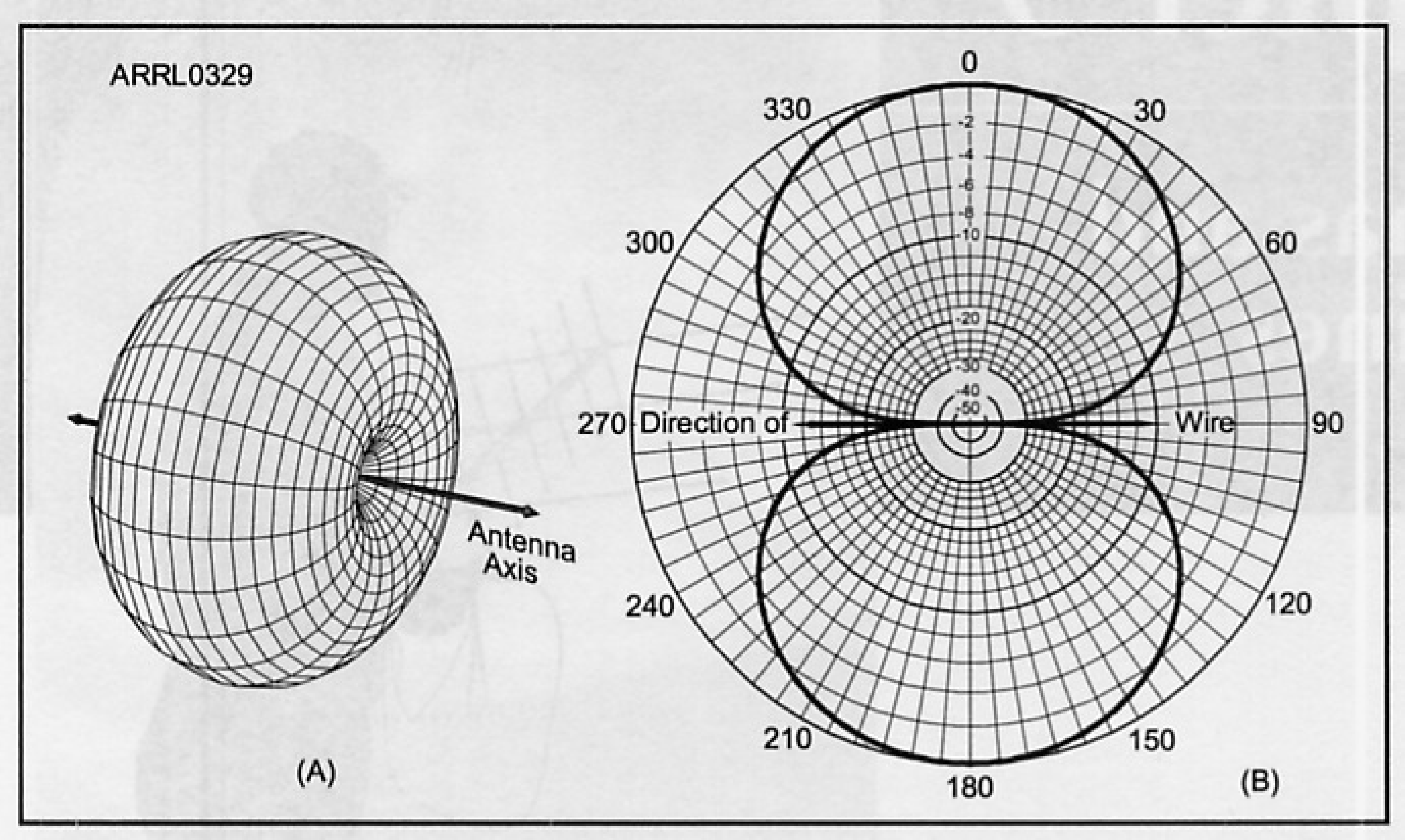
CHAPTER 9 – ANTENNAS AND FEED LINES

9.1 BASICS OF ANTENNAS (page 9-1)

ANTENNA RADIATION PATTERNS (page 9-1)



See the antenna radiation pattern. The item on the right is looking down on the antenna. Full scale, the outer ring, is the maximum power. Inner rings are minus dB from the maximum power.

Antenna radiation patterns describe the antenna's radiated signal in the far field which begins several wavelengths from the antenna. In the far field, the pattern shape is independent of distance.

Question E9B12: What is the far field of an antenna?
Answer: The region where the shape of the antenna pattern is independent of distance.

ANTENNA GAIN (page 9-2)

THE ISOTROPIC RADIATOR (page 9-2)

An isotropic radiator is a theoretical, point size antenna that is assumed to radiate equally in all directions.

The isotropic antenna also provides a useful reference for comparing the difference among real antennas.

Question E9A01: What describes an isotropic antenna?
Answer: A theoretical antenna used as a reference for antenna gain.

CHAPTER 9 – ANTENNAS AND FEED LINES

DIRECTIONAL ANTENNAS (page 9-3)

In a perfect directional antenna the radio energy would be concentrated in one direction only. This is called the forward direction, or the major lobe, or the main lobe of radiation.

An antenna's gain is the ratio between the signal radiated from an antenna in the direction of the main lobe and the signal of a reference antenna,

Question E9A07: What is meant by antenna gain?
Answer: The ratio of the radiated signal strength of an antenna in the direction of maximum radiation to that of a reference antenna.

An isotropic radiator has no directivity at all, because all the radiated signal strength is in the same direction.

Question E9A02: What antenna has no gain in any direction?
Answer: Isotropic antenna.

The gain of directional antennas is the results of concentrating the radio wave in one direction at the expense of radiation in other directions. There is no difference in the total amount of radiated power.

Question E9B07: How does the total amount of radiation emitted by a directional gain antenna compare with the total amount of radiation emitted from an isotropic antenna, assuming each is driven by the same amount of power?
Answer: They are the same.

Radiation in the main lobe of a dipole is 2.15 dB greater than would be expected from an isotropic radiator.

Gain in dBi (isotropic) = Gain in dBd (dipole) + 2.15 dB

Gain in dBd (dipole) = Gain in dBi (isotropic) -2.15 db

6 dBi – 2.15 db = 3.85 dBd

12 dBi – 2.15 = 9.85 dBd

Question E9A12: How much gain does an antenna have compared to a 1/2-wavelength dipole when it has 6 dB gain over an isotropic antenna?
Answer: 3.85 dB.

Question E9A13: How much gain does an antenna have compared to a 1/2-wavelength dipole when it has 12 dB gain over an isotropic antenna?
Answer: 9.85 dB.

BANDWIDTH AND PATTERN RATIOS (page 9-4)

Beam width is the angular distance between points on either side of the major lobe at which the gain is 3 dB below the maximum.

