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LEVEL 2: General

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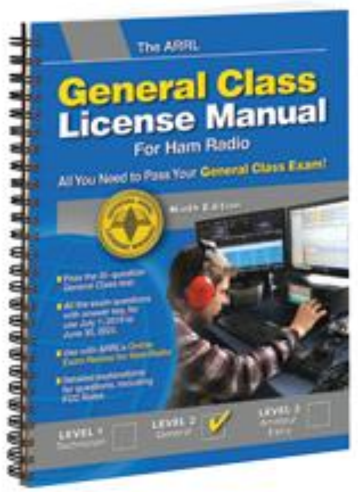

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Module 7

ARRL General Class
Chapter 7 – Antennas
(7.1, 7.2, 7.3, 7.4, 7.5)

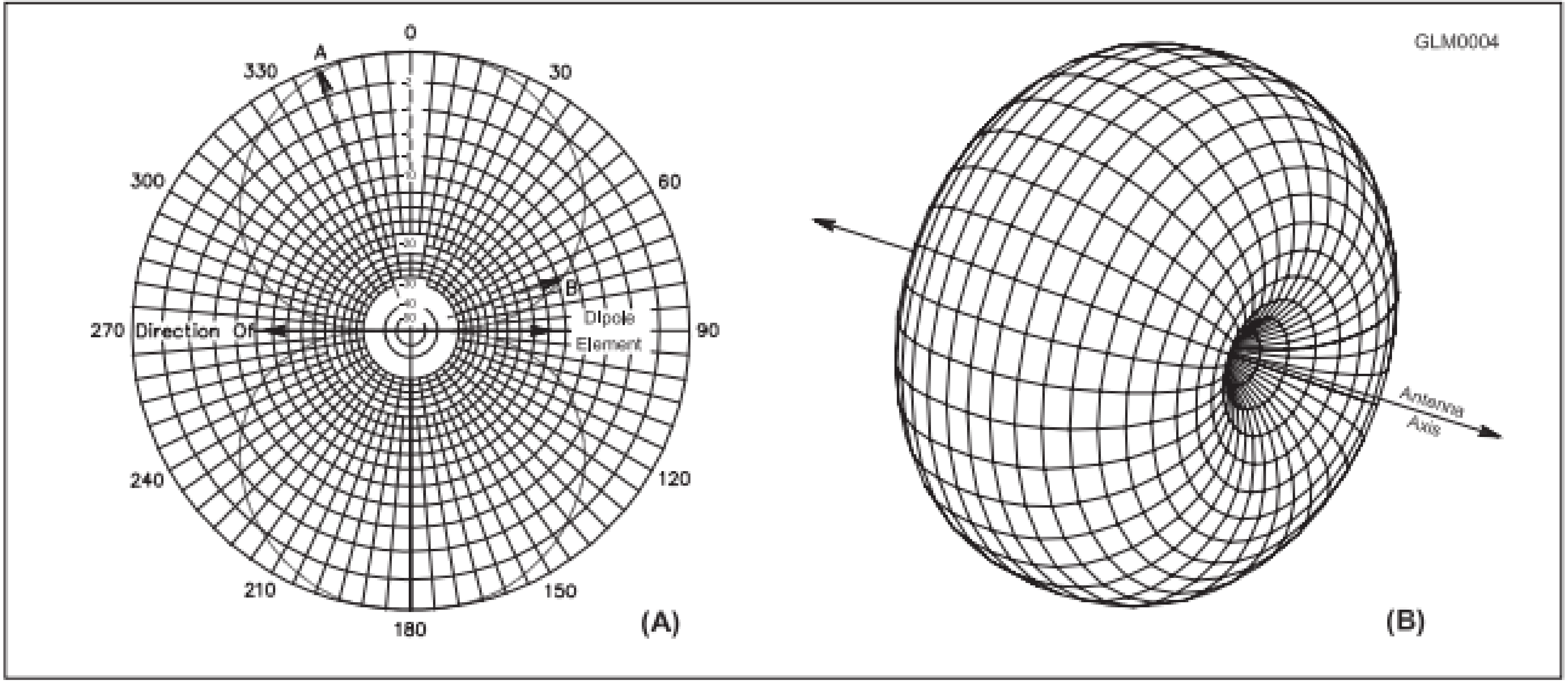
Dipoles, Ground-planes, Yagi Antennas, Loop Antennas, Specialized Antennas, Feed Lines

Dipoles

- The most fundamental antenna
- Straight conductor that is 1⁄2 wavelength (λ/2) long with feed point in the middle
- Radiates strongest broadside to its axis in a plane containing the antenna's conductor
- Weakest radiation is off the ends (see Fig 7.1)
- Shape of azimuth pattern for a dipole in free space is a figure 8

Fig 7.1

Part **A** shows the radiation pattern in the plane of a dipole located in free space. The dipole element is located on the line from 270 to 90 degrees in this figure. Part **B** shows the three-dimensional radiation pattern in all directions around the dipole.

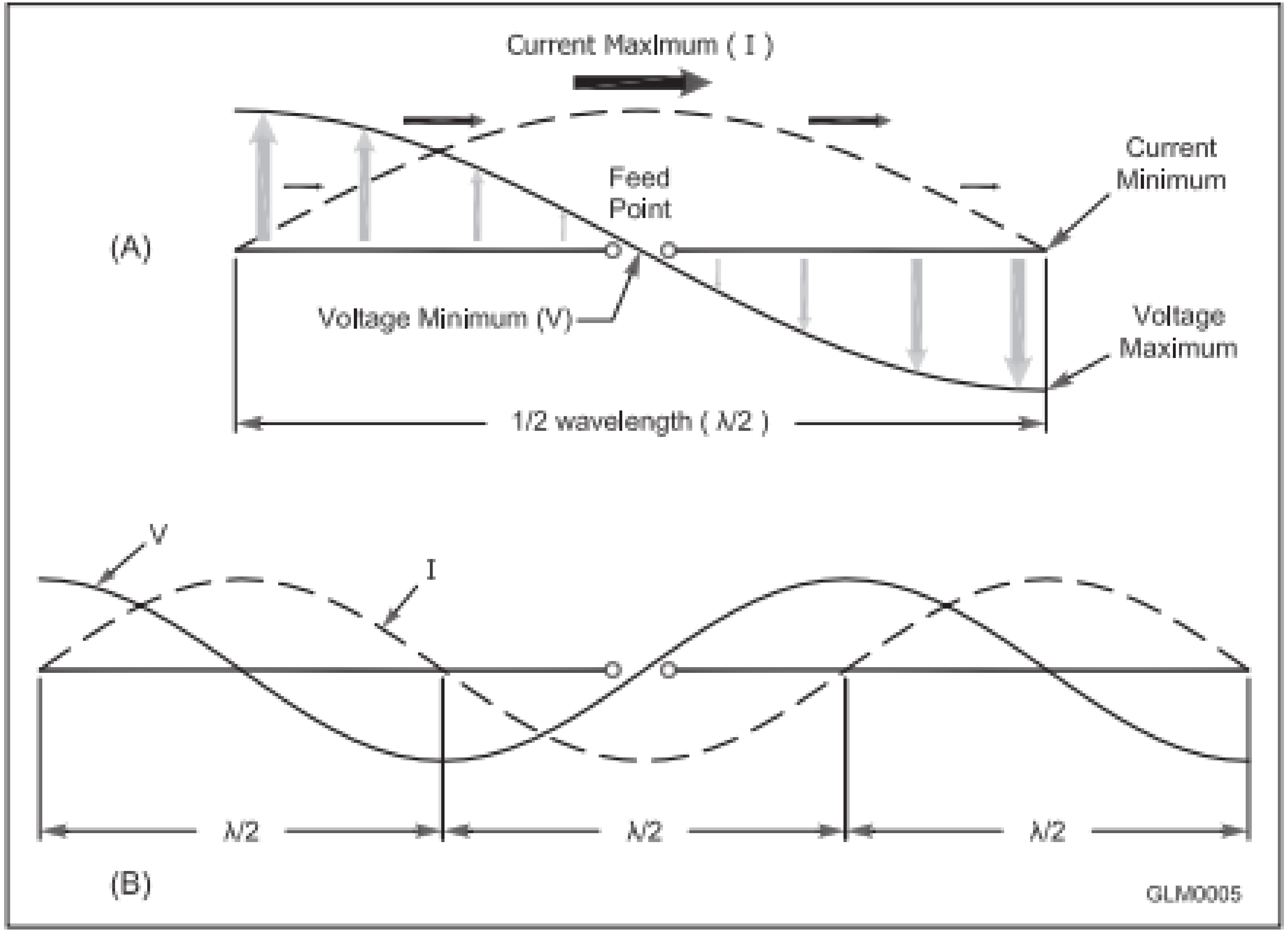


Dipoles (cont.)

