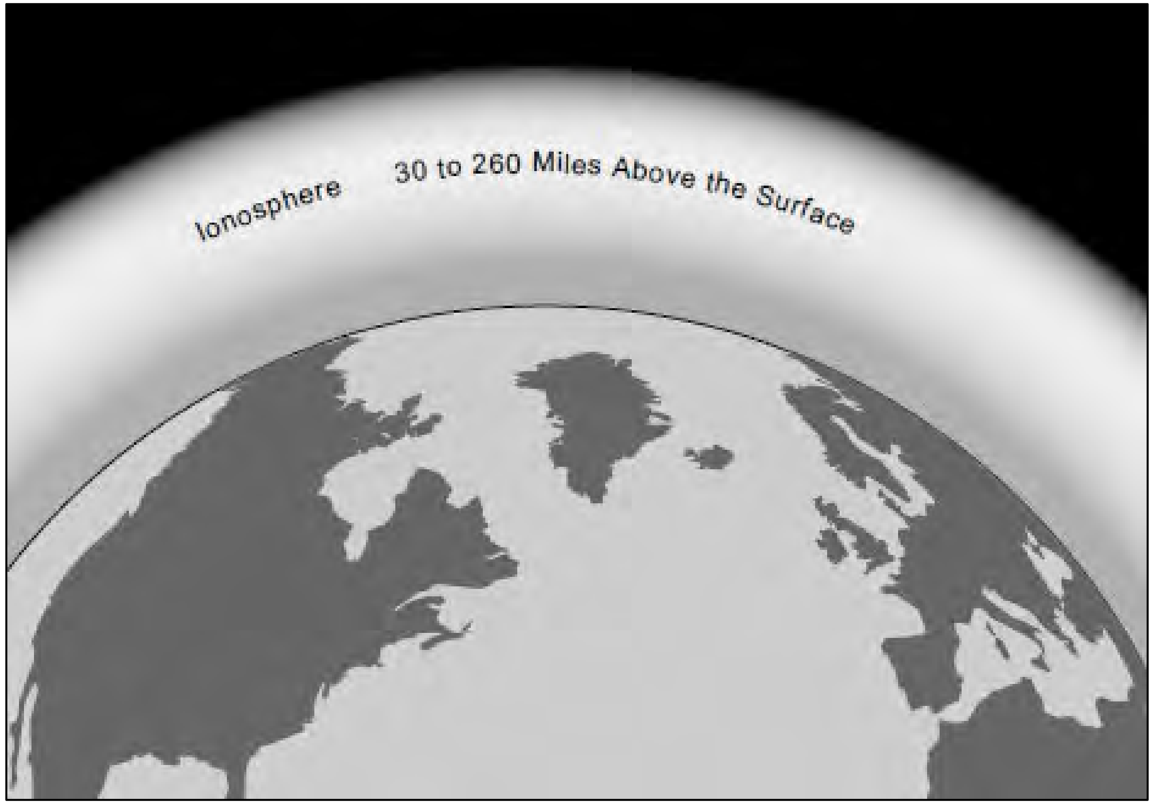
Why is the radio horizon for VHF and UHF signals more distant than the visual horizon?

A. Radio signals move somewhat faster than the speed of light
B. Radio waves are not blocked by dust particles
C. The atmosphere refracts radio waves slightly
D. Radio waves are blocked by dust particles

T3C11 C 4-2

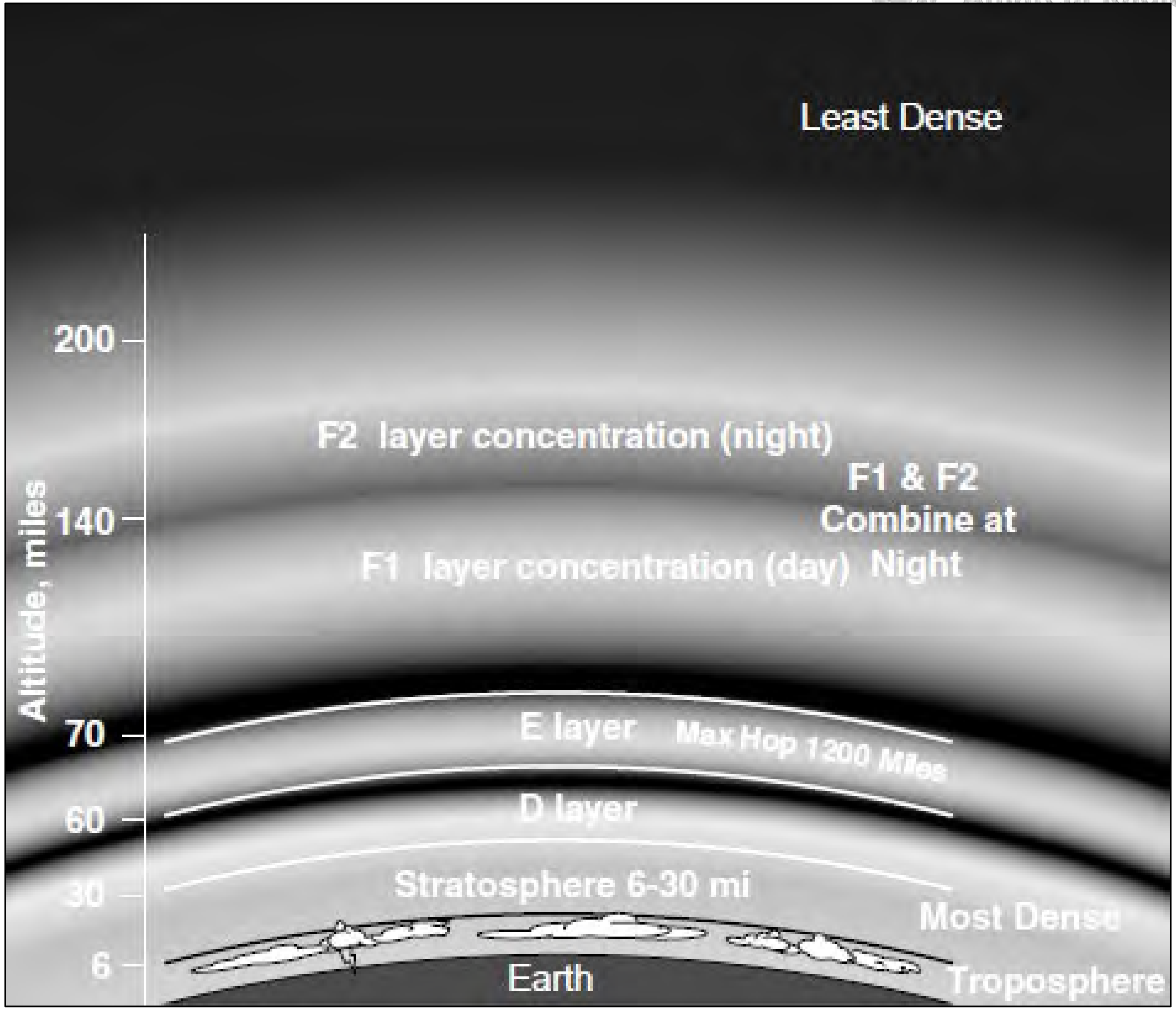
The Ionosphere

- 30 to 260 miles above Earth's surface
- Atmosphere thin enough for atoms to be ionized by solar ultraviolet radiation
- Ions are electrically *conductive*
- Because of varying density, the ionosphere forms *layers* with different amounts of ionization
- Ionization varies with solar illumination (hourly) and intensity of solar radiation
- Higher ionization refracts or bends radio waves more strongly



Ionosphere Layers

- Layers: D, E, F1 and F2
- Depending on whether it is night or day and on the intensity of solar radiation, these layers can *refract* (E, F1 and F2 layers) or *absorb* (D and E layers) radio waves
- Each reflection from the ionosphere is called a *hop* (can go hundreds or thousands of miles)



Sunspot Cycle / Activity

- 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
- *F* layers can reflect 6 meter (50 MHz) signals at the sunspot cycle's peak
- Patches of the *E* layer can become sufficiently ionized to reflect VHF and UHF signals (called *sporadic E*) … most common during early summer and mid-winter months on 10, 6, and occasionally 2 meters

The Ionosphere – An RF Mirror

- Ionosphere can refract radio waves back to Earth – acts like reflection
- Most refraction occurs in the *F* layer
- Reflection depends on frequency and angle of incidence
- Too high a frequency or angle and the waves are lost to space