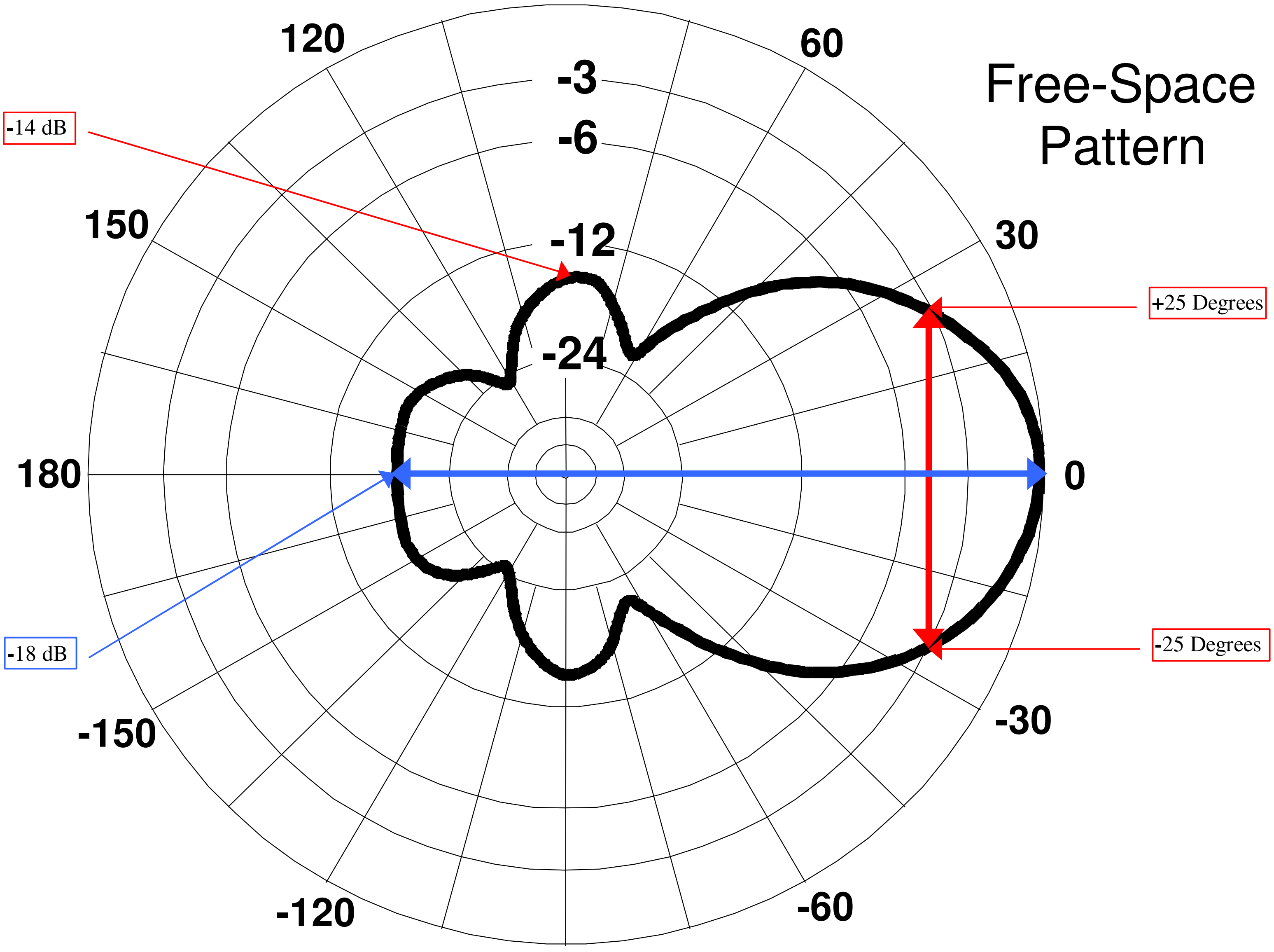
Question E9B08: How can the approximate beam-width in a given plane of a directional antenna be determined?
Answer: Note the two points where the signal strength of the antenna is 3 dB less than maximum and compute the angular difference.

CHAPTER 9 – ANTENNAS AND FEED LINES

As gain of an antenna increases the beam width decreases.

Question E9A06: How does the beam width of an antenna vary as the gain is increased?
Answer: It decreases.

Figure E9-1



Question E9B01: In the antenna radiation pattern shown in Figure E9-1, what is the 3 dB beam-width?
Answer: 50 degrees.

Question E9B02: In the antenna radiation pattern shown in Figure E9-1, what is the front-to-back ratio?
Answer: 18 dB.

Question E9B03: In the antenna radiation pattern shown in Figure E9-1, what is the front-to-side ratio?
Answer: 14 dB.

CHAPTER 9 – ANTENNAS AND FEED LINES

RADIATION AND OHMIC RESISTANCE (page 9-6)

The power applied to an antenna is dissipated in the form of radio waves and ohmic resistance.

Ohmic resistance is the heat loss in the wire as well as heat loss in the radio waves absorbed by materials near by.

In the case of radiated power, resistance is an assumed resistance, that if actually present, would dissipate the power actually radiated by the antenna. This assumed resistance is called the radiation resistance.

The total resistance of an antenna is the Radiation Resistance plus Ohmic Resistance.

Question E9A14: What is meant by the radiation resistance of an antenna?
Answer: The value of a resistance that would dissipate the same amount of power as that radiated from an antenna.

Question E9A05: What is included in the total resistance of an antenna system?
Answer: Radiation resistance plus ohmic resistance.

FEED POINT IMPEDANCE (page 9-6)

Feed point impedance is changed by position of the antenna including height, location of the antenna with respect to other objects, length/diameter ratio of the conductor that make up the antenna.

Question E9A04: Which of the following factors may affect the feed point impedance of an antenna?
Answer: Antenna height, conductor length/diameter ratio and location of nearby conductive objects.

ANTENNA EFFICIENCY (page 9-7)

Antenna Efficiency – the ratio of power radiated as radio waves to the total power input to the antenna.

Remember: $\text{Power} = I^2 \times R$

$$\text{Efficiency} = (\text{Radiation Power} \ / \ \text{Total Power}) \times 100\ \%$$

$$\text{Efficiency} = ((I^2 \times \text{Radiation Resister}) \ / \ (I^2 \times \text{Total Resistance})) \times 100\ \%$$

$$\text{Efficiency} = (\text{Radiation Resistance} / \text{Total Resistance}) \times 100\ \%$$

Question E9A09: How is antenna efficiency calculated?
Answer: (radiation resistance / total resistance) x 100 per cent.

To be effective a 1/4 wave length ground mounted antenna requires a ground system of radial wires.

Question E9A10: Which of the following choices is a way to improve the efficiency of a ground-mounted quarter-wave vertical antenna?
Answer: Install a good radial system.