- Dipole is often used as reference antenna for gain measurements
  - Gain measured in dBd
  - Isotropic antenna as the reference, gain is given in dBi
    - Isotropic antenna: radiates equally in all directions
  - Convert dBd to dBi by adding 2.15 dB
  - Convert dBi to dBd by subtracting 2.15 dB
- Current in half-wave dipole is highest in middle, Ø at ends; voltage along dipole is highest at ends and lowest in middle (Fig 7.2)

Fig 7.2

The half-wave dipole at A has its maximum current in the middle and maximum voltage at each end. Feed point impedance is lowest in the middle. At odd harmonics of the fundamental frequency, the dipole's feed point impedance is low at the midpoint once again as shown at B.



Dipoles (cont.)

- Impedance increases as feed point is moved away from the center; several thousand ohms at the ends
- Example: *End-fed half-wave* (EFHW) antenna … popular for portable operating (lightweight and easy to install)
  - EFHW is just a half-wave dipole fed at one end
- Calculating free-space length …
  - In free space, 1⁄2 wavelength in feet equals 492 divided by frequency in MHz

Example: What is the approximate length in feet of a 1/2-wave dipole resonant at 3.550 MHz?

$$Free\ Space\ Length = \frac{492}{frequency\ (MHz)} = \frac{492}{3.55} = 139\ \mathrm{ft}$$

Example: What is the approximate length in feet of a 1⁄2-wave dipole for 14.250 MHz?

$$Free\ Space\ Length = \frac{492}{frequency\ (MHz)} = \frac{492}{14.25} = 34.5\ \text{ft}$$

Dipoles (cont.)

- Center-fed dipoles are easiest to use on the band for which they are resonant
- The feed point impedance is a good match for 50 or 75-Ω coax and for coax on odd multiples of the fundamental frequency
- A dipole doesn't need to be straight to be effective
  - Dipole can be supported in the center where the feed line can be conveniently attached
  - This configuration is called an *inverted V*

Ground Plane Verticals

- The ground-plane antenna is one-half of a dipole with the missing portion made up by an electrical mirror, called the *ground plane*
  - Made from sheet metal or a screen of *radial* wires
  - Basic ground-plane is 1⁄4-wavelength ($\lambda/4$) long with feed point at the junction of antenna and ground plane
- For HF ground-plane antennas at ground level, radial wires are laid on surface of ground or buried within a few inches of surface

Ground Plane Verticals (cont.)

- Ground-planes are called *verticals* because that's the usual way of constructing and installing them
- Ground-plane radiates best broadside to its axis
- If installed vertically, the ground-plane antenna's pattern is omnidirectional, uniform in all azimuth angles or directions
  - Useful for VHF and UHF mobile/portable communications where signals may come from any direction

Fig 7.3

The ground plane, whether made of solid metal or radial wires, creates an electrical mirror image of the 1⁄4-wavelength antenna. This creates the electrical equivalent of a dipole antenna.

The feed point impedance at the base of the ideal ground-plane is 35 Ω, half of a complete dipole's impedance, because only half of the antenna is physically there and able to radiate energy.

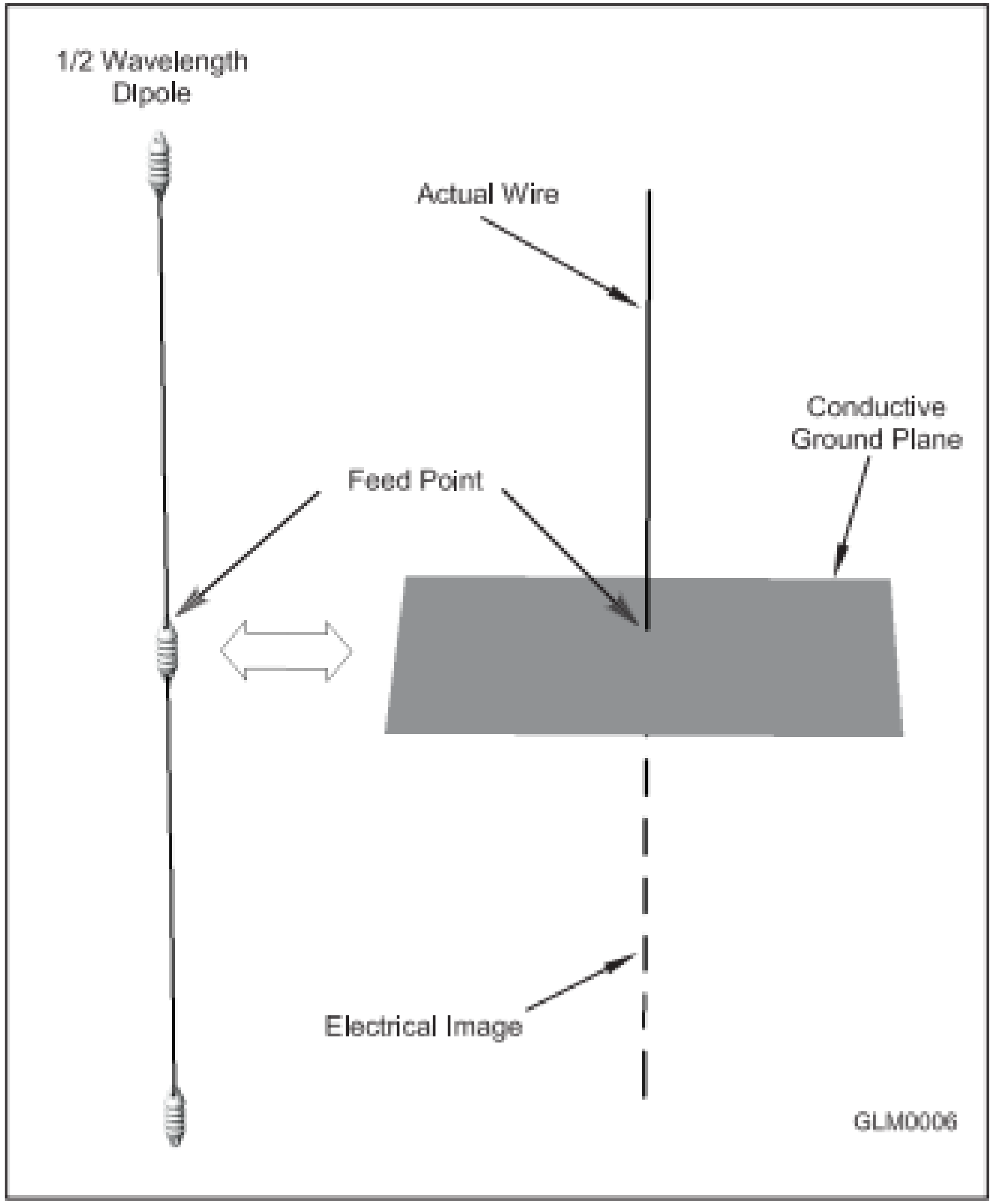
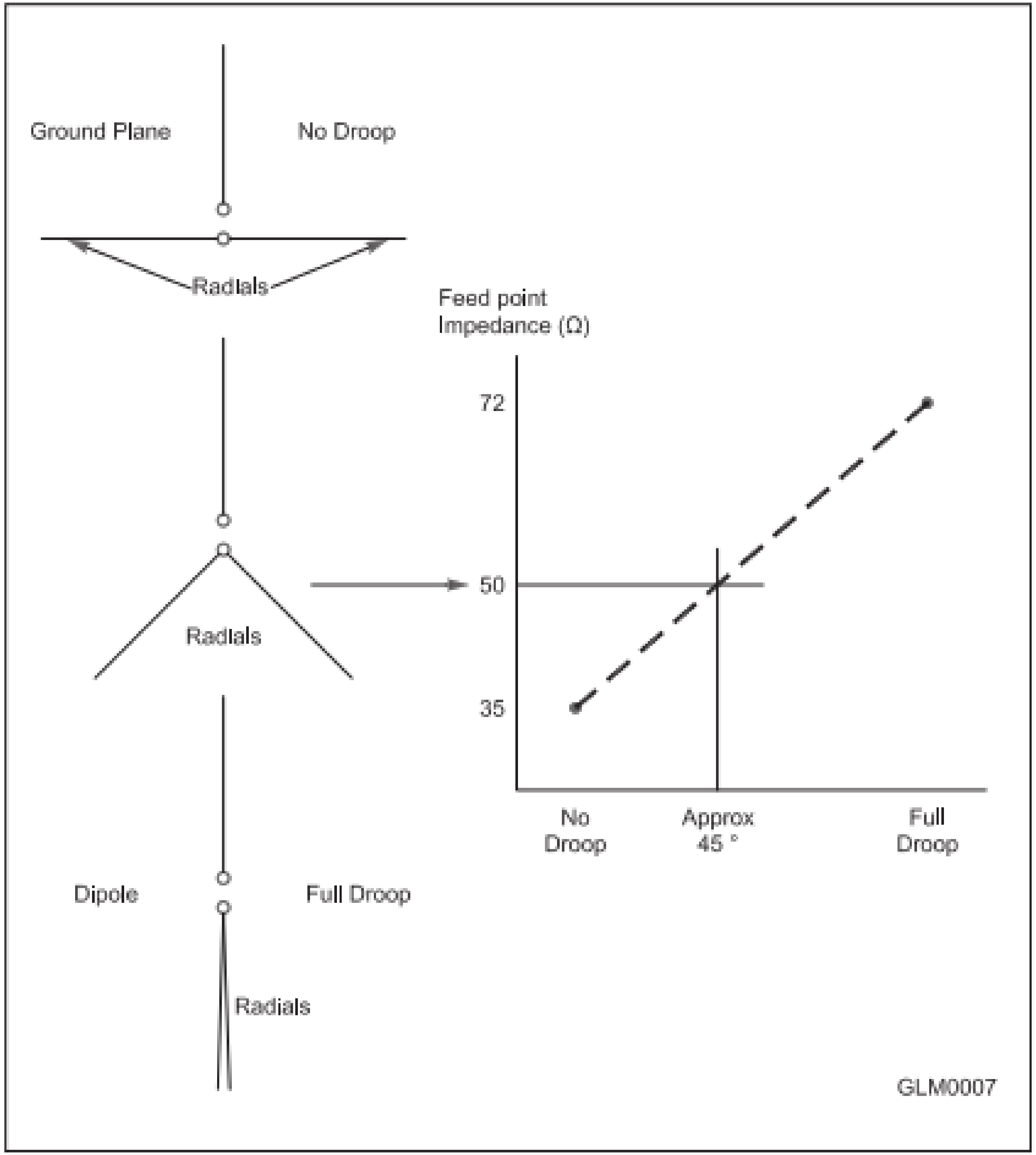