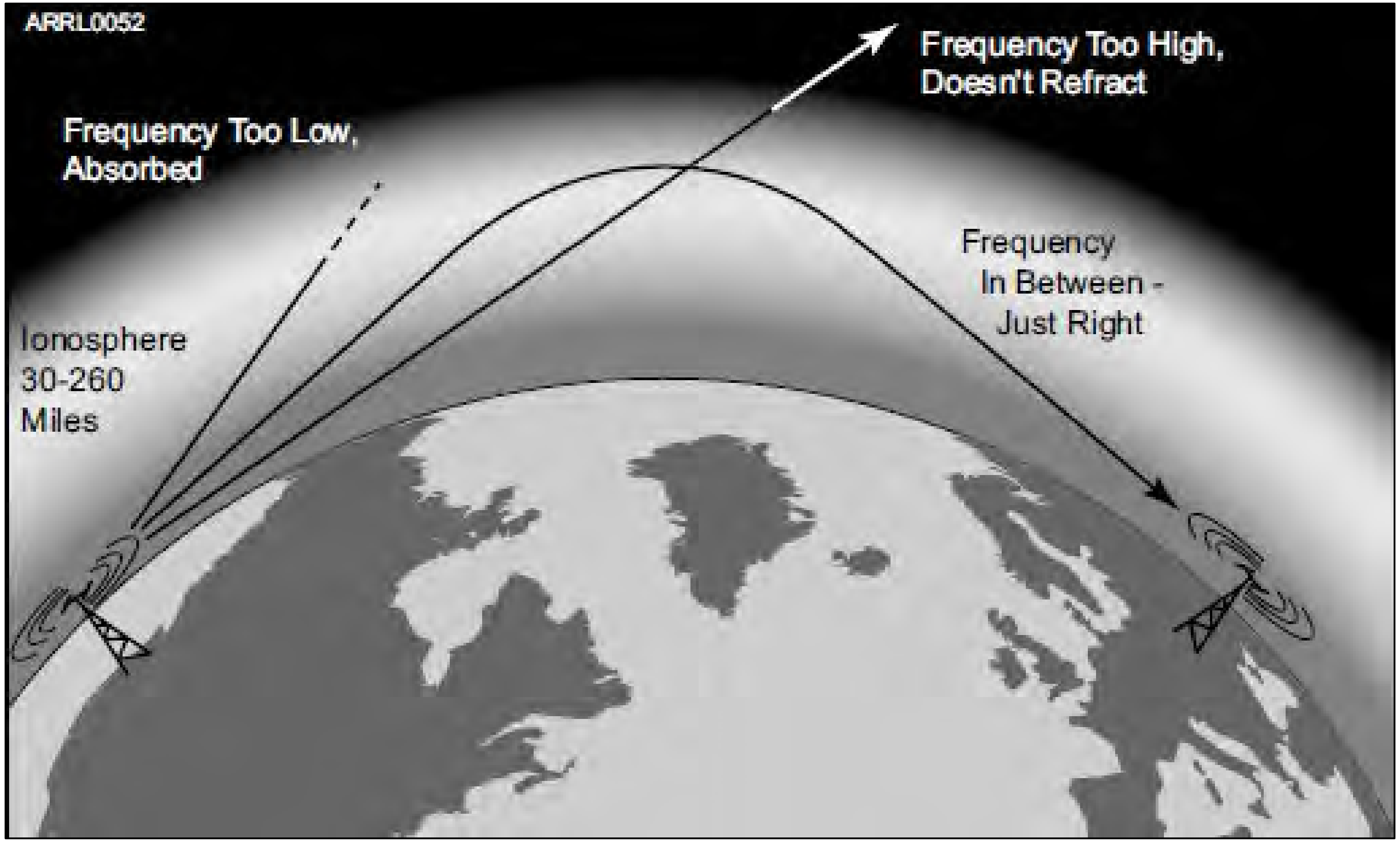


Fig 4.2: Signals in the right range of frequencies are refracted back toward the Earth and are received hundreds or thousands of miles away.

Ionosphere (cont.)

- The highest frequency signal that can be reflected back to a point on the Earth between the transmitter and receiver is the *maximum usable frequency*
- 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
- *E* region of the ionosphere is also home to *meteor trails*
  - Bouncing signals off of these ionized trails is called *meteor scatter propagation*
  - Best band for meteor scatter is 6 meters, and contacts can be made at distances up to 1200 to 1500 miles

PRACTICE QUESTIONS

Which region of the atmosphere can refract or bend HF and VHF radio waves?

A. The stratosphere
B. The troposphere
C. The ionosphere
D. The mesosphere

T3A11 C 4-3

Why are simplex UHF signals rarely heard beyond their radio horizon?

A. They are too weak to go very far
B. FCC regulations prohibit them from going more than 50 miles
C. UHF signals are usually not propagated by the ionosphere
D. UHF signals are absorbed by the ionospheric D region

T3C01 C 4-3

What is a characteristic of HF communication compared with communications on VHF and higher frequencies?

A. HF antennas are generally smaller
B. HF accommodates wider bandwidth signals
C. Long-distance ionospheric propagation is far more common on HF
D. There is less atmospheric interference (static) on HF

T3C02 C 4-3

What is a characteristic of VHF signals received via auroral backscatter?

A. They are often received from 10,000 miles or more
B. They are distorted and signal strength varies considerably
C. They occur only during winter nighttime hours
D. They are generally strongest when your antenna is aimed west

T3C03 B 4-3

Which of the following types of propagation is most commonly associated with occasional strong signals on the 10, 6, and 2 meter bands from beyond the radio horizon?

A. Backscatter
B. Sporadic E
C. D region absorption
D. Gray-line propagation

T3C04 B 4-3

What band is best suited for communicating via meteor scatter?

A. 33 centimeters
B. 6 meters
C. 2 meters
D. 70 centimeters

T3C07 B 4-3

What is generally the best time for long-distance 10 meter band propagation via the F region?

A. From dawn to shortly after sunset during periods of high sunspot activity
B. From shortly after sunset to dawn during periods of high sunspot activity
C. From dawn to shortly after sunset during periods of low sunspot activity
D. From shortly after sunset to dawn during periods of low sunspot activity

T3C09 A 4-3

Which of the following bands may provide long-distance communications via the ionosphere’s F region during the peak of the sunspot cycle?

A. 6 and 10 meters

B. 23 centimeters

C. 70 centimeters and 1.25 meters

D. All these choices are correct

T3C10 A 4-3

Antenna and Radio Wave Basics

- 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
- For an antenna to do that job efficiently, its dimensions must be an appreciable fraction of the signal’s wavelength
- The radio wave is an *electromagnetic wave* that contains both electric and magnetic energy or fields created by the RF current
- The electric and magnetic fields are at right angles to each other and oscillate at the same frequency as the RF current in the antenna

Antenna 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
- *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

Wave Polarization

- Refers to the orientation of the radio wave's electric field
  - 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* (both vertical and horizontal antennas are effective for receiving and transmitting on the HF bands where skip propagation is common)
- When the polarizations of transmit and receive antennas aren't aligned the same, the received signal can be dramatically reduced (less current is created in the antenna)
- *Summary: Antenna and wave polarization must match for maximum reception*

PRACTICE QUESTIONS

What happens when antennas at opposite ends of a VHF or UHF line of sight radio link are not using the same polarization?

A. The modulation sidebands might become inverted
B. Received signal strength is reduced
C. Signals have an echo effect
D. Nothing significant will happen

T3A04 B 4-5

Which of the following results from the fact that signals propagated by the ionosphere are elliptically polarized?

A. Digital modes are unusable
B. Either vertically or horizontally polarized antennas may be used for transmission or reception
C. FM voice is unusable
D. Both the transmitting and receiving antennas must be of the same polarization

T3A09 B 4-5

What is the relationship between the electric and magnetic fields of an electromagnetic wave?

A. They travel at different speeds
B. They are in parallel
C. They revolve in opposite directions
D. They are at right angles

T3B01 D 4-5

What property of a radio wave defines its polarization?

A. The orientation of the electric field
B. The orientation of the magnetic field
C. The ratio of the energy in the magnetic field to the energy in the electric field
D. The ratio of the velocity to the wavelength

T3B02 A 4-5

What are the two components of a radio wave?