ANTENNA POLARIZATION (page 9-7)

If the electric field of the radiation from an antenna is oriented parallel to the surface of the earth we say the antenna is horizontally polarized. (Remember this for the next page.)

CHAPTER 9 – ANTENNAS AND FEED LINES

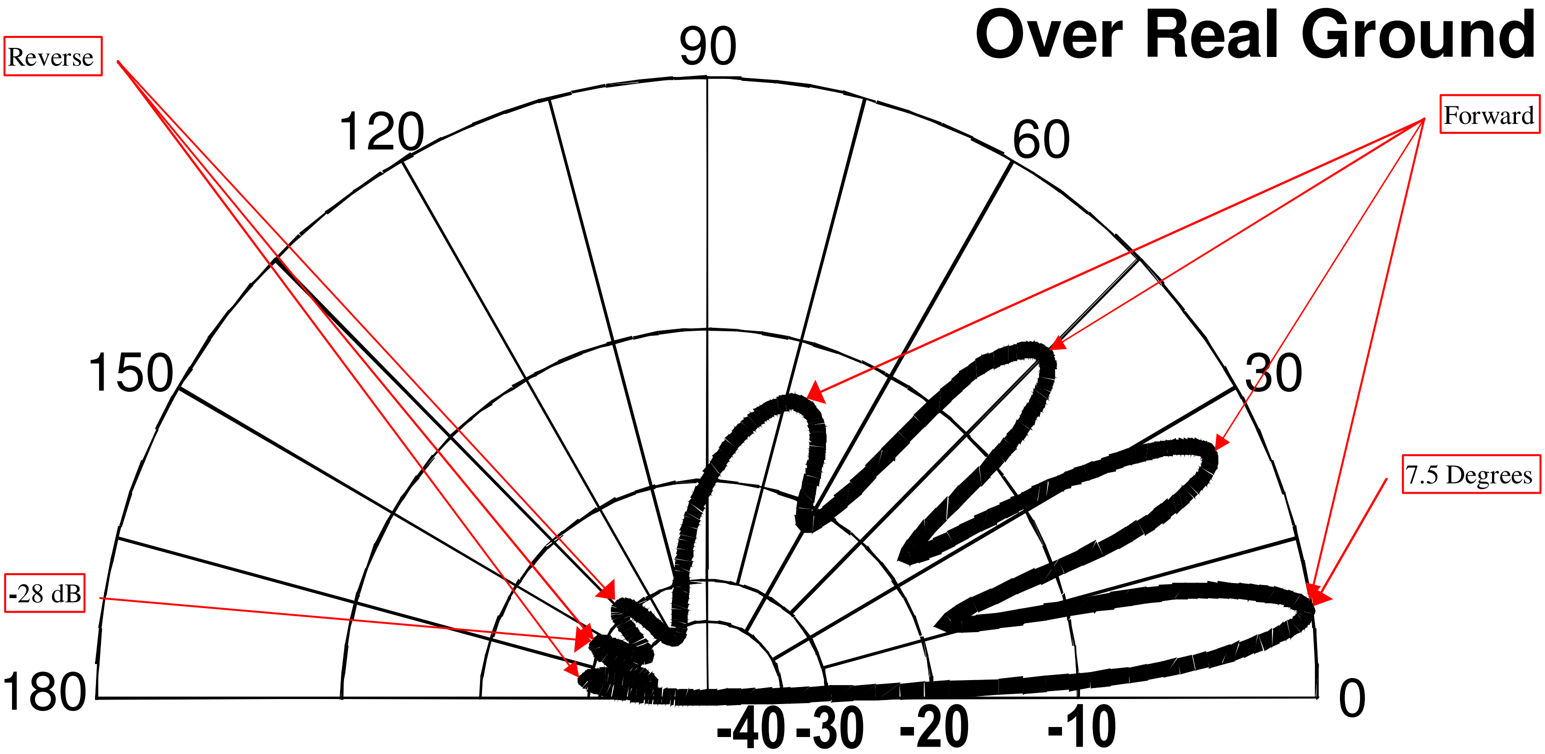
ANTENNA PATTERN TYPES (page 9-8)

E AND H PLANES (page 9-8)

The E-plane pattern is taken in the plane of the electric field and the H-plane pattern in the plane of the magnetic field.

AZIMUTHAL AND ELEVATION PATTERNS (page 9-8)

Figure E9-2



For a horizontally polarized antenna (like a dipole), the E-plane is parallel to the surface of the Earth and shows the antenna’s radiation pattern in directions around the antenna. This is called azimuthal pattern. The H-plane pattern of the same antenna is called the elevation pattern and shows the antenna’s radiation pattern at different angles above the Earth

Question E9B05: What type of antenna pattern over real ground is shown in Figure E9-2?
Answer: Elevation.

Question E9B16: How many elevation lobes appear in the forward direction of the antenna radiation pattern shown in Figure E9-2?
Answer: 4.

Question E9B06: What is the elevation angle of peak response in the antenna radiation pattern shown in Figure E9-2?
Answer: 7.5 degrees.

Question E9B15: What is the front-to-back ratio of the radiation pattern shown in Figure E9-2?
Answer: 28 dB.

CHAPTER 9 – ANTENNAS AND FEED LINES

BANDWIDTH (page 9-8)

The antenna is expected to perform to some specified level – this is the performance requirement.

As the frequency changes, the electrical size of the antenna changes and all of its electrical components change too. This means the antenna's gain, feed point impedance, radiation pattern, and so forth will also change.

In general, the band width of an antenna is the frequency range over which it satisfies a performance requirement.

Question E9A08: What is meant by antenna bandwidth?
Answer: The frequency range over which an antenna satisfies a performance requirement

An antenna's band width is affected by the antenna's Q. The antenna's Q is defined as the energy stored in the fields around the antenna divided by the power the antenna radiates.

The higher an antenna's Q, the narrower (decrease) its SWR bandwidth will be.

Question E9D08: What happens as the Q of an antenna increases?
Answer: SWR bandwidth decreases.

EFFECTS OF GROUND AND GROUND SYSTEMS (page 9-9)

Losses caused by low conductivity in the soil near the antenna dramatically reduce the antenna's signal strength at low angles.

The low-angle radiation from a vertically polarized antenna mounted over seawater will be much stronger than for a similar antenna mounted over rocky soil.

Question E9A11: Which of the following factors determines ground losses for a ground-mounted vertical antenna operating in the 3 MHz to 30 MHz range?
Answer: Soil conductivity.

Question E9C13: What is the main effect of placing a vertical antenna over an imperfect ground?
Answer: It reduces low-angle radiation.

Question E9C11: How is the far-field elevation pattern of a vertically polarized antenna affected by being mounted over seawater versus rocky ground?
Answer: The low-angle radiation increases.

HEIGHT ABOVE GROUND (page 9-9)

As an antenna height is raised above ground the vertical angle of maximum radiation pattern drops.