Fig 7.4

The feed point impedance of a ground-plane antenna with radials perpendicular to the antenna is approximately 35 Ω, resulting in a 1.4:1 SWR with 50-Ω coaxial cable. Drooping or sloping the radials gradually raises the feed point impedance until, with the radials drooped so far as to become the other half of a dipole, feed point impedance becomes 72 Ω. A 50-Ω feed point is reached with radials drooping approximately 45 degrees.



Ground Planes (cont.)

- A droop angle between 30 and 45 degrees as shown in Fig 7.4 results in the feed point impedance increasing to approx. 50 Ω (matches coaxial cable)
- As with the dipole, it is not useful to provide a one-size-fits-all formula for length of a ground-plane antenna
- Since the ground-plane is one-half the size of a dipole, start with one-half the free-space length (246 / f in MHz) and be prepared to trim the antenna’s length

Example: What is the approximate length in feet of a 1⁄4-wave ground-plane antenna resonant at 28.5 MHz?

$$Free\ Space\ Length = \frac{246}{f} = \frac{246}{28.5} = 8.6\ ft$$

Mobile HF Antennas

- Mobile HF antennas are often some form of ground-plane
  - Most popular is the vertically-oriented *whip*
- A full-sized λ/4 mobile whip is not feasible on bands below 28 and 24 MHz (too long)
- *Loading techniques* are used to increase their electrical length
  - Loading coils: A coil added at base or somewhere along the length
  - Capacitance hats: Spokes or a wheel-shaped structure is added near the top of the antenna
  - Linear loading: Part of the antenna is folded back on itself

Mobile HF Antennas (cont.)

- Another common feature on mobile whips is corona ball at the tip
  - Does add a small amount of loading capacitance, but primary function is to eliminate high-voltage discharges from the sharp tip of the antenna while transmitting
- A loaded antenna is not as efficient as a full-sized straight whip and will have a small operating bandwidth without retuning
- The screwdriver antenna design — a whip with an adjustable loading coil at the base — has gained popularity for HF mobile operation as a good compromise between performance and convenience

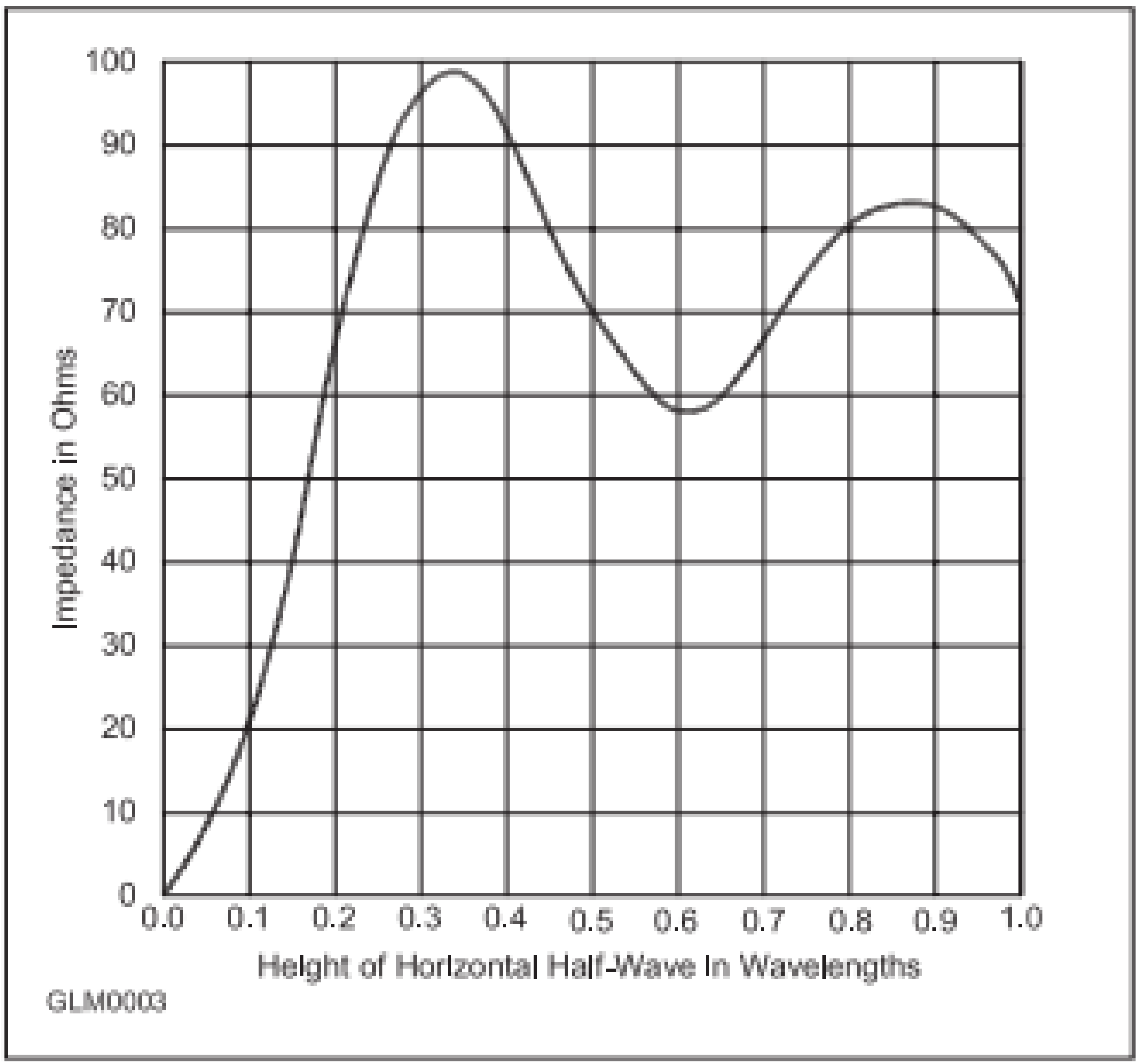
Effects of Ground

- A dipole's feed point impedance and radiation pattern are both affected by its physical height above ground
- Feed point impedance is affected because the electrical image is electrically reversed from the actual dipole
- As the image and antenna get closer together, the actual antenna begins to be "shorted out" by the image
- Below 1⁄4 wavelength in height, dipole's feed point impedance steadily decreases until it is close to Ø at ground level