A. Impedance and reactance
B. Voltage and current
C. Electric and magnetic fields
D. Ionizing and non-ionizing radiation

T3B03 C 4-5

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

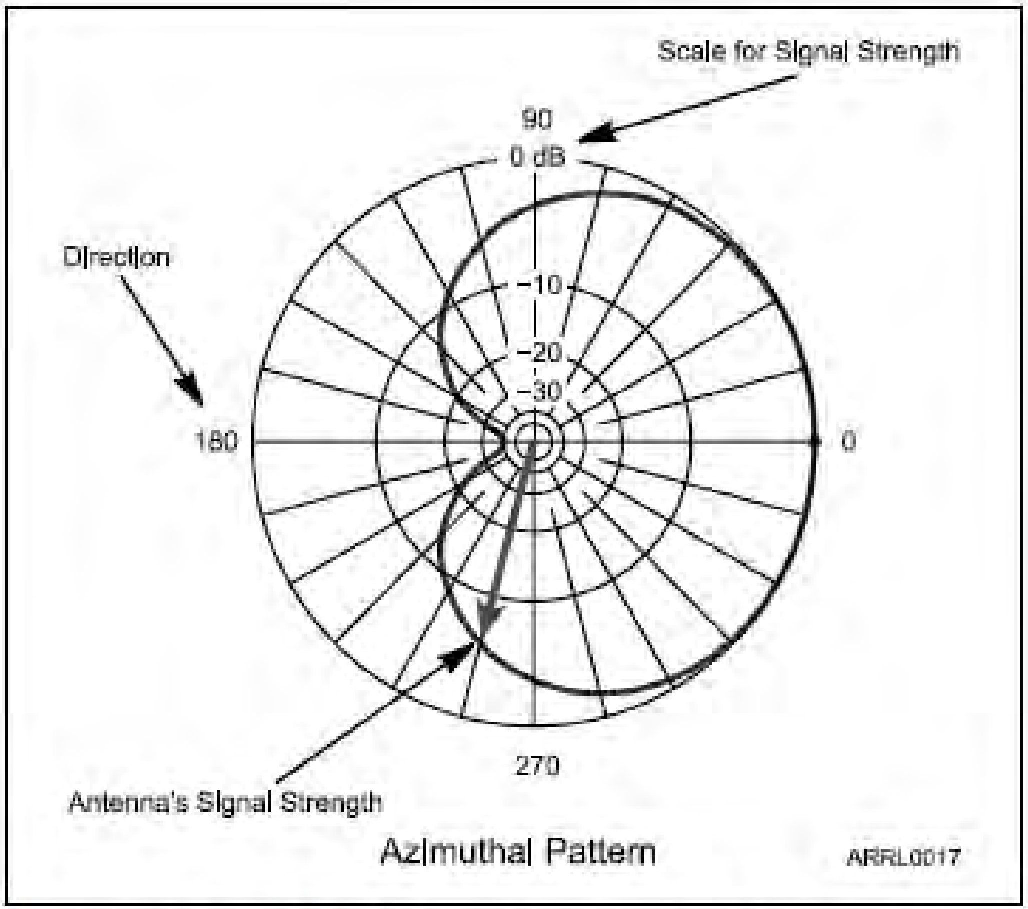


Figure 4.5 — As if looking down on the antenna from above, the azimuth radiation pattern shows how well the antenna transmits or receives in all horizontal directions. The distance from the center of the graph to the solid line is a measure of the antenna's ability to receive or transmit in that direction.

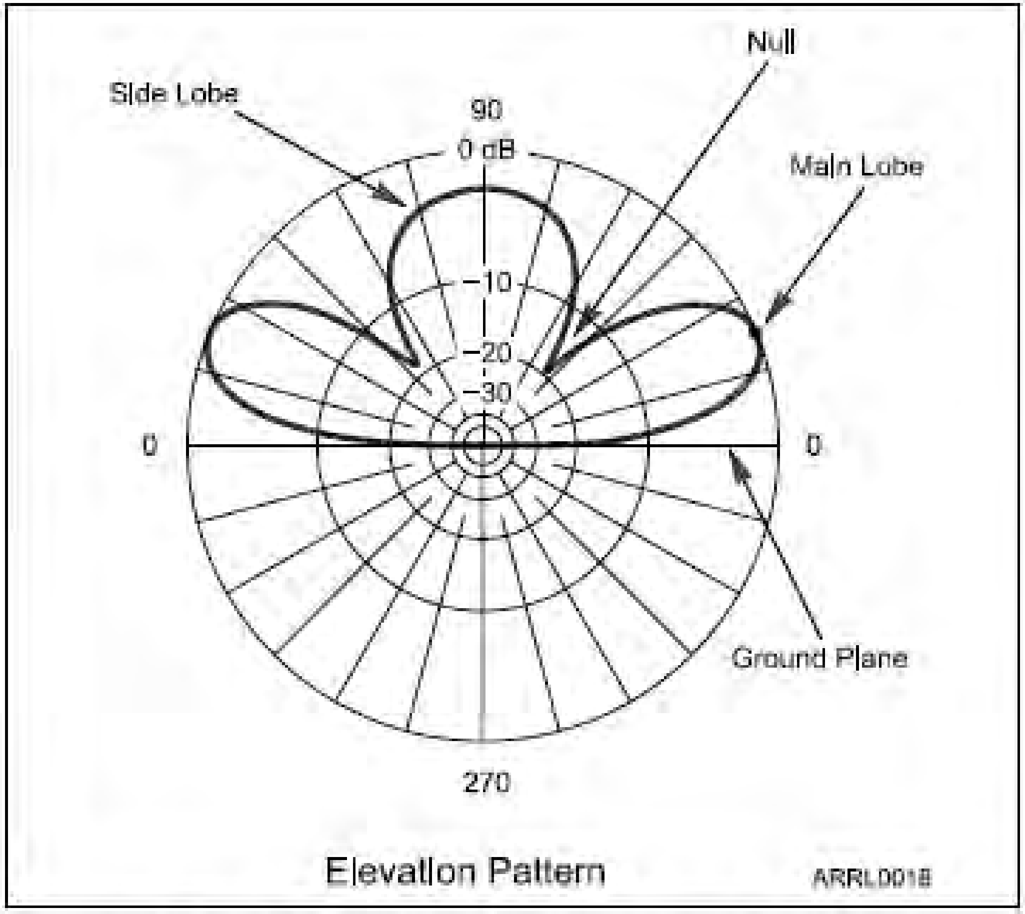


Figure 4.6 — The elevation pattern looks at the antenna from the side to see how well it receives and transmits at different angles above a horizontal plane.

Antenna Radiation Patterns (cont.)

(from previous screen)

- 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
- Graphs calibrated in dB
- Most common type of radiation pattern is an *azimuthal pattern* that shows the antenna's gain in horizontal directions around the antenna
- An *elevation pattern* shows the strength of the radiated energy in vertical directions as if the antenna is viewed from the side

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
- *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
- *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

The Decibel (dB*)

- A ratio expressed as a power of 10 to make large numbers easier to work with
- Decibel measures the ratio of two quantities as a power of 10
  - 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

* *Pronounced "dee-bee"*

PRACTICE QUESTIONS

What is antenna gain?

A. The additional power that is added to the transmitter power
B. The additional power that is required in the antenna when transmitting on a higher frequency
C. The increase in signal strength in a specified direction compared to a reference antenna
D. The increase in impedance on receive or transmit compared to a reference antenna

T9A11 C 4-7

Which decibel value most closely represents a power increase from 5 watts to 10 watts?

A. 2 dB
B. 3 dB
C. 5 dB
D. 10 dB

T5B09 B 4-8

Which decibel value most closely represents a power decrease from 12 watts to 3 watts?

A. –1 dB

B. –3 dB

C. –6 dB

D. –9 dB

T5B10 C 4-8

Which decibel value represents a power increase from 20 watts to 200 watts?