Question E9C15: How does the radiation pattern of a horizontally polarized 3-element beam antenna vary with its height above ground?
Answer: The main lobe takeoff angle decreases with increasing height.

CHAPTER 9 – ANTENNAS AND FEED LINES

TERRAIN (page 9-10)

The major lobe's takeoff angle will typically be lower in the direction of a slope – down hill I assume.

Question E9C14: How does the performance of a horizontally polarized antenna mounted on the side of a hill compare with the same antenna mounted on flat ground?
Answer: The main lobe takeoff angle decreases in the downhill direction.

GROUND CONNECTIONS (page 9-10)

Wide flat copper straps are the standard for low RF impedance.

Question E9D11: Which of the following types of conductors would be best for minimizing losses in a station's RF ground system?
Answer: A wide flat copper strap.

A single ground rod doesn't offer enough surface area to guarantee a low-impedance connection to the Earth. Several interconnected ground rods (three or four is a good compromise) make a much better connection.

Question E9D12: Which of the following would provide the best RF ground for your station?
Answer: An electrically short connection to 3 or 4 interconnected ground rods driven into the Earth.

9.2 PRACTICAL ANTENNAS (page 9-11)

DIPOLE VARIATIONS (page 9-11)

FOLDED DIPOLE (page 9-11)

A folded dipole is a wire antenna made from a 1-wavelength long wire that is formed into a very thin loop ½ λ long

Question E9C08: What is a folded dipole antenna?
Answer: A dipole consisting of one wavelength of wire forming a very thin loop.

The impedance of a folded dipole is four times the impedance of a dipole. (4 × 73 = 292 Ω)

Question E9C07: What is the approximate feed point impedance at the center of a two-wire folded dipole antenna?
Answer: 300 ohms.

ZEPP AND EXTENDED DOUBLE ZEPP ANTENNA (page 9-12)

The Zepp is simply a half-wave dipole with an open-wire feed line connected at one end.

Question E9C10: Which of the following describes a Zepp antenna?
Answer: An end fed dipole antenna.

The high feed point impedance could be reduced by lengthening the dipole until it is approximately 5/8 wavelengths long creating the extended Zepp. Two extended Zepps can also be connected together. This creates the extended double Zepp which is 2 × 5/8 = 1.25 wavelengths long. (A 160 meter antenna would be about 600 feet long.)

Question E9C12: Which of the following describes an extended double Zepp antenna?
Answer: A center fed 1.25 wavelength antenna (two 5/8 wave elements in phase).

CHAPTER 9 – ANTENNAS AND FEED LINES

G5RV ANTENNA (page 9-12)

A variation on the center-fed dipole was invented by G5RV. This multi-band dipole has a length of open-wire line that is selected to produce a low impedance on at least one band so that a 1:1 choke balun can be used for attaching a 50 Ω coax.

Question E9C09: What is a G5RV antenna?

Answer: A multi-band dipole antenna fed with coax and a balun through a selected length of open wire transmission line.

OFF-CENTER FED DIPOLE (page 9-12)

The off-center-fed dipole or **OCFD** takes advantage of placing the feed point where the impedance is similar on more than one band, approximately 1/3 the way from one end, generally in the neighborhood of 150 – 300 Ω. A suitable matching device such as a 4:1 impedance transformer is then used to reduce the feed point impedance to something closer to 50 Ω

Question E9C05: What is an OCFD antenna?

Answer: A dipole feed approximately 1/3 the way from one end with a 4:1 balun to provide multi-band operation.

SHORTENED AND MULTI-BAND ANTENNAS (page 9-12)

LOADED WHIPS (page 9-12)

Mobil antennas for HF operation: As the operating frequency is lowered, the feed point impedance, of such an antenna, has decreasing radiation resistance in series with an increasing capacitive reactance.

Question E9D10: What happens to feed point impedance at the base of a fixed length HF mobile antenna as the frequency of operation is lowered?

Answer: The radiation resistance decreases and the capacitive reactance increases.

To tune out the capacitive reactance and resonate the antenna, a series inductive reactance, or loading coil is used.

Question E9D09: What is the function of a loading coil used as part of an HF mobile antenna?

Answer: To cancel capacitive reactance.

The tradeoff of using loading coils in a shortened antenna is that the SWR bandwidth of the antenna is reduced (decreases).

Question E9D06: What happens to the bandwidth of an antenna as it is shortened through the use of loading coils?

Answer: It is decreased.

One advantage of placing the loading coil at least part way up the whip is that the current distribution along the antenna is improved, and that increases the radiation resistance. Antennas will have a lower current (minimum losses) through a larger loading coil and larger loading coils should have a high Q – ratio of reactance to resistance.

Question E9D04: Why should an HF mobile antenna loading coil have a high ratio of reactance to resistance?

Answer: To minimize losses

Assuming a high Q coil, center loading offers the best compromise for minimizing losses in an electrically-short vertical antenna.

Question E9D03: Where should a high Q loading coil be placed to minimize losses in a shortened vertical antenna?
Answer: Near the center of the vertical radiator.

Top loading adds a “capacitive hat” above the loading coil, either just above the coil or near the top of the whip. The added capacitance reduces the resonating value of inductance and the size of the loading coil. Using a smaller loading inductor reduces the loading coil’s resistive loss and improves the antenna radiation efficiency.

Question E9D07: What is an advantage of using top loading in a shortened HF vertical antenna?
Answer: Improved radiation efficiency.

TRAP ANTENNAS (page 9-13)

Using a single antenna on multiple bands requires a different approach. By using tuned circuits called traps strategically placed in a dipole, the antenna can be made resonate and used as a multi-band antenna on a number of different frequencies.

Trap dipoles and beam antennas have two major disadvantages. (One is that for lower frequency bands, the series inductance, loading from the traps, raises the antenna Q, which lowers the antenna’s SWR bandwidth.). Because they are a multi-band antenna, they will do a good job of radiating any harmonics present in the transmitter output,

Question E9D05: What is a disadvantage of using a multi-band trapped antenna?
Answer: It might radiate harmonics.

TRAVELING WAVE ANTENNAS (page 9-17)

The traveling wave antenna is a long-wire antenna up to several wavelengths long.