Fig 7.5

The feed point impedance of a horizontal dipole over perfect ground varies dramatically with height. At ground level, the antenna is effectively “shorted out” by its electrical image. As the antenna is raised, the impedance gradually approaches the 72-Ω feed point impedance of a dipole in free space.

Above 1⁄4 λ, the impedance varies as suggested by Figure 7.5, eventually reaching a stable value at a height of several wavelengths.



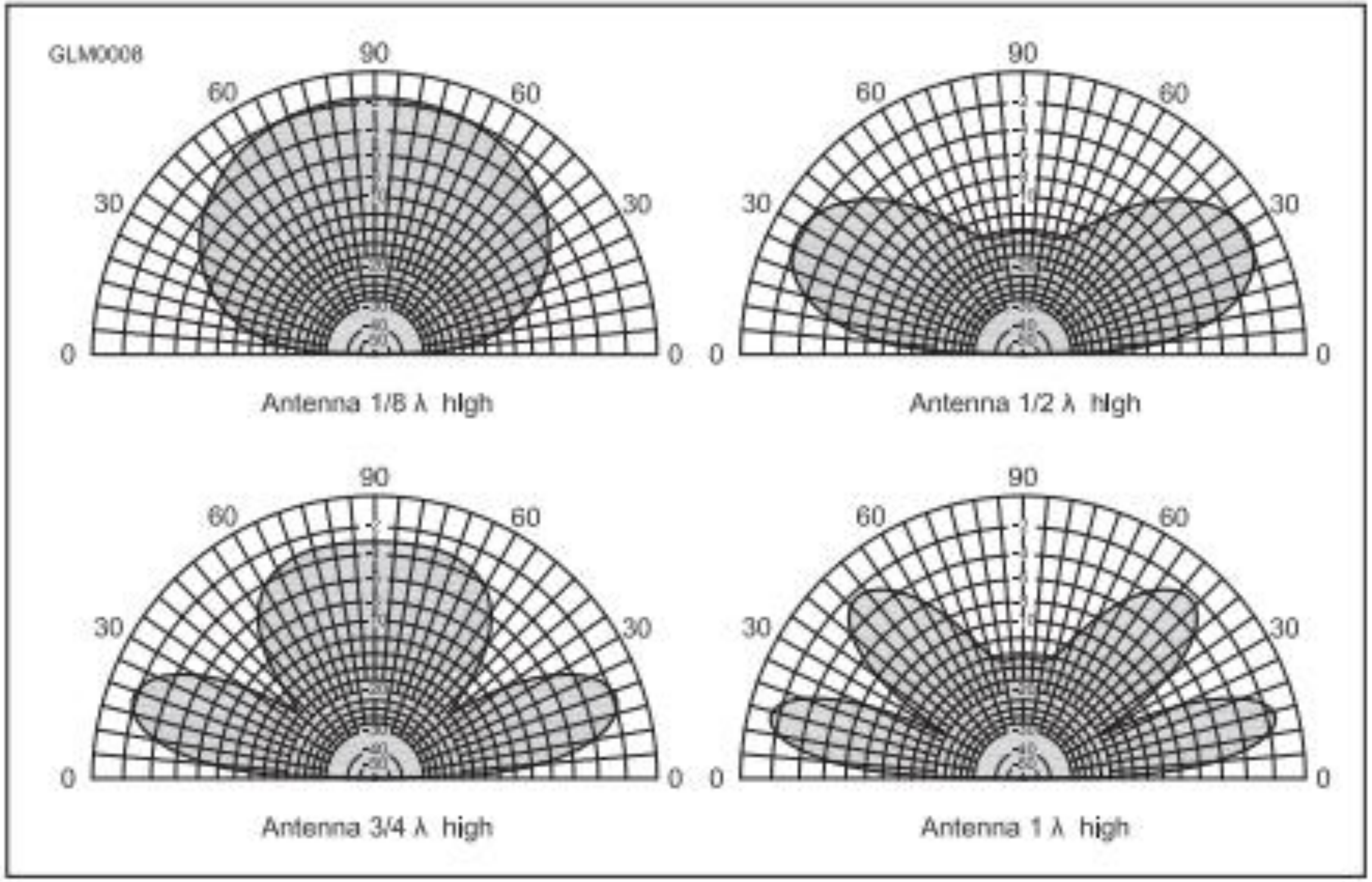
Effects of Ground (cont.)

- Height above ground also affects radiation patterns because of reflection of the antenna’s radiated energy by the ground
- The direct and reflected signals take different amounts of time to travel to the receiving antenna so they can add together, cancel each other, or any combination in between
- Fig 7.6 shows what happens when a dipole is raised in steps from a very low height to more than one wavelength above ground

Fig 7.6

As a low dipole starting at 1⁄8 wavelength above ground is raised, the effects of its electrical ground image cause the elevation pattern to flatten out. At multiples of 1/2 wavelength in height, the pattern has a null in the vertical direction because the direct and reflected signals cancel.

At heights below 1⁄2 wavelength, the dipole's pattern is almost omnidirectional and is maximum straight up.



NVIS Propagation

- *Near-vertical incidence sky-wave* propagation are signals that go straight up
- Signals radiated at high vertical angles on low frequencies are usually reflected back to the ground over a wide area, ensuring good communication
- Horizontal dipoles from 1⁄10 to 1⁄4 wavelength high produce an omnidirectional, high-angle pattern ideal for NVIS use
- Use by many public service teams

Effects of Ground (cont.)

- Polarization also affects the amount of signal that is lost from the resistance of the ground
- Radio waves reflecting from the ground have lower losses when the polarization of the wave is parallel to the ground (i.e., *horizontally polarized*)
- Because the radiation pattern is made up of reflected waves combining with direct waves that are not reflected, lower reflection loss results in stronger maximum signal strength

Antenna Terms

- Feed point impedance: Ratio of RF voltage to current at an antenna’s feed point
- Resonant: When antenna feed point impedance is completely resistive with no reactance
- Radiation pattern: Graph of antenna’s signal strength in every direction or at every vertical angle
- Azimuthal pattern: Shows signal strength in horizontal directions
- Elevation pattern: Shows signal strength in vertical directions
- Lobes: Regions in the radiation pattern where antenna is radiating a signal
- Nulls: Points at which radiation is at a minimum between lobes
- Isotropic antenna: Radiates equally in every possible direction (*theoretical only*)
- Omnidirectional antenna: Radiates a signal equally in every horizontal direction
- Directional antenna: Radiates preferentially in one or more directions
- Gain: Concentrating transmitted or received signals in a specific direction
- Front-to-back ratio: Ratio of gain in the preferred or forward direction to the opposite direction
- Front-to-side ratio: Ratio of gain in the preferred or forward direction to directions at right angles

PRACTICE QUESTIONS

What is the purpose of a capacitance hat on a mobile antenna?

A. To increase the power handling capacity of a whip antenna
B. To allow automatic band changing
C. To electrically lengthen a physically short antenna
D. To allow remote tuning

What is the purpose of a corona ball on an HF mobile antenna?

A. To narrow the operating bandwidth of the antenna
B. To increase the “Q” of the antenna
C. To reduce the chance of damage if the antenna should strike an object
D. To reduce RF voltage discharge from the tip of the antenna while transmitting

What is one disadvantage of using a shortened mobile antenna as opposed to a full-size antenna?