A. 10 dB
B. 12 dB
C. 18 dB
D. 28 dB

T5B11 A 4-8

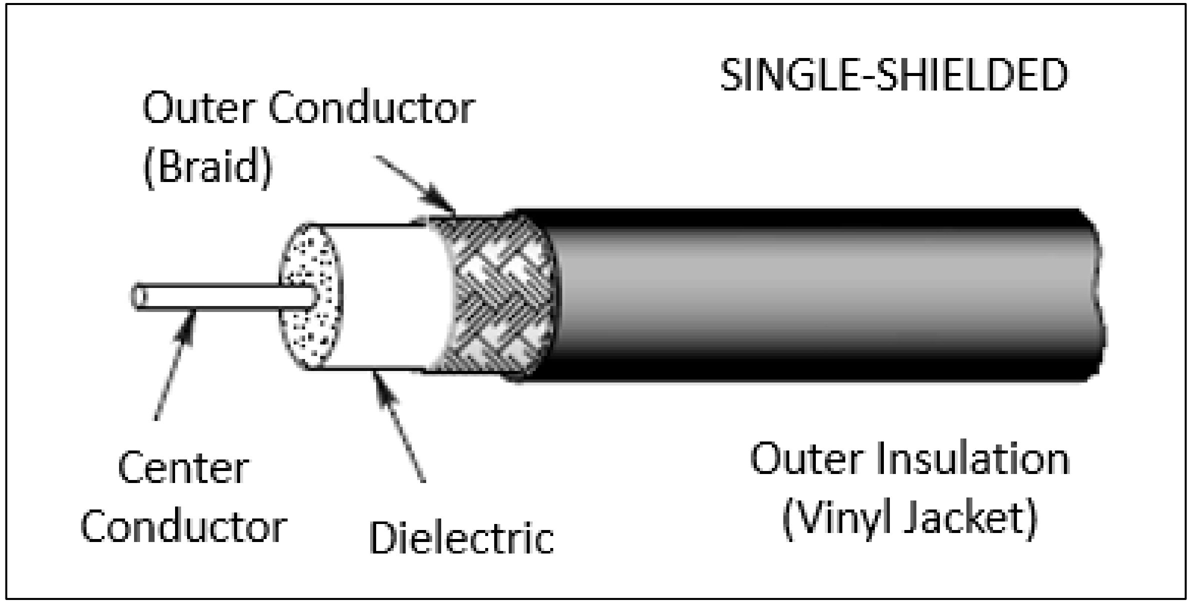
Feed Lines & SWR

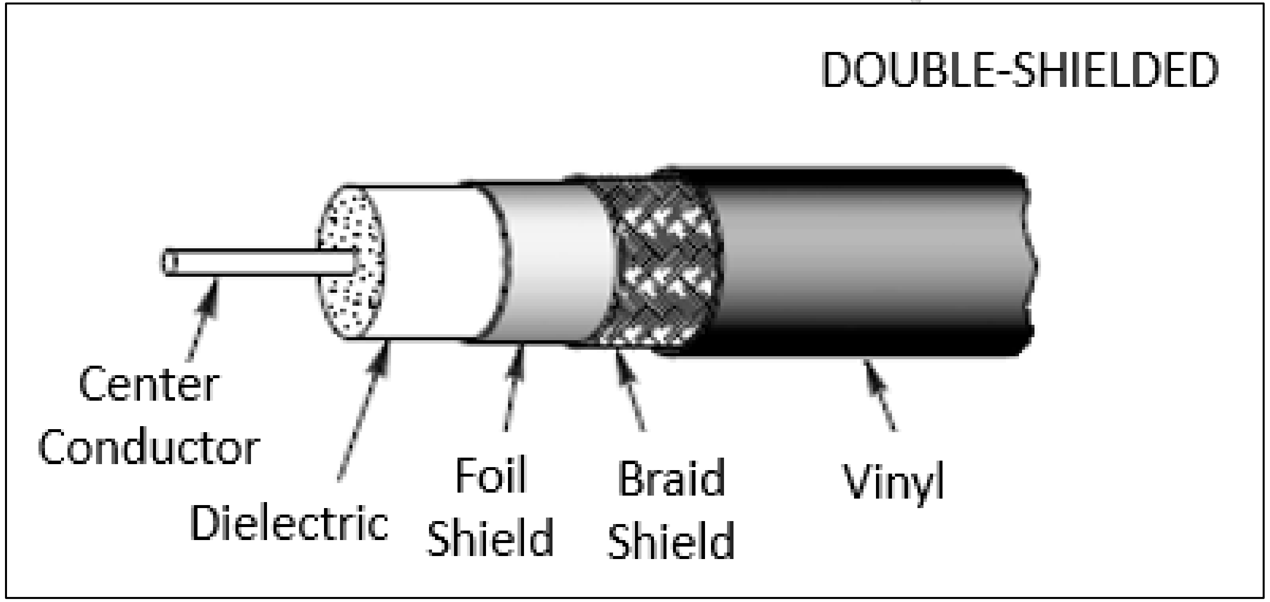
- The purpose of the feed line is to get RF power from your station to the antenna
- Basic feed line types
  - *Coaxial cable* (coax)
  - *Open-wire line* (OWL) also called *ladder line* or window line
- Power lost as heat in the feed line is called loss and it increases with frequency
- Feed lines used at radio frequencies use special materials and construction methods to minimize power being dissipated as heat by *feed line loss* and to avoid signals leaking in or out

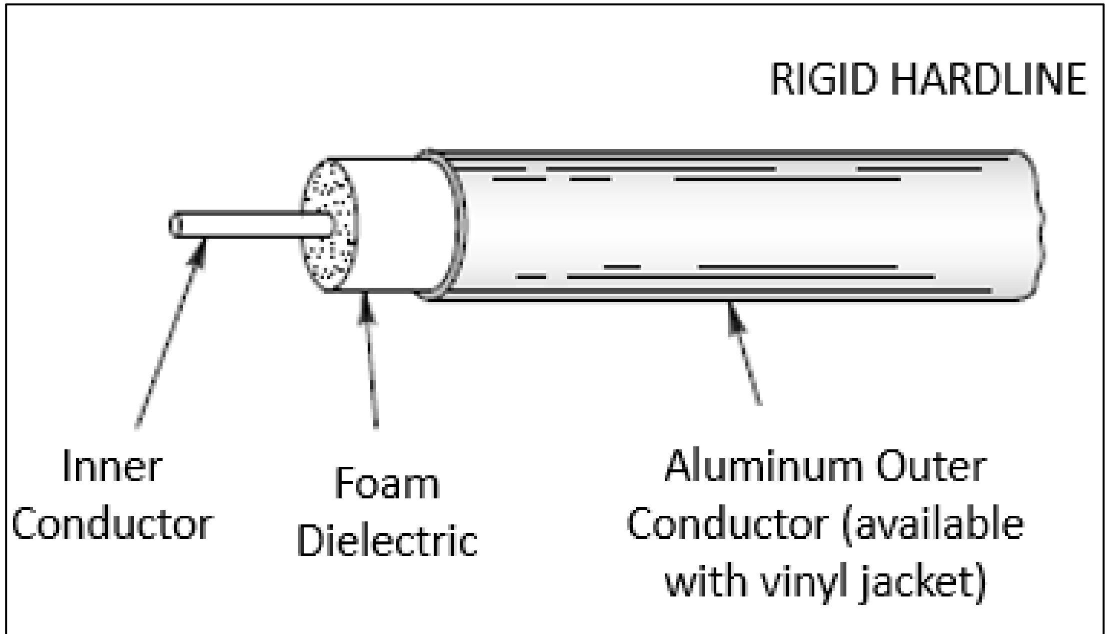
Feed Line Vocabulary

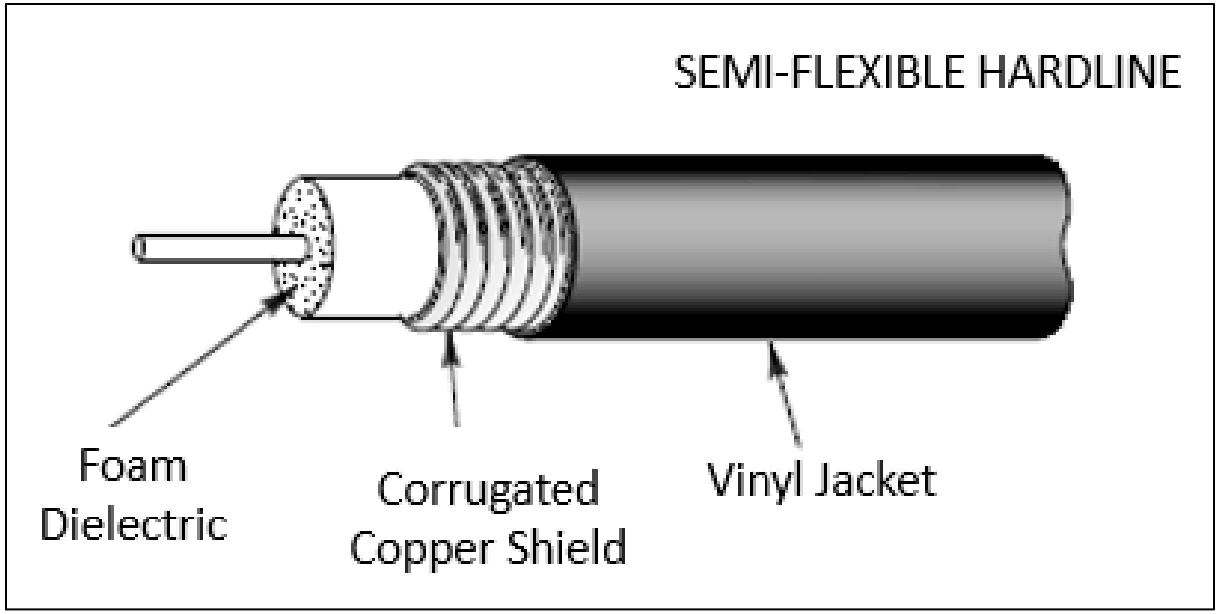
- *Center conductor*: Central wire
- *Dielectric*: Insulation surrounding center conductor
- *Shield*: Braid or foil surrounding dielectric
- *Jacket*: Protective outer plastic coating
- *Forward (reflected) power*: RF power traveling toward (away from) a load such as an antenna