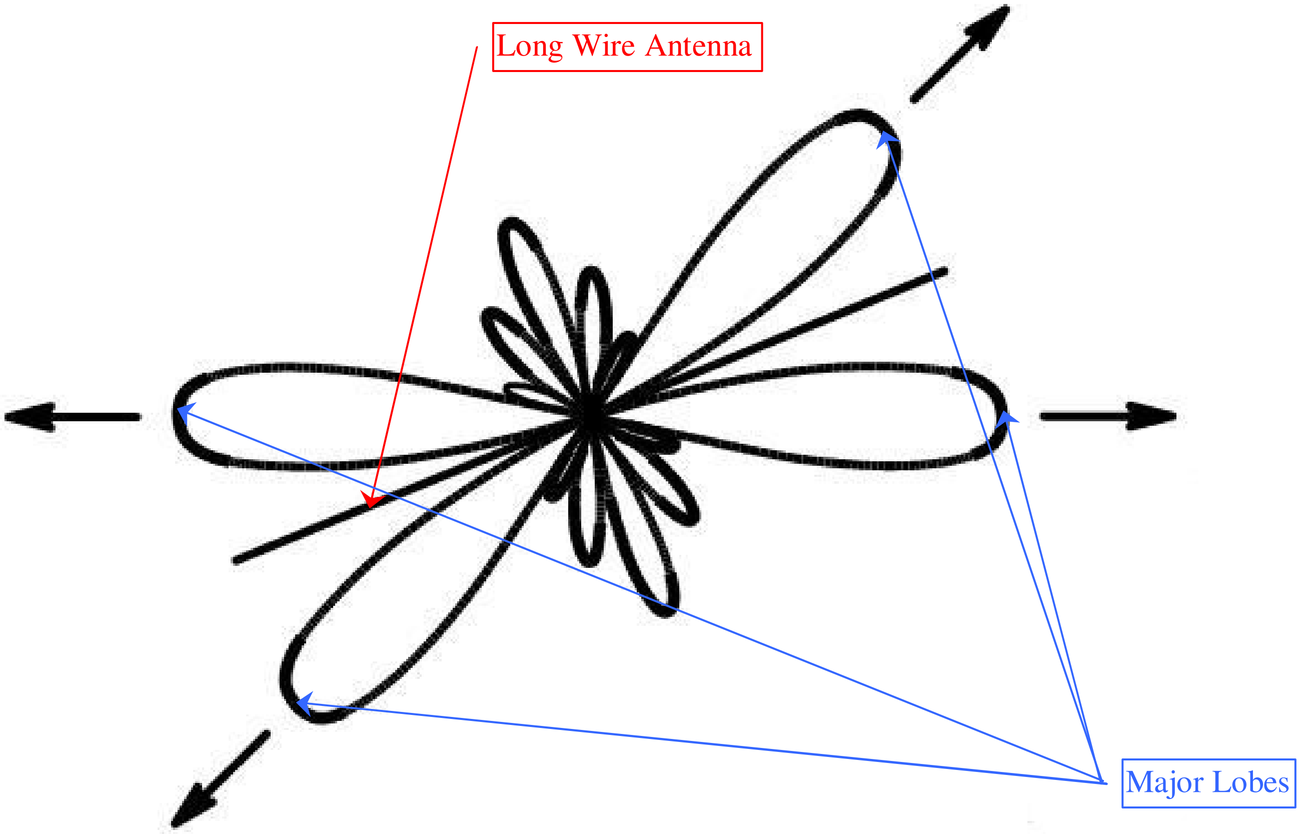
Their distinguishing feature is that the radio-frequency current that generates the radio waves travels through the antenna in one direction. This is in contrast to a *resonant antenna*, such as the monopole or dipole, in which the antenna acts as a resonator, with radio currents traveling in both directions, bouncing back and forth between the ends of the antenna. An advantage of traveling wave antennas is that since they are non-resonant they often have a wider bandwidth than resonant antennas. Common types of traveling wave antenna are the Beverage antenna and the rhombic antenna.

The long wire has four major lobes. The longer the wire, the closer to the direction of the wire the lobes become,

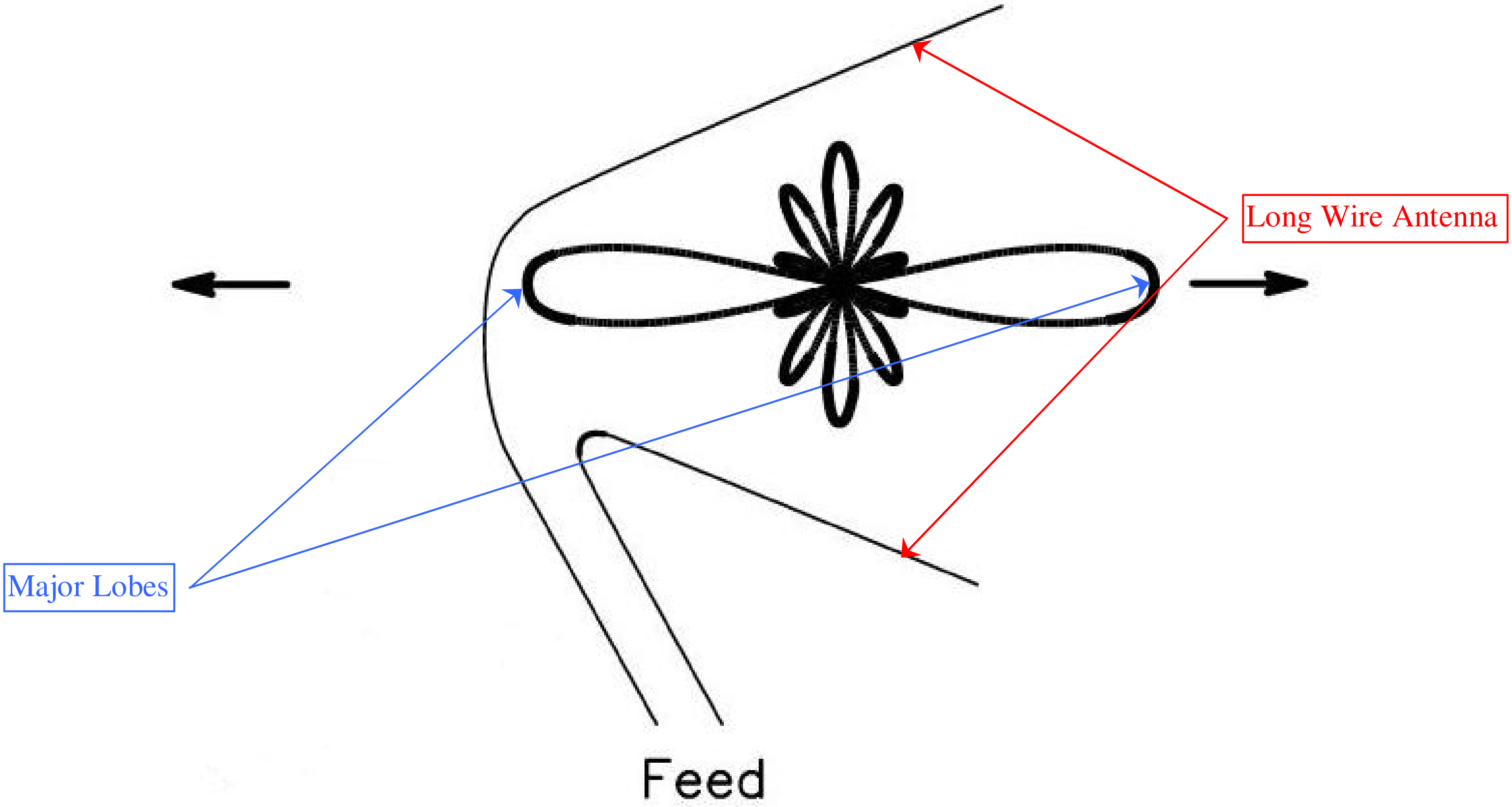
Question E9C04: What happens to the radiation pattern of an un-terminated long wire antenna as the wire length is increased?
Answer: The lobes align more in the direction of the wire.