A. Short antennas are more likely to cause distortion of transmitted signals
B. Short antennas can only receive circularly polarized signals
C. Operating bandwidth may be very limited
D. Harmonic radiation may increase

Which of the following is a common way to adjust the feed-point impedance of a quarter wave ground-plane vertical antenna to be approximately 50 ohms?

A. Slope the radials upward
B. Slope the radials downward
C. Lengthen the radials
D. Shorten the radials

Which of the following best describes the radiation pattern of a quarter-wave, ground-plane vertical antenna?

A. Bi-directional in azimuth
B. Isotropic
C. Hemispherical
D. Omnidirectional in azimuth

What is the radiation pattern of a dipole antenna in free space in a plane containing the conductor?

A. It is a figure-eight at right angles to the antenna
B. It is a figure-eight off both ends of the antenna
C. It is a circle (equal radiation in all directions)
D. It has a pair of lobes on one side of the antenna and a single lobe on the other side

How does antenna height affect the horizontal (azimuthal) radiation pattern of a horizontal dipole HF antenna?

A. If the antenna is too high, the pattern becomes unpredictable
B. Antenna height has no effect on the pattern
C. If the antenna is less than 1/2 wavelength high, the azimuthal pattern is almost omnidirectional
D. If the antenna is less than 1/2 wavelength high, radiation off the ends of the wire is eliminated

Where should the radial wires of a ground-mounted vertical antenna system be placed?

A. As high as possible above the ground
B. Parallel to the antenna element
C. On the surface of the Earth or buried a few inches below the ground
D. At the center of the antenna

How does the feed-point impedance of a 1/2 wave dipole antenna change as the antenna is lowered below 1/4 wave above ground?

A. It steadily increases
B. It steadily decreases
C. It peaks at about 1/8 wavelength above ground
D. It is unaffected by the height above ground

How does the feed point impedance of a 1/2 wave dipole change as the feed point is moved from the center toward the ends?

A. It steadily increases
B. It steadily decreases
C. It peaks at about 1/8 wavelength from the end
D. It is unaffected by the location of the feed point

Which of the following is an advantage of a horizontally polarized as compared to a vertically polarized HF antenna?

A. Lower ground reflection losses
B. Lower feed-point impedance
C. Shorter radials
D. Lower radiation resistance

What is the approximate length for a 1/2 wave dipole antenna cut for 14.250 MHz?

A. 8 feet
B. 16 feet
C. 24 feet
D. 33 feet

What is the approximate length for a 1/2 wave dipole antenna cut for 3.550 MHz?

A. 42 feet
B. 84 feet
C. 132 feet
D. 263 feet

What is the approximate length for a 1/4 wave vertical antenna cut for 28.5 MHz?

A. 8 feet
B. 11 feet
C. 16 feet
D. 21 feet

How does antenna gain stated in dBi compare to gain stated in dBd for the same antenna?

A. dBi gain figures are 2.15 dB lower than dBd gain figures
B. dBi gain figures are 2.15 dB higher than dBd gain figures
C. dBi gain figures are the same as the square root of dBd gain figures multiplied by 2.15
D. dBi gain figures are the reciprocal of dBd gain figures + 2.15 dB

What is meant by the terms dBi and dBd when referring to antenna gain?

A. dBi refers to an isotropic antenna, dBd refers to a dipole antenna
B. dBi refers to an ionospheric reflecting antenna, dBd refers to a dissipative antenna
C. dBi refers to an inverted-vee antenna, dBd refers to a downward reflecting antenna
D. dBi refers to an isometric antenna, dBd refers to a discone antenna

Which of the following antenna types will be most effective as a Near Vertical Incidence Skywave (NVIS) antenna for short-skip communications on 40 meters during the day?

A. A horizontal dipole placed between 1/10 and 1/4 wavelength above the ground
B. A vertical antenna placed between 1/4 and 1/2 wavelength above the ground
C. A left-hand circularly polarized antenna
D. A right-hand circularly polarized antenna

What is the feed-point impedance of an end-fed half-wave antenna?

A. Very low
B. Approximately 50 ohms
C. Approximately 300 ohms
D. Very high

How does a “screwdriver” mobile antenna adjust its feed-point impedance?

A. By varying its body capacitance
B. By varying the base loading inductance
C. By extending and retracting the whip
D. By deploying a capacitance hat

What is the common name of a dipole with a single central support?

A. Inverted V
B. Inverted L
C. Sloper
D. Lazy H

Yagi/Directional Antenna Basics

- Directional antennas create gain as well as reject interference and noise from other than the desired direction
- By aiming your antenna in the direction shown on the *azimuthal projection map*, you will be beaming your signal directly at the other station
- Dipole, ground-plane, and random wire antennas use a single radiating element
- An array antenna uses two or more elements to create maximum field strength in a specific direction, called the *main lobe* or *major lobe* of the radiation pattern

Directional Antennas (cont.)

- Two types of arrays: *driven* and *parasitic*
  - Driven array: all of the antenna elements are connected to the transmitter and are called *driven elements*
  - Parasitic array: one or more of the elements are not connected to the feed line but influence the antenna's pattern by interacting with the radiated energy from the driven element(s)
- Whether an array is driven or parasitic, its radiation pattern is determined by *constructive* and *destructive interference*

Yagi Structure

- Most popular of all directional antennas because of its simple construction and good performance
- Yagi is a parasitic array with a single driven element and at least one parasitic element
- The driven element (DE) is a resonant dipole, approximately 1⁄2 wavelength long
- Parasitic elements placed in the direction of maximum gain are called *directors* and are slightly shorter than the driven element
- Parasitic elements in the direction of minimum gain are called *reflectors* and are slightly longer than the driven element
- The front-to-back ratio is the ratio of signal strength at the peak of the radiation pattern's major lobe to that in exactly the opposite direction

Yagi Design Tradeoffs

- Primary variables for Yagi antennas are the length and diameter of each element and their placement along the boom of the antenna
- These affect gain, SWR, and front-to-back ratio in different ways:
  - More directors increase gain
  - A longer boom with a fixed number of directors increases gain up to a maximum length beyond which gain is reduced
  - Larger diameter elements reduce SWR variation with frequency (increases SWR bandwidth
  - Placement and tuning of elements affects gain and feed point impedance (and SWR)
- There are other general rules of cause-and-effect, but these are typical of the decisions that antenna designers (and purchasers) should consider

Yagi Impedance Matching

- Most Yagi designs that have desirable radiation patterns also have a feed point impedance somewhat below 50 Ω (regular coax) … results in an undesirable SWR > 2:1
- Most common technique for matching impedance is gamma match (see Fig 7.9A in text)
- A mechanical advantage of the gamma match over other techniques is that the driven element need not be insulated from the boom, simplifying construction

Yagi Impedance Matching (cont.)

- *Beta match* (or “hairpin”) … see Fig 7.9C: a short length or “stub” of parallel conductor transmission line connected directly across the driven element feed point
  - The stub acts as an inductive reactance that can compensate for any capacitive reactance at the feed point
  - The balun is used to maintain electrical balance between both halves of the driven element
- Other techniques, such as the omega match, impedance transformers, and transmission line stubs are described in references such as *The ARRL Antenna Book*

PRACTICE QUESTIONS

Which of the following describes an azimuthal projection map?

A. A map that shows accurate land masses
B. A map that shows true bearings and distances from a particular location
C. A map that shows the angle at which an amateur satellite crosses the equator
D. A map that shows the number of degrees longitude that an amateur satellite appears to move westward at the equator with each orbit

Which of the following would increase the bandwidth of a Yagi antenna?

A. Larger-diameter elements
B. Closer element spacing
C. Loading coils in series with the element
D. Tapered-diameter elements

What is the approximate length of the driven element of a Yagi antenna?

A. 1/4 wavelength
B. 1/2 wavelength
C. 3/4 wavelength
D. 1 wavelength

How do the lengths of a three-element Yagi reflector and director compare to that of the driven element?

A. The reflector is longer, and the director is shorter
B. The reflector is shorter, and the director is longer
C. They are all the same length
D. Relative length depends on the frequency of operation

How does increasing boom length and adding directors affect a Yagi antenna?