Coaxial Cable







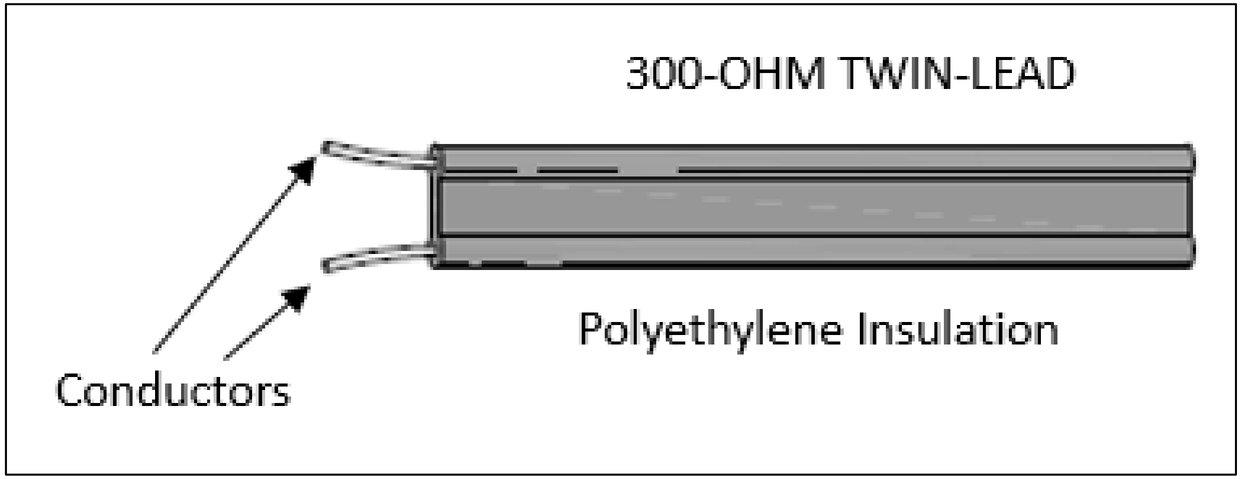


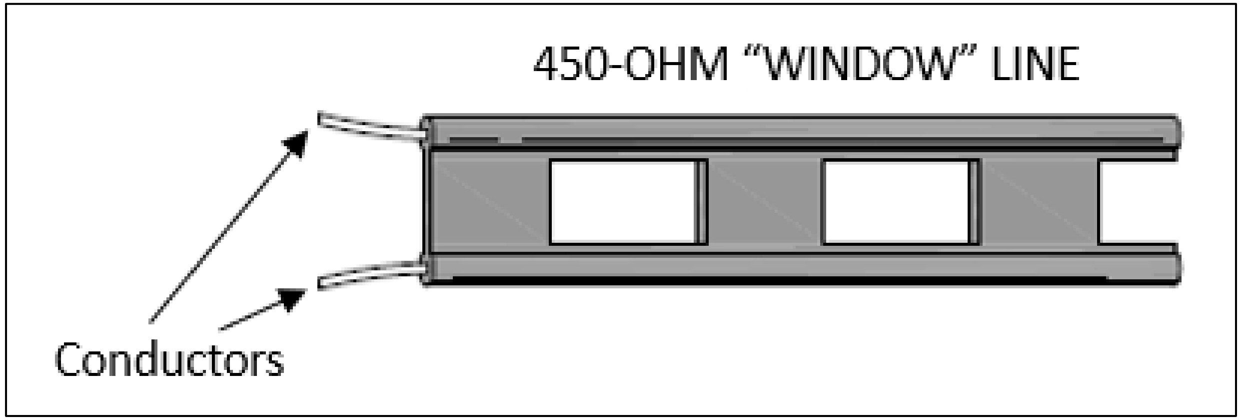
Coaxial Cable (cont.)

- Most common feed line
- Easy to use
- Carries the radio signal on the surface of the center conductor and the inside surface of the shield
  - Not affected by nearby materials
- Has higher loss than open-wire line at most frequencies
- Air-insulated *hard line* has lowest loss (but, limits the amount of bending)

Open-Wire Line

- Lighter and less expensive than coax
- 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
- Open-wire feed lines cannot be buried or installed in metal conduits and must be kept clear of nearby conducting surfaces





Characteristic Impedance

- The impedance presented to a wave traveling through a feed line
- Given in ohms (Ω), symbolized as ZØ
- Depends on how the feed line is constructed and what materials are used
  - Coax: 50 and 75 Ω
  - OWL: 300, 450, and 600 Ω
- Most coaxial cable used in ham radio has a characteristic impedance of 50 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*

SWR (cont.)

- 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)
- 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

SWR (cont.)

- 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

PRACTICE QUESTIONS

What happens to power lost in a feed line?

A. It increases the SWR
B. It is radiated as harmonics
C. It is converted into heat
D. It distorts the signal

T7C07 C 4-9

What is the most common impedance of coaxial cables used in amateur radio?

A. 8 ohms
B. 50 ohms
C. 600 ohms
D. 12 ohms

T9B02 B 4-9

Why is coaxial cable the most common feed line for amateur radio antenna systems?

A. It is easy to use and requires few special installation considerations
B. It has less loss than any other type of feed line
C. It can handle more power than any other type of feed line
D. It is less expensive than any other type of feed line

T9B03 A 4-9

What happens as the frequency of a signal in coaxial cable is increased?

A. The characteristic impedance decreases
B. The loss decreases
C. The characteristic impedance increases
D. The loss increases

T9B05 D 4-9

Which of the following types of feed line has the lowest loss at VHF and UHF?

A. 50-ohm flexible coax
B. Multi-conductor unbalanced cable
C. Air-insulated hardline
D. 75-ohm flexible coax

T9B11 C 4-17

Which of the following should be considered when selecting an accessory SWR meter?

A. The frequency and power level at which the measurements will be made
B. The distance that the meter will be located from the antenna
C. The types of modulation being used at the station
D. All these choices are correct

T4A02 A 4-10

What reading on an SWR meter indicates a perfect impedance match between the antenna and the feed line?

A. 50:50
B. Zero
C. 1:1
D. Full Scale

T7C04 C 4-10

Why do most solid-state transmitters reduce output power as SWR increases beyond a certain level?

A. To protect the output amplifier transistors
B. To comply with FCC rules on spectral purity
C. Because power supplies cannot supply enough current at high SWR
D. To lower the SWR on the transmission line

T7C05 A 4-10

What does an SWR reading of 4:1 indicate?

A. Loss of -4 dB
B. Good impedance match
C. Gain of +4 dB
D. Impedance mismatch

T7C06 D 4-10

What is a benefit of low SWR?

A. Reduced television interference
B. Reduced signal loss
C. Less antenna wear
D. All these choices are correct

T9B01 B 4-10

What can cause erratic changes in SWR?

A. Local thunderstorm
B. Loose connection in the antenna or feed line
C. Over-modulation
D. Overload from a strong local station

T9B09 B 4-10

What is standing wave ratio (SWR)?

A. A measure of how well a load is matched to a transmission line
B. The ratio of amplifier power output to input
C. The transmitter efficiency ratio
D. An indication of the quality of your station's ground connection

T9B12 A 4-9

Practical Antenna Systems: Dipoles

- Simplest type of antenna
- Dipole means "two electrical parts"
- Made from a straight conductor of wire one-half wavelength (1⁄2 λ) long with a feed point somewhere along the antenna
- Most are oriented horizontally, particularly on the lower frequency bands, and radiate a horizontally polarized signal
  - Can also be installed vertically, sloping or even drooping from a single support in the middle (inverted-V)
- The radiation pattern isolated in space looks like a donut

Ground Plane Antennas

- Most common type is one-quarter wavelength long (1⁄4 λ) with the feed point at the base
- Acts like one-half of a dipole with the missing portion made up by the electrical mirror formed by the ground plane
- Made from sheet metal or a screen of wires called radials that extend out from the base
- Extended length of a 5⁄8-λ ground-plane focuses more energy toward the horizon (better range)
- To reduce the physical size of the antenna, it is often constructed with some of the radiating conductor wound into a coil or a separate inductor inserted in the antenna … called is called *inductive loading*