On the next page is a picture of a long wire antenna with four major lobes.

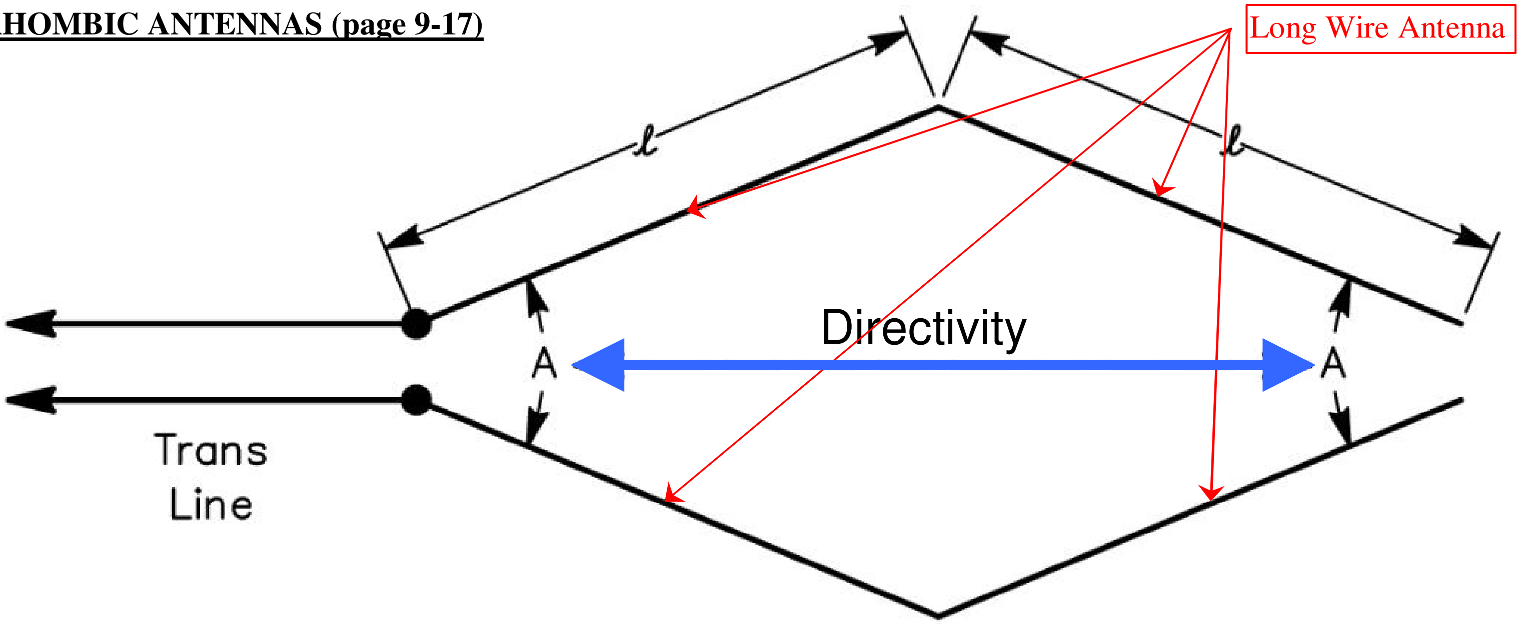
That is followed by two long wire antennas placed together but with a slight angle between them.



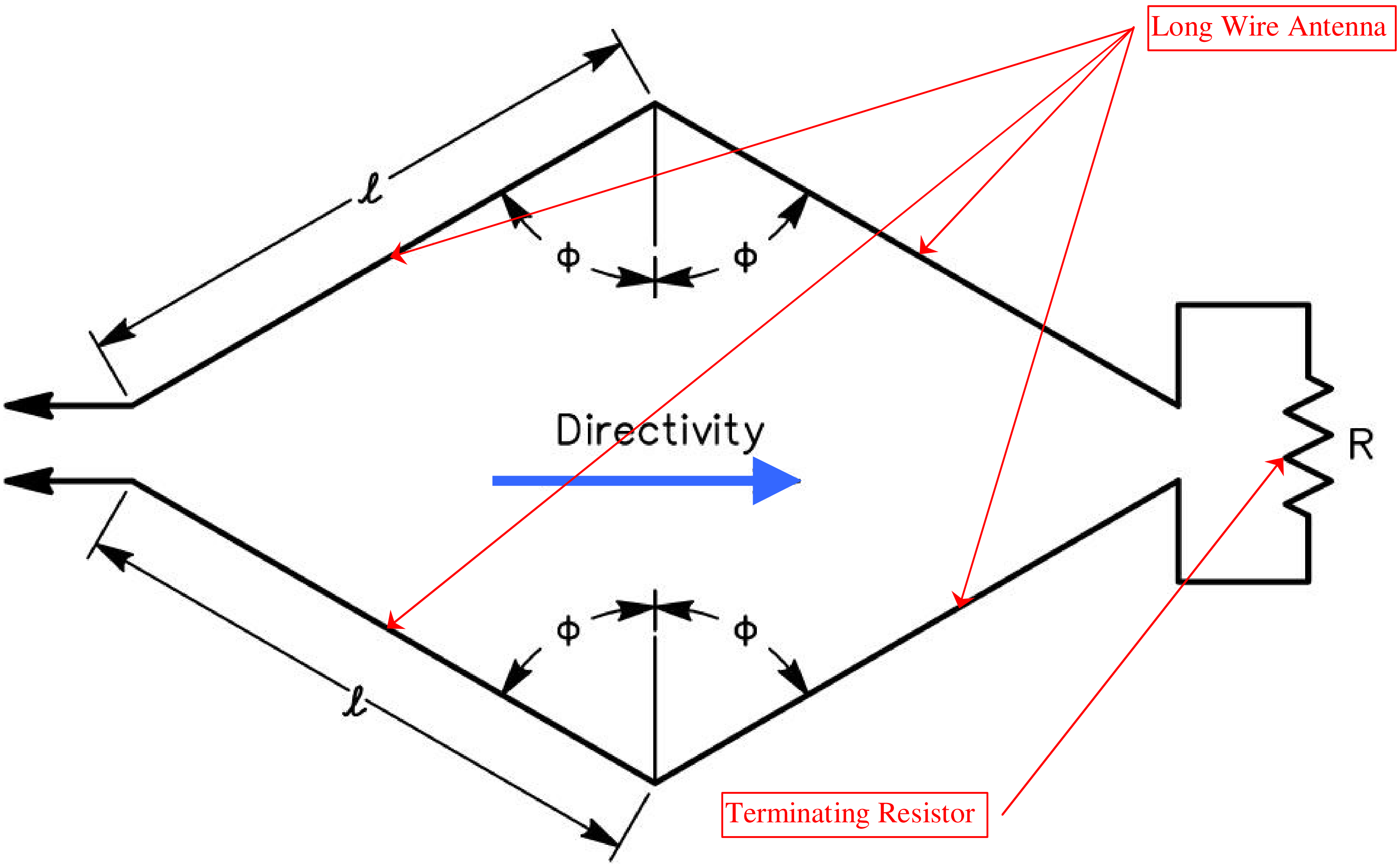
If two long wires are combined and fed out-of-phase their major lobes will coincide in two directions. This antenna is known as the Vee beam. (Actually it is a V beam but we like to spell it as we think it sounds – Vee.)