A. Gain increases
B. Beamwidth increases
C. Front-to-back ratio decreases
D. Front-to-side ratio decreases

What does “front-to-back ratio” mean in reference to a Yagi antenna?

A. The number of directors versus the number of reflectors
B. The relative position of the driven element with respect to the reflectors and directors
C. The power radiated in the major radiation lobe compared to that in the opposite direction
D. The ratio of forward gain to dipole gain

What is meant by the “main lobe” of a directive antenna?

A. The magnitude of the maximum vertical angle of radiation
B. The point of maximum current in a radiating antenna element
C. The maximum voltage standing wave point on a radiating element
D. The direction of maximum radiated field strength from the antenna

Which of the following can be adjusted to optimize forward gain, front-to-back ratio, or SWR bandwidth of a Yagi antenna?

A. The physical length of the boom
B. The number of elements on the boom
C. The spacing of each element along the boom
D. All these choices are correct

Which HF antenna would be the best to use for minimizing interference?

A. A quarter-wave vertical antenna
B. An isotropic antenna
C. A directional antenna
D. An omnidirectional antenna

Which of the following is an advantage of using a gamma match with a Yagi antenna?

A. It does not require that the driven element be insulated from the boom
B. It does not require any inductors or capacitors
C. It is useful for matching multiband antennas
D. All these choices are correct

What is a beta or hairpin match?

A. It is a shorted transmission line stub placed at the feed point of a Yagi antenna to provide impedance matching
B. It is a ¼ wavelength section of 75 ohm coax in series with the feed point of a Yagi to provide impedance matching
C. It is a series capacitor selected to cancel the inductive reactance of a folded dipole antenna
D. It is a section of 300 ohm twinlead used to match a folded dipole antenna

Loop Antennas

- Can be circular, square, triangular or any simple open shape that is not too narrow
- Feed line can be attached at a break in the loop or a smaller loop can be used to couple RF energy to the main loop
- A square loop with each leg 1⁄4 wavelength long is a *quad loop*
- Triangular or *delta loops* are usually symmetrical, each leg 1⁄3 wavelength long
- A one-wavelength loop acts electrically like two dipoles connected end-to-end with the open ends brought together
  - Circumference much larger than 1 λ, current patterns around loop have more than 2 peaks and nulls … result is an essentially omnidirectional pattern with the peak angle of radiation somewhat lower than a dipole at the same height

Quad and Delta Loop Beams

- Popular variation of the Yagi beam uses quad loops for elements (*quad*)
  - Has two or more full-sized loops mounted on a boom
- Quad or delta loop beam driven elements are approximately 1 λ in circumference and operate on the same principles of re-radiation and phase shift as does the Yagi
- The driven element of a quad is about 1⁄4 λ per side and of a symmetrical delta loop about 1⁄3 λ per side
- Quad and delta loop reflectors are about 5% longer in circumference than the driven element, and the directors about 5% shorter
- Front-to-back ratio is generally better for the Yagi

Small Loops

- When the circumference of the loop becomes less than 1⁄3 λ, the current in the loop becomes relatively uniform all the way around the loop
- This causes the radiation pattern to develop sharp nulls broadside to the plane of the loop
- In wide use as receiving antennas and portable or low-profile transmitting antennas
- The sharp null broadside to the loop makes them effective for direction-finding

Halo Antennas

- Dipole bent into a circle or square (the “squalo”) with the ends separated by a small gap
- Not a continuous loop, but often viewed as a 1⁄2 λ loop
- Usually mounted horizontally so they produce an omnidirectional pattern with the horizontal polarization preferred for VHF weak-signal operation
- Halos for 6 and 2 meters can be mounted on a vehicle for mobile operation

PRACTICE QUESTIONS

What configuration of the loops of a two-element quad antenna must be used for the antenna to operate as a beam antenna, assuming one of the elements is used as a reflector?

A. The driven element must be fed with a balun transformer

B. There must be an open circuit in the driven element at the point opposite the feed point

C. The reflector element must be approximately 5 percent shorter than the driven element

D. The reflector element must be approximately 5 percent longer than the driven element

Approximately how long is each side of the driven element of a quad antenna?

A. 1/4 wavelength
B. 1/2 wavelength
C. 3/4 wavelength
D. 1 wavelength

How does the forward gain of a two-element quad antenna compare to the forward gain of a three element Yagi antenna?

A. About the same
B. About 2/3 as much
C. About 1.5 times as much
D. About twice as much

In which direction is the maximum radiation from a portable VHF/UHF “halo” antenna?

A. Broadside to the plane of the halo
B. Opposite the feed point
C. Omnidirectional in the plane of the halo
D. Toward the halo’s supporting mast

In which direction or directions does an electrically small loop (less than 1/3 wavelength in circumference) have nulls in its radiation pattern?

A. In the plane of the loop
B. Broadside to the loop
C. Broadside and in the plane of the loop
D. Electrically small loops are omnidirectional

What is the combined vertical and horizontal polarization pattern of a multi-wavelength, horizontal loop antenna?

A. A figure-eight, similar to a dipole
B. Four major loops with deep nulls
C. Virtually omnidirectional with a lower peak vertical radiation angle than a dipole
D. Radiation maximum is straight up

Random Wire Antennas

- Not always practical to have a 1⁄2 or 1⁄4 λ long resonant antenna
  - A random wire antenna can be used
- Connected directly to the output of the transmitter (or tuner) without a feed line
- *May result in significant RF currents and voltages on the station equipment that could cause RF burns*
- Can give excellent results on any band for which the transmitter or tuner can accept the feed point impedance

Stacked Antennas

- Stacking antennas (vertically or horizontally) results in more gain (see Fig 7.14 in text)
- As more and more directors are added, the *beamwidth* of the main lobe (angle between points on the main lobe at which gain is 3 dB less than maximum) narrows
- Vertically stacking antennas increases gain and narrows the elevation beamwidth
- Most vertical stacks, with the antennas directly above each other, space the antennas about λ/2 apart. Spaced λ/2 apart, the additional gain for a vertical stack of two horizontally-polarized beams is about 3 dB.

Log Periodics (or *Logs*)

- TV antennas are often log periodics
- "Log" refers to as *logarithmic* … *periodic* means the spacing of the elements along the boom
- The length and the spacing of the elements increases logarithmically from one end to the other
- Designed to have a consistent radiation pattern and low SWR over a wide frequency bandwidth (as much as 10:1)
  - Meaning the log periodic can be used over several bands
- Not as much gain or front-to-back ratio as a Yagi antenna