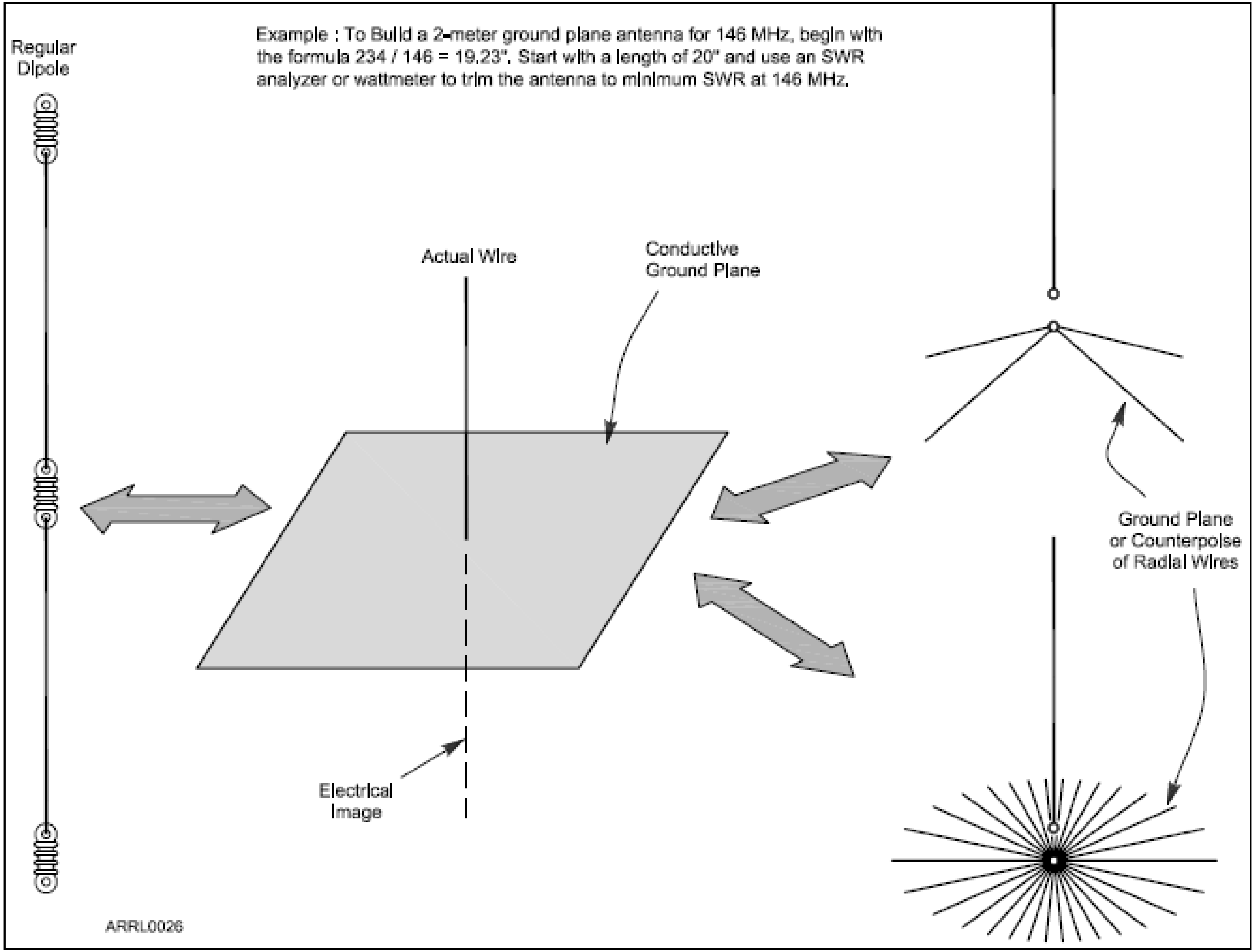


Figure 4.10 — A *ground-plane* makes up an electrical mirror that creates an image of the missing half of a ground-plane antenna. The result is an antenna that acts very much like a dipole. The ground plane can be made up of a screen of wires (often used at HF) or a metal surface at VHF and UHF. For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

Antennas for Handheld Radios

- The flexible antenna used with most handheld radios is called a *rubber duck* (ground-plane antenna shortened by coiling the conductor inside a plastic coating)
  - Doesn’t transmit or receive as well as a full-sized ground-plane antenna
  - For best performance, hold the transceiver so that the antenna is vertical
  - Not very effective inside vehicles … up to 20 time less effective than an external mobile antenna
- Easy to connect handhelds to full-sized antennas … uses standard RF connectors … a 5-watt handheld can easily reach 10 miles with a “good” antenna

Calculating Antenna Length (dipole)

- To calculate length of a resonant dipole 1⁄2-λ long …

Length (in feet) = 468 / frequency (in MHz) … or
Length = 468 / f

Example: At 50.1 MHz (in the 6 meter band), dipole length is calculated as 468 / 50.1 = 9.33 feet = 112 inches long

NOTE: The value of the constant used in the formula accounts for effects that cause an antenna to act like it is a little longer electrically than it is physically. The actual resonant length is affected by height above ground, its electrical properties, and nearby conductive objects. So …

Make the dipole a few percent longer at first (use 490 instead of 468), then use an SWR meter or antenna analyzer to determine the resonant frequency. Assuming the resonant frequency is too low because the dipole is too long, shorten it until the dipole is resonant at the desired frequency.

Calculating Ground Plane Length

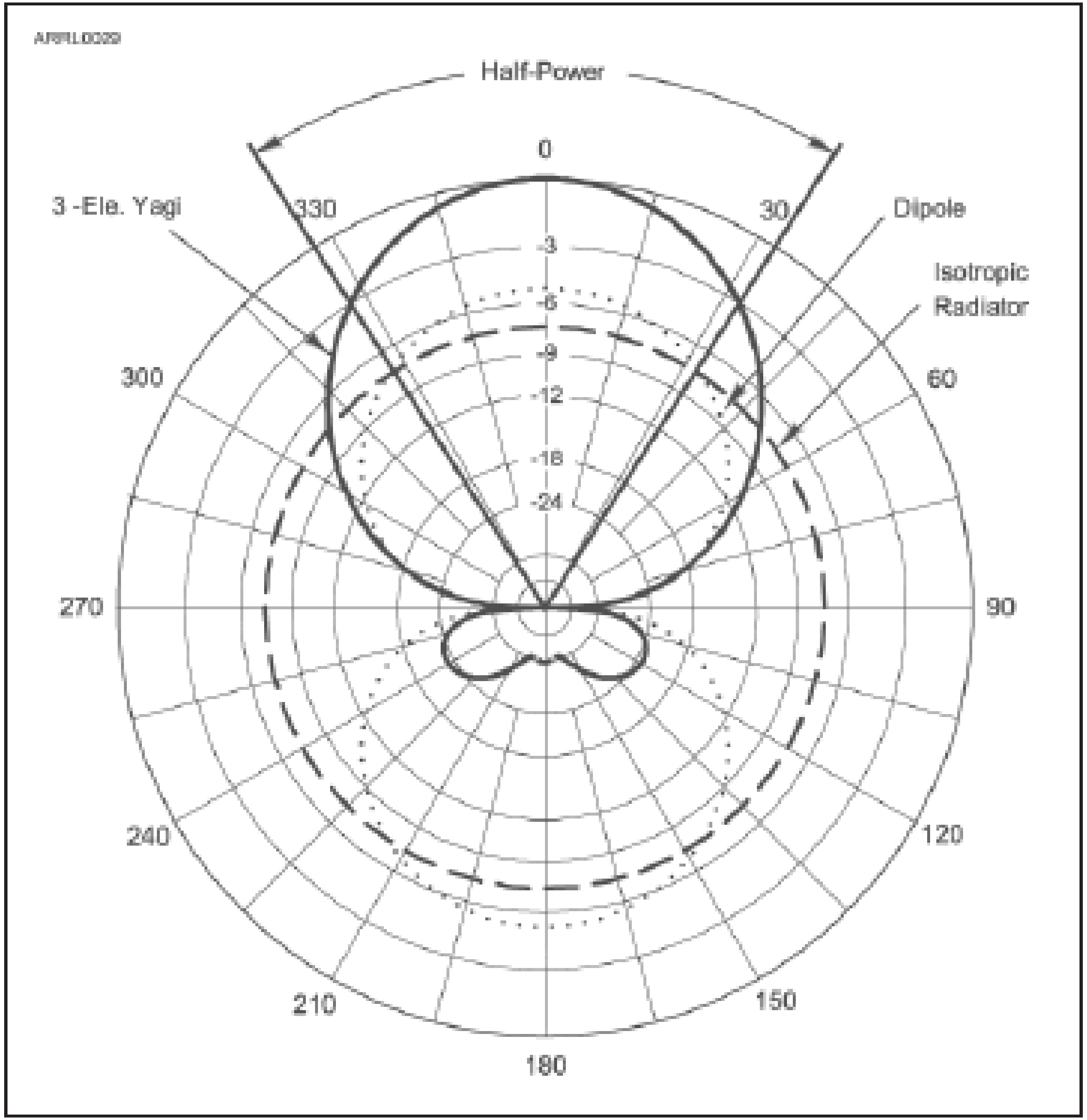
- The length of a ground-plane antenna is half that of a dipole and is often estimated as: length (in feet) = 234 / frequency (in MHz)
- Example: At 146 MHz, a λ/4 ground-plane is 234 / 146 = 1.6 feet = 19 ¼ inches long
- Length adjustments also apply (similar to previous note about dipoles)

Directional Antennas

- Simple dipoles, ground-planes, and loops work well, but they have little gain (radiation patterns don’t have strongly preferred directions)
- Use a *directional beam antenna* get the best reception in one direction
- On VHF and UHF, if a direct signal path is blocked, a beam antenna can be used to aim the signal at a reflecting surface to bypass the obstruction
- Most widely used type of beam antennas are *Yagis*
- Yagi beam antennas have much more *gain* than omni-directionals in their preferred direction

Yagi

Figure 4.13 — The radiation pattern of a typical, three-element Yagi antenna with a driven element, reflector, and director shows that most of the *antenna's energy is focused in one direction along the boom* of the antenna (along the 0-180 axis of the graph.) Smaller amounts are radiated toward the side and back. This antenna also rejects noise and interference from the side and back. The round pattern of the isotropic antenna and the figure-eight pattern of a dipole are included for reference.