RHOMBIC ANTENNAS (page 9-17)



Long Wire Antenna



Long Wire Antenna

Terminating Resistor

Vee beams can be combined creating the rhombic antenna. Rhombic antennas are high gain antennas. Open ended rhombic antennas are bi-directional. Adding a terminating resistor to the open end makes the rhombic antenna unidirectional toward the resistor.

Question E9C06: What is the effect of a terminating resistor on a rhombic antenna?
Answer: It changes the radiation pattern from bidirectional to unidirectional.

CHAPTER 9 – ANTENNAS AND FEED LINES

BEVERAGE ANTENNAS (page 9-18)

Perhaps the best known type of wave antenna is the Beverage antenna. A Beverage antenna is simply a wire antenna, at least one wavelength long, supported along its length at a fairly low height and terminated at the far end in its characteristic impedance.

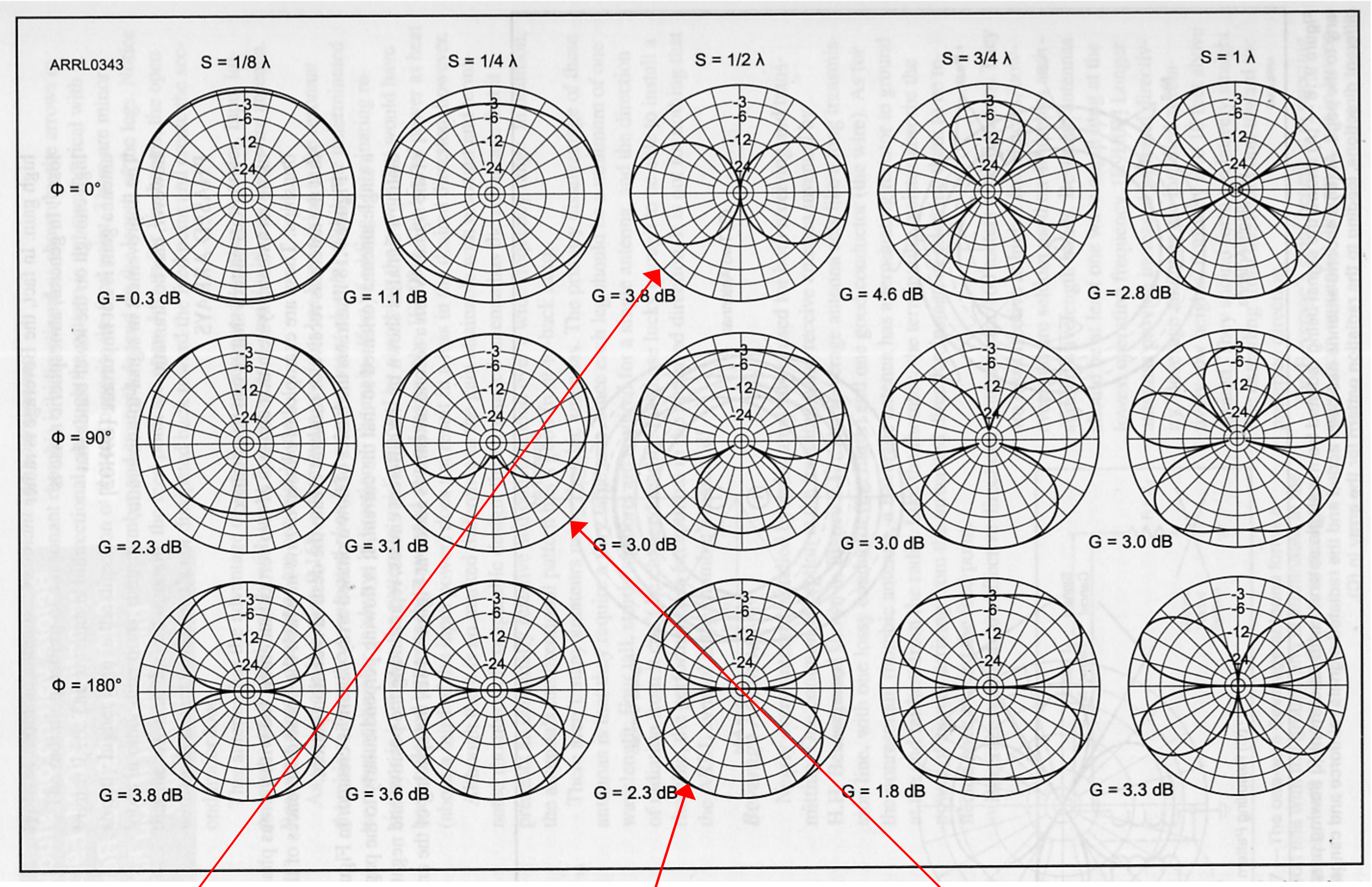
Question E9H01: When constructing a Beverage antenna, which of the following factors should be included in the design to achieve good performance at the desired frequency?
Answer: It should be one or more wavelengths long.

Many 160-meter enthusiasts have used Beverage antennas to enhance the signal-to-noise while attempting to extract weak signals from the often high levels of atmospheric noise and interference on the low bands. Therefore atmospheric noise is high enough on the low bands that antenna gain is not important.

Question E9H02: Which is generally true for low band (160 meter and 80 meter) receiving antennas?
Answer: Atmospheric noise is so high that gain over a dipole is not important.

PHASED ARRAYS (page 9-19)

Various pattern shapes can be obtained using an antenna system that consist of two vertical antennas fed with various phase relationships



E9C03 E9C01 E9C02

CHAPTER 9 – ANTENNAS AND FEED LINES

Question E9C03: What is the radiation pattern of two 1/4 wavelength vertical antennas spaced a 1/2 wavelength apart and fed in phase?
Answer: A Figure-8 broadside to the axis of the array.