Beverage Antennas

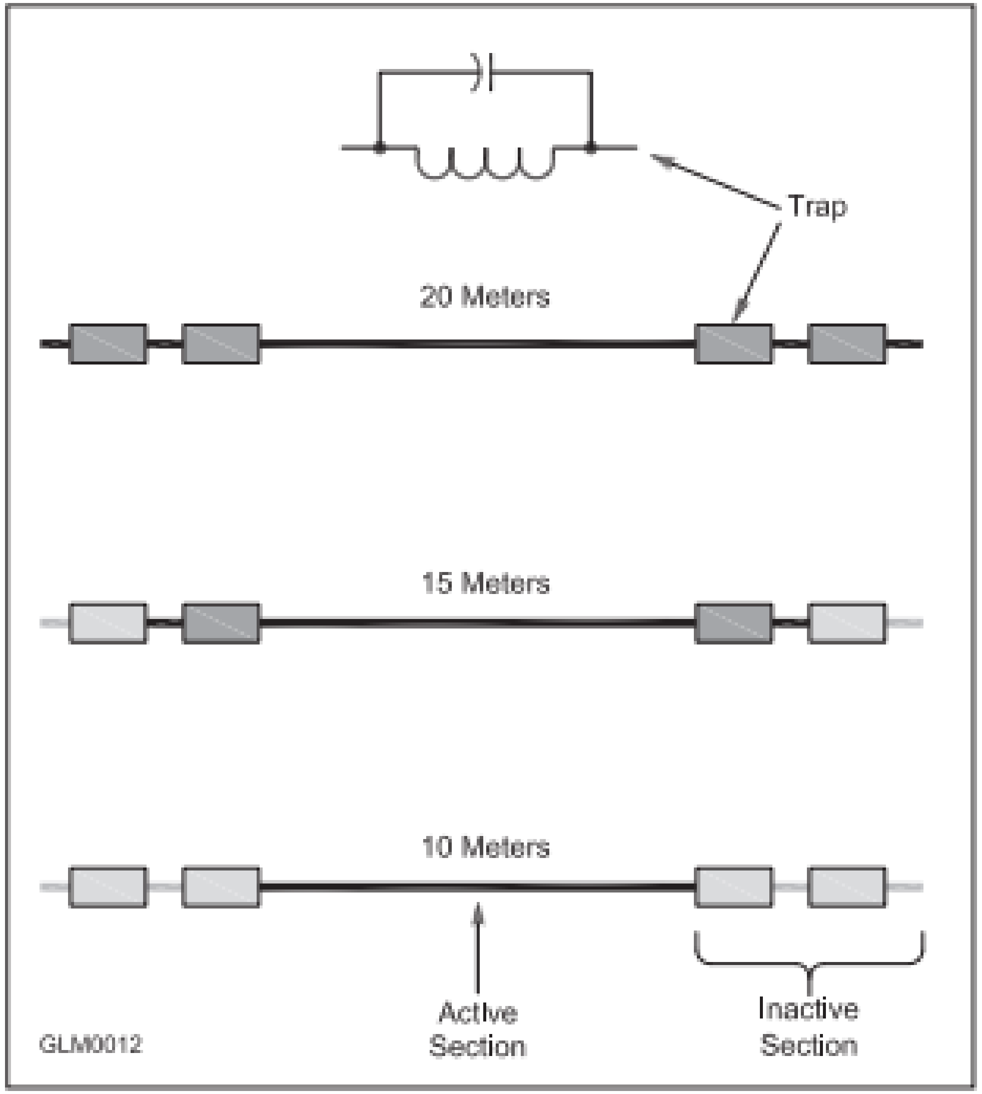
- Invented by Harold Beverage (see Fig 7.16 in text)
- Designed not to have high gain, but to reject noise and interfering signals that are not from the desired direction
  - Result is lower signal strength but a better signal-to-noise ratio
- Referred to as a *traveling wave antenna*
- Consists of a long, low wire (usually less than 20 feet high) aligned with the preferred signal direction
- Used exclusively for directional receiving on the lower HF bands (40 meters and longer wavelengths)
- Has high ground losses and is too inefficient for use as a transmitting antenna

Multiband Antennas

- What hams generally mean by multiband antenna is a design that reconfigures itself electrically for each band of operation
- Most basic multiband antenna … *trap dipole* (See Fig 7.17 … next slide)
  - Each trap is a parallel LC circuit
  - At resonance acts like an open circuit, below resonance like an inductor, and above resonance like a capacitor
  - At lower frequencies, the traps add inductance to the antenna, making the antenna look electrically longer
  - At higher frequencies, the capacitance electrically shortens the antenna

Fig 7.17

Traps are parallel LC circuits. They may be made from discrete inductors and capacitors or may use coaxial cable or metal sleeves. The traps act like open circuits at their resonant frequency, causing different sections of the antenna to be active on different bands. This drawing shows a trap antenna that works on 10, 15, and 20 meters.



Trap Dipoles (cont.)

- The lowest frequency of operation the antenna acts like a regular dipole, shortened by the inductance of the trap
- Yagis can also use traps to work on several bands
  - 3-element tribander Yagi with traps in the elements works well on 20, 15 & 10 meters
- Trap drawbacks
  - Because it works on multiple bands, radiates harmonics and spurious signals (up to transmitter operator to be sure those signals are not generated)
  - Trap losses and reduce the efficiency of the antenna
  - Will not radiate quite as well as a full-sized antenna

PRACTICE QUESTIONS

What is one disadvantage of a directly fed random-wire HF antenna?

A. It must be longer than 1 wavelength
B. You may experience RF burns when touching metal objects in your station
C. It produces only vertically polarized radiation
D. It is more effective on the lower HF bands than on the higher bands

How does the gain of two three-element, horizontally polarized Yagi antennas spaced vertically ½ wavelength apart typically compare to the gain of a single three-element Yagi?

A. Approximately 1.5 dB higher

B. Approximately 3 dB higher

C. Approximately 6 dB higher

D. Approximately 9 dB higher

What is the primary purpose of antenna traps?

A. To permit multiband operation
B. To notch spurious frequencies
C. To provide balanced feed-point impedance
D. To prevent out-of-band operation

What is an advantage of vertical stacking of horizontally polarized Yagi antennas?

A. It allows quick selection of vertical or horizontal polarization
B. It allows simultaneous vertical and horizontal polarization
C. It narrows the main lobe in azimuth
D. It narrows the main lobe in elevation

Which of the following is an advantage of a log periodic antenna?

A. Wide bandwidth
B. Higher gain per element than a Yagi antenna
C. Harmonic suppression
D. Polarization diversity

Which of the following describes a log periodic antenna?

A. Element length and spacing vary logarithmically along the boom
B. Impedance varies periodically as a function of frequency
C. Gain varies logarithmically as a function of frequency
D. SWR varies periodically as a function of boom length

What is the primary use of a Beverage antenna?

A. Directional receiving for low HF bands
B. Directional transmitting for low HF bands
C. Portable direction finding at higher HF frequencies
D. Portable direction finding at lower HF frequencies

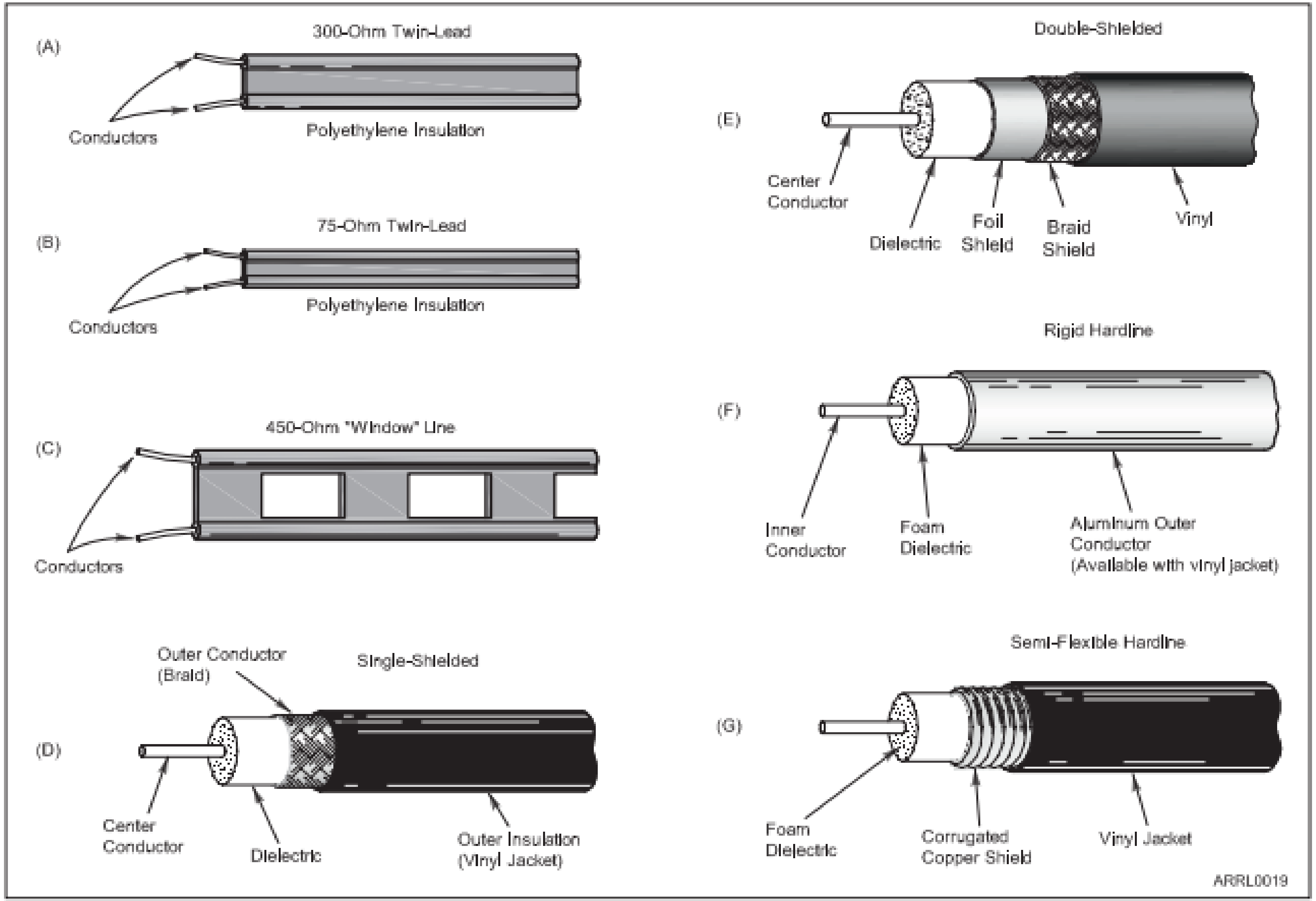
Which of the following is a disadvantage of multiband antennas?