Yagis (cont.)

- Horizontally polarized Yagis are usually used for long-distance communications (results in lower ground losses when the wave reflects from or travels along the ground)
- As frequency increases and the size of Yagi elements become smaller, it becomes more difficult to construct practical antennas
  - Above 1GHz, *dish antennas* become practical

Figure 4.14 — N7CFO's dish antenna operates on 10 GHz and is portable enough to be taken on contest outings.

PRACTICE QUESTIONS

Which of the following describes a type of antenna loading?

A. Electrically lengthening by inserting inductors in radiating elements
B. Inserting a resistor in the radiating portion of the antenna to make it resonant
C. Installing a spring in the base of a mobile vertical antenna to make it more flexible
D. Strengthening the radiating elements of a beam antenna to better resist wind damage

T9A02 A 4-12

Which of the following describes a simple dipole oriented parallel to Earth's surface?

A. A ground-wave antenna
B. A horizontally polarized antenna
C. A travelling-wave antenna
D. A vertically polarized antenna

T9A03 B 4-12

What is a disadvantage of the short, flexible antenna supplied with most handheld radio transceivers, compared to a full-sized quarter-wave antenna?

A. It has low efficiency

B. It transmits only circularly polarized signals

C. It is mechanically fragile

D. All these choices are correct

T9A04 A 4-12

Which of the following increases the resonant frequency of a dipole antenna?

A. Lengthening it
B. Inserting coils in series with radiating wires
C. Shortening it
D. Adding capacitive loading to the ends of the radiating wires

T9A05 C 4-12

What is a disadvantage of using a handheld VHF transceiver with a flexible antenna inside a vehicle?

A. Signal strength is reduced due to the shielding effect of the vehicle
B. The bandwidth of the antenna will decrease, increasing SWR
C. The SWR might decrease, decreasing the signal strength
D. All these choices are correct

T9A07 A 4-12

What is the approximate length, in inches, of a quarter-wavelength vertical antenna for 146 MHz?

A. 112

B. 50

C. 19

D. 12

T9A08 C 4-12

What is the approximate length, in inches, of a half-wavelength 6 meter dipole antenna?

A. 6
B. 50
C. 112
D. 236

T9A09 C 4-12

In which direction does a half-wave dipole antenna radiate the strongest signal?

A. Equally in all directions
B. Off the ends of the antenna
C. In the direction of the feed line
D. Broadside to the antenna

T9A10 D 4-12

What is an advantage of a 5/8 wavelength whip antenna for VHF or UHF mobile service?

A. It has more gain than a 1/4-wavelength antenna
B. It radiates at a very high angle
C. It eliminates distortion caused by reflected signals
D. It has 10 times the power gain of a 1/4 wavelength whip

T9A12 A 4-12

What antenna polarization is normally used for long-distance CW and SSB contacts on the VHF and UHF bands?

A. Right-hand circular
B. Left-hand circular
C. Horizontal
D. Vertical

T3A03 C 4-15

When using a directional antenna, how might your station be able to communicate with a distant repeater if buildings or obstructions are blocking the direct line of sight path?

A. Change from vertical to horizontal polarization

B. Try to find a path that reflects signals to the repeater

C. Try the long path

D. Increase the antenna SWR

T3A05 B 4-15

What is a beam antenna?

A. An antenna built from aluminum I-beams
B. An omnidirectional antenna invented by Clarence Beam
C. An antenna that concentrates signals in one direction
D. An antenna that reverses the phase of received signals

T9A01 C 4-15

Which of the following types of antenna offers the greatest gain?

A. 5/8 wave vertical
B. Isotropic
C. J pole
D. Yagi

T9A06 D 4-15

Practical Feed Lines & Associated Equipment

Table 4.1: Common Types of Coaxial Cable

Loss in dB

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

Coaxial Cable (called COAX)

- See Table 4.1
- Performance of coaxial cable depends on the integrity of its outer jacket
- Moisture contamination is the most common cause of coax failure
- Prolonged exposure to the ultraviolet (UV) in sunlight will also cause the plastic in the jacket to degrade … then cracks … then moisture
  - Some coax jackets use a pigment to absorb & block UV
- Coax should not be bent sharply (can short center conductor to outer braid)

Coaxial Feed Line Connectors

- Type of connector to use depends on signal frequency
- UHF* series of connectors (PL-259 plugs and SO-239 receptacles) are the most widely-used for HF equipment
- Above 400 MHz, the Type N connectors are used
- Water in coaxial cable degrades the effectiveness of the braided shield (increases losses)
- In low-loss air-core or "open-cell foam" coax, special techniques are required to prevent water absorption

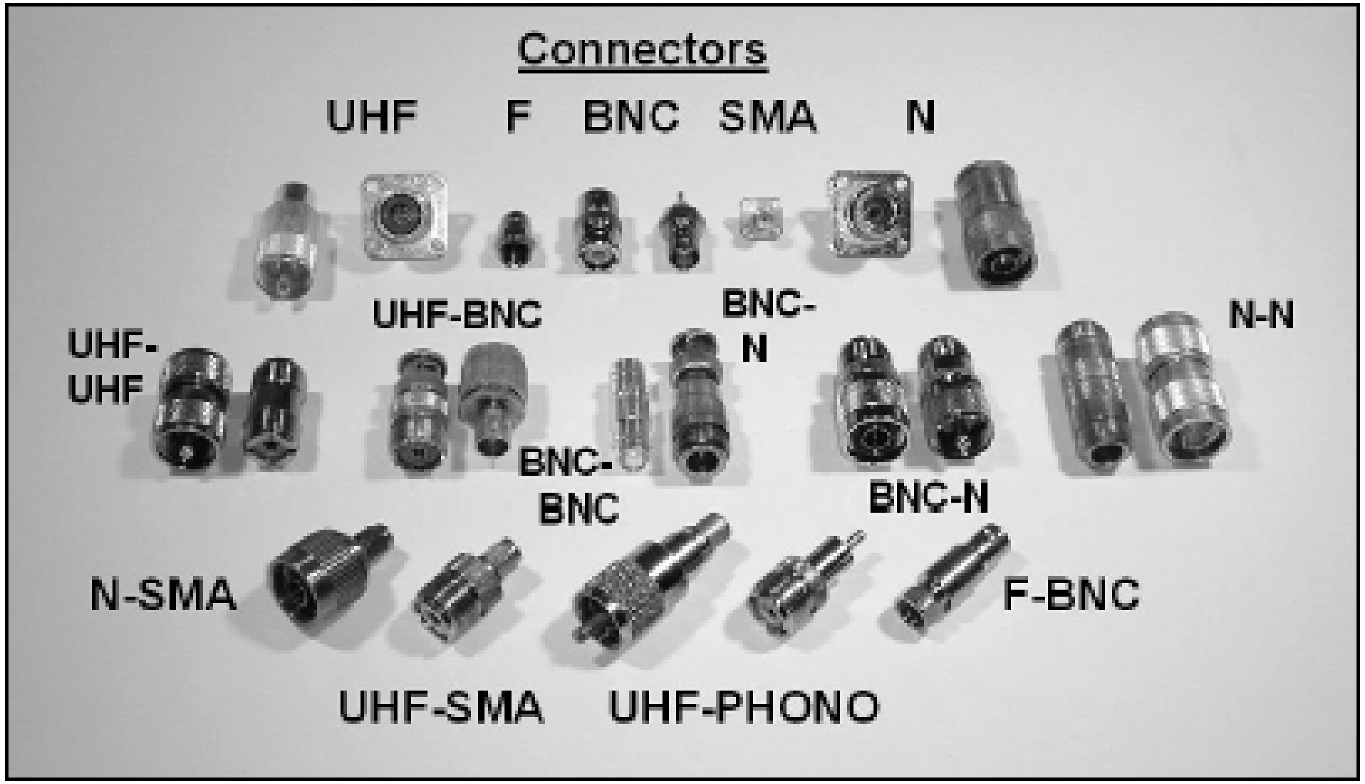


Figure 4.15 — The photo shows a variety of common coaxial connectors that hams use. The larger connectors are used for higher power transmitters and antennas. The most common are the UHF and N styles. Special adapters are used to make connections between cables and equipment that have different styles of connectors.

* UHF in this case is NOT Ultra High Frequency!

SWR Meters and Wattmeters

- SWR Meters measure SWR by placing them in series with the feed line, usually right at the output of the radio
  - Many radios include a built-in SWR meter
- Alternatively, a *directional wattmeter* can be used to measure SWR
  - Measure power flowing toward the antenna and power reflected from the antenna by rotating a sensing element or turning a switch

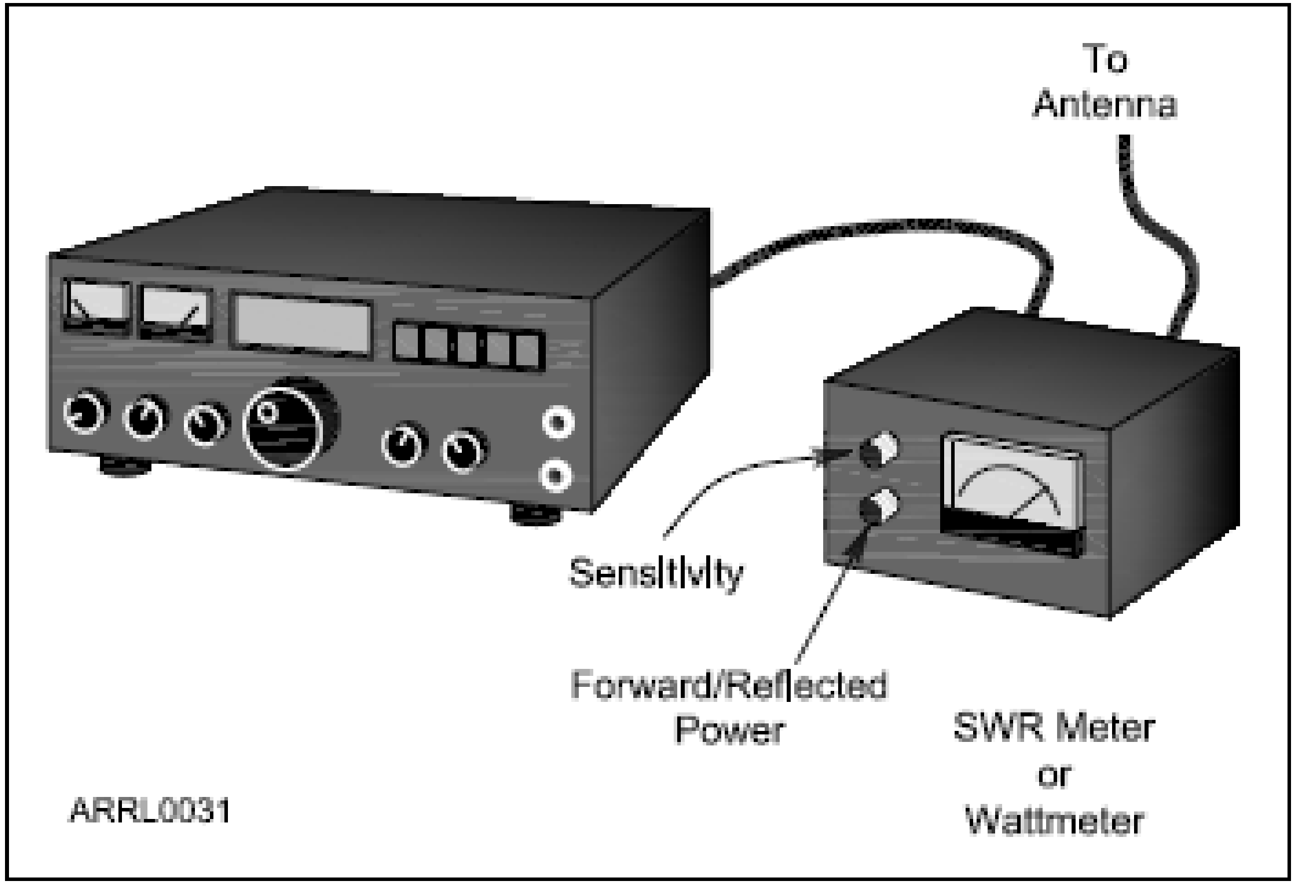


Figure 4.16 — The SWR meter measures power flowing toward the antenna (forward) and toward the transmitter (reflected or reverse).

Antenna Tuners

- *Impedance matchers* or *transmatches* or *antenna tuners* are used If the SWR at the end of the feed line is too high for the radio to operate properly
  - Connected at the output of the transmitter
  - Adjusted until the SWR measured at the transmitter output is acceptably close to 1:1 (antenna system's impedance has been matched to that of the transmitter output)
- Most tuners combine the functions of impedance matcher, directional wattmeter and antenna switch
- Automatic tuners sense when SWR is high and make the necessary adjustments

Antenna Analyzers

- Used to measure an antenna system without using a transmitter whose signal might cause interference

Figure 4.18 — The popular MFJ series of antenna analyzers are used to adjust and troubleshoot antenna systems. The instrument contains a low-power signal source with an adjustable frequency and an SWR meter. The LCD display shows the operating frequency and information about the antenna impedance. The meters show SWR and feed point impedance.

ARRL The National Association for Amateur Radio®

PRACTICE QUESTIONS

Which of the following causes failure of coaxial cables?

A. Moisture contamination
B. Solder flux contamination
C. Rapid fluctuation in transmitter output power
D. Operation at 100% duty cycle for an extended period

T7C09 A 4-17

Why should the outer jacket of coaxial cable be resistant to ultraviolet light?

A. Ultraviolet resistant jackets prevent harmonic radiation
B. Ultraviolet light can increase losses in the cable’s jacket
C. Ultraviolet and RF signals can mix, causing interference
D. Ultraviolet light can damage the jacket and allow water to enter the cable

T7C10 D 4-17

What is a disadvantage of air core coaxial cable when compared to foam or solid dielectric types?

A. It has more loss per foot
B. It cannot be used for VHF or UHF antennas
C. It requires special techniques to prevent moisture in the cable
D. It cannot be used at below freezing temperatures

T7C11 C 4-17

Which of the following types of solder should not be used for radio and electronic applications?

A. Acid-core solder
B. Lead-tin solder
C. Rosin-core solder
D. Tin-copper solder

T7D08 A 4-17

What is the characteristic appearance of a cold tin-lead solder joint?

A. Dark black spots
B. A bright or shiny surface
C. A rough or lumpy surface
D. Excessive solder

T7D09 C 4-17

Which of the following RF connector types is most suitable for frequencies above 400 MHz?

A. UHF (PL-259/SO-239)
B. Type N
C. RS-213
D. DB-25

T9B06 B 4-17

Which of the following is true of PL-259 type coax connectors?

A. They are preferred for microwave operation
B. They are watertight
C. They are commonly used at HF and VHF frequencies
D. They are a bayonet-type connector

T9B07 C 4-17

Which of the following is a source of loss in coaxial feed line?

A. Water intrusion into coaxial connectors
B. High SWR
C. Multiple connectors in the line
D. All these choices are correct

T9B08 D 4-17

What is the electrical difference between RG-58 and RG-213 coaxial cable?

A. There is no significant difference between the two types
B. RG-58 cable has two shields
C. RG-213 cable has less loss at a given frequency
D. RG-58 cable can handle higher power levels

T9B10 C 4-17

Where should an RF power meter be installed?

A. In the feed line, between the transmitter and antenna
B. At the power supply output
C. In parallel with the push-to-talk line and the antenna
D. In the power supply cable, as close as possible to the radio

T4A05 A 4-18

Which of the following is used to determine if an antenna is resonant at the desired operating frequency?

A. A VTVM
B. An antenna analyzer
C. A Q meter
D. A frequency counter

T7C02 B 4-18

Which instrument can be used to determine SWR?

A. Voltmeter
B. Ohmmeter
C. Iambic pentameter
D. Directional wattmeter

T7C08 D 4-18

What is the major function of an antenna tuner (antenna coupler)?

A. It matches the antenna system impedance to the transceiver’s output impedance
B. It helps a receiver automatically tune in weak stations
C. It allows an antenna to be used on both transmit and receive
D. It automatically selects the proper antenna for the frequency band being used

T9B04 A 4-18

END OF MODULE 4

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