A. They present low impedance on all design frequencies
B. They must be used with an antenna tuner
C. They must be fed with open wire line
D. They have poor harmonic rejection

Feed Lines / Characteristic Impedance

- *Balanced feed lines* consist of two parallel conductors separated by insulating material in the form of strips or spacers
- Have different characteristic impedances (Z_0) that characterize how electromagnetic energy is carried by the feed line (different from resistance)
- For parallel-conductor feed lines, the radius of the conductors and the distance between them determine Z_0
- Most common type is *window line*
- Typical impedance for window line is 450 Ω (some as low as 400 Ω)
- Most common characteristic impedances for *coaxial feed lines* used by amateurs are 50 Ω and 75 Ω

Some common types of parallel conductor and coaxial cables used by amateurs. Parallel conductor line (A, B, C) has two parallel conductors separated by insulation (dielectric). Coaxial cable (D, E, F, G) or "coax" has a center conductor surrounded by insulation. The center conductor may be made from stranded or solid wire. The second conductor, called the shield, covers the insulation and is in turn covered by the plastic outer jacket. The shield may be made from braid, or from solid aluminum or copper.



Forward & Reflected Power & SWR

- A feed line transfers **ALL** of its power to an antenna when the antenna and feed line impedances are *matched*
  - If impedances don’t match, some of the power is *reflected* by antenna
    - *Forward power*: power traveling toward the antenna
    - *Reflected power*: power reflected by the antenna
- Power in a feed line is reflected at any point at which the impedance of the feed line changes
  - Can be at an antenna, connector, or from a different type of feed line

SWR

- *Standing waves* carry forward power and reflected power from stationary interference patterns inside the feed line
- The ratio of the peak voltage in the standing wave to the minimum voltage is called the *standing wave ratio* (SWR)
  - Measures how well antenna and feed line impedances are matched
  - 1:1 is a perfect match … none of the power is reflected
  - SWR = infinity (∞) indicates that all the power was reflected
- SWR is always greater than 1:1 (for example, 3:1 and not 1:3)

Calculating SWR

SWR is equal to the ratio of the higher of antenna feed point impedance or feed line characteristic impedance to the lower.

Example: What is the SWR in a 50-Ω feed line connected to a 200-Ω load?

$$SWR = \frac{200}{50} = 4 = 4:1$$

Example: What is the SWR in a 50-Ω feed line connected to a 10-Ω load?

$$SWR = \frac{50}{10} = 5 = 5:1$$

SWR (cont.)

- Can be measured anywhere along feed line
  - Most commonly measured at connection to transmitter
- Transmitting equipment is designed to work at full power with an SWR at the input to the feed line of 2:1 or lower
- Antennas that are much too short or too long will not work well and will have extreme feed point impedances, causing high SWR

Impedance Matching

- Matching feed line and load (antenna) impedances eliminates standing waves from reflected power and maximizes power delivered to the load (but, not always practical)
- Devices used to reduce SWR are called: impedance matcher, transmatch, antenna coupler, and antenna tuner
  - Tuners do NOT tune the antenna at all — only changes impedance of the antenna system at end of feed line to match that of transmitter
- T network: impedance matching circuit for HF antennas (Fig 7.19)

Impedance Matching (cont.)

- Devices constructed from inductors and capacitors that are adjustable by the operator
- T circuit can match a wide range of impedances at the feed line connection to 50 Ω that matches transmitter output impedance
- *It is important to remember that the SWR in the feed line between the impedance matching device and the antenna does not change … the device just changes the load going to the transmitter … SWR in feed line stays the same*

Feed Line Loss

- Feed lines dissipate a little of the energy they carry as heat (called *attenuation* or *loss*)
- Loss is measured in dB per unit of length, usually dB/100 feet
- Loss increases with frequency for all types of feed lines
- The smaller the cable diameter, the higher the loss
- Increasing SWR in a feed line also increases the total loss
- The higher the feed line loss, the lower the measured SWR will be at the input to the line

PRACTICE QUESTIONS

What type of device is often used to match transmitter output impedance to an impedance not equal to 50 ohms?

A. Balanced modulator
B. SWR bridge
C. Antenna coupler or antenna tuner
D. Q multiplier

Which of the following factors determine the characteristic impedance of a parallel conductor antenna feed line?

A. The distance between the centers of the conductors and the radius of the conductors
B. The distance between the centers of the conductors and the length of the line
C. The radius of the conductors and the frequency of the signal
D. The frequency of the signal and the length of the line

What are the typical characteristic impedances of coaxial cables used for antenna feed lines at amateur stations?

A. 25 and 30 ohms
B. 50 and 75 ohms
C. 80 and 100 ohms
D. 500 and 750 ohms

What is the typical characteristic impedance of “window line” parallel transmission line?

A. 50 ohms
B. 75 ohms
C. 100 ohms
D. 450 ohms

What might cause reflected power at the point where a feed line connects to an antenna?

A. Operating an antenna at its resonant frequency
B. Using more transmitter power than the antenna can handle
C. A difference between feed-line impedance and antenna feed-point impedance
D. Feeding the antenna with unbalanced feed line

How does the attenuation of coaxial cable change as the frequency of the signal it is carrying increases?

A. Attenuation is independent of frequency
B. Attenuation increases
C. Attenuation decreases
D. Attenuation reaches a maximum at approximately 18 MHz

In what units is RF feed line loss usually expressed?

A. Ohms per 1000 feet
B. Decibels per 1000 feet
C. Ohms per 100 feet
D. Decibels per 100 feet

What must be done to prevent standing waves on an antenna feed line?

A. The antenna feed point must be at DC ground potential
B. The feed line must be cut to a length equal to an odd number of electrical quarter wavelengths
C. The feed line must be cut to a length equal to an even number of physical half wavelengths
D. The antenna feed point impedance must be matched to the characteristic impedance of the feed line

If the SWR on an antenna feed line is 5 to 1, and a matching network at the transmitter end of the feed line is adjusted to 1 to 1 SWR, what is the resulting SWR on the feed line?

A. 1 to 1
B. 5 to 1
C. Between 1 to 1 and 5 to 1 depending on the characteristic impedance of the line
D. Between 1 to 1 and 5 to 1 depending on the reflected power at the transmitter

What standing wave ratio will result when connecting a 50 ohm feed line to a non-reactive load having 200 ohm impedance?

A. 4:1
B. 1:4
C. 2:1
D. 1:2

What standing wave ratio will result when connecting a 50 ohm feed line to a non-reactive load having 10 ohm impedance?

A. 2:1
B. 50:1
C. 1:5
D. 5:1

What standing wave ratio will result when connecting a 50 ohm feed line to a non-reactive load having 50 ohm impedance?

A. 2:1
B. 1:1
C. 50:50
D. 0:0

What is the interaction between high standing wave ratio (SWR) and transmission line loss?

A. There is no interaction between transmission line loss and SWR
B. If a transmission line is lossy, high SWR will increase the loss
C. High SWR makes it difficult to measure transmission line loss
D. High SWR reduces the relative effect of transmission line loss

What is the effect of transmission line loss on SWR measured at the input to the line?

A. The higher the transmission line loss, the more the SWR will read artificially low
B. The higher the transmission line loss, the more the SWR will read artificially high
C. The higher the transmission line loss, the more accurate the SWR measurement will be
D. Transmission line loss does not affect the SWR measurement

END OF MODULE 7

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Feel free to contact me if you find errors or have suggestions for improvement.