Question E9C01: What is the radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed 180 degrees out of phase?
Answer: A figure-8 oriented along the axis of the array.

Question E9C02: What is the radiation pattern of two 1/4 wavelength vertical antennas spaced 1/4 wavelength apart and fed 90 degrees out of phase?
Answer: Cardioid.

These arrays are constructed by using physically identical antennas that are fed with phasing lines that create the necessary phase differences between them. This ensures that each element radiates a signal with the necessary phase to create the desired antenna pattern.

Question E9E12: What is the primary purpose of a phasing line when used with an antenna having multiple driven elements?
Answer: It ensures that each driven element operates in concert with the others to create the desired antenna pattern.

A Wilkinson power divider can be used to split the power from the transmitter into equal portions while preventing changes in the loads from affecting power flow to the other loads.

Question E9E13: What is a use for a Wilkinson divider?
Answer: It is used to divide power equally between two 50 ohm loads while maintaining 50 ohm input impedance.

SATELLITE ANTENNAS (page 9-21)

GAIN AND ANTENNA SIZE (page 9-21)

The gain of a parabolic antenna is directly proportional to the square of the dish diameter and directly proportional to the square of the frequency. That means the gain will increase by 6 dB if either the dish diameter or the operating frequency is doubled.

Question E9D01: How does the gain of an ideal parabolic dish antenna change when the operating frequency is doubled?
Answer: Gain increases by 6 dB.

WHAT ABOUT POLARIZATION? (page 9-22)

A circularly polarized antenna can be constructed from two dipoles or Yagis mounted at 90° with respect to each other and fed 90° out of phase.

Question E9D02: How can linearly polarized Yagi antennas be used to produce circular polarization?
Answer: Arrange two Yagis perpendicular to each other with the driven elements at the same point on the boom fed 90 degrees out of phase.

CHAPTER 9 – ANTENNAS AND FEED LINES

RECEIVING LOOP ANTENNAS (page 9-23)

A simple receiving antenna at MF or HF is a small loop antenna consisting of one or more turns of wire wound in the shape of a large open inductor or coil.

Question E9H09: Which of the following describes the construction of a receiving loop antenna?
Answer: One or more turns of wire wound in the shape of a large open coil.

The output voltage of the loop can be increased by increasing the number of turns in the loop or increasing the loop area.

Question E9H10: How can the output voltage of a multiple turn receiving loop antenna be increased?
Answer: By increasing either the number of wire turns in the loop or the area of the loop structure or both.

DIRECTION-FINDING AND DIRECTION-FINDING (DF) ANTENNAS (page 9-24)

Some form of RF attenuation is desirable to allow proper operation of the receiver under high signal conditions, such as when zeroing-in on the transmitter at close range. Otherwise the strong signal may overload the receiver.

Question E9H07: Why is it advisable to use an RF attenuator on a receiver being used for direction finding?
Answer: It prevents receiver overload which could make it difficult to determine peaks or nulls.

A shielded loop has the additional advantage of being easier to balance with respect to ground, reducing antenna effect and giving deeper, sharper nulls.

Question E9H04: What is an advantage of using a shielded loop antenna for direction finding?
Answer: It is electro statically balanced against ground, giving better nulls.

The wire-loop antenna is a simple one to construct, but the bidirectional pattern is a major drawback. You can't tell which of the two directions points to the signal source. Thus, a single null reading with a small loop antenna will not indicate the exact direction toward the transmitter – only the line along which it lies.

Question E9H05: What is the main drawback of a wire-loop antenna for direction finding?
Answer: It has a bidirectional pattern.

TRIANGULATION (page 9-25)

If two or more Radio Direction Finding (RDF) bearing measurements are made at several locations separated by a significant distance, the bearing lines can be drawn from those positions as represented on a map. This technique is called triangulation.

Question E9H06: What is the triangulation method of direction finding?
Answer: Antenna headings from several different receiving locations are used to locate the signal source.

CHAPTER 9 – ANTENNAS AND FEED LINES

SENSE ANTENNAS (page 9-25)

A loop antenna may be made to have a single null if a second antenna element, called a sense antenna, is added. A Sense antenna must be connected to the loop antenna with a 90° phase shift.

Question E9H08: What is the function of a sense antenna?
Answer: It modifies the pattern of a DF antenna array to provide a null in one direction.

The loop antenna and the sensing-element antenna patterns combine to form the cardioid pattern which has a very sharp null.

Question E9H11: What characteristic of a cardioid pattern antenna is useful for direction finding?
Answer: A very sharp single null.

TERRAIN EFFECTS (page 9-25)

9.3 ANTENNA SYSTEMS (page 9-26)

EFFECTIVE RADIATED POWER (page 9-26)

When evaluating total station performance, accounting for the effects of the entire system is important, including antenna gain, Transmitting performance is usually computed as effective radiated power (ERP). Include the gain and loss of all system components when computing the entire station's output power.

Question E9A18: What term describes station output, taking into account all gains and losses?
Answer: Effective radiated power.

$$\text{Effective Radiated Power} = \text{Transmitter Power Output} \times \text{System Gain}$$

$$\text{ERP} = \text{TPO} \times \text{System Gain}$$

(Equation 9.4A)

The system gain consists of all the components of the station including things like antenna gain and coax loss. Since the system gains and losses are usually expressed in decibels, they can simply be added together, with losses written as negative values.

The Extra Manual says: "System gain must then be converted back to a linear value from dB to calculate ERP."

$$\text{“ERP} = \text{TPO} \times \text{anti-log}_{10}(\text{System Gain} / 10)\text{”}$$

(Equation 9.4B)

The Extra Manual also says: "It is also common to work in entirely in dBm (is a decibel referenced to one milliwatt) and dB (is a dimensionless unit, used for quantifying the ratio between two values) until the final results for ERP is obtained and then converted back to watts."

$$\text{“ERP (in dBm)} = \text{TPO (in dbm)} + \text{System Gain (in dB)”}$$

(Equation 9.4C)

$\text{Power}_{(\text{dBm})} = 10 \times \log_{10}(1000 \times \text{Power}_{(\text{Watts})} / 1\ \text{Watt})$ Example for 200W: $10 \times \log_{10}(1000 \times 200_{\text{Watts}}) = 53_{\text{dBm}}$

CHAPTER 9 – ANTENNAS AND FEED LINES

Questions: E9A15, E9A16, and E9A17:

System Gain = (-2 dB) + (-2.2 dB) + (+7 dBd) = 2.8 dB

(dBd is dB referenced to a dipole. That is supposed to be the standard for antennas.)

ERP = 150 watts × anti-log10 (2.8 dB/10) = 150 × 1.905460718 = 285.8191077 watts

Question E9A15: What is the effective radiated power relative to a dipole of a repeater station with 150 watts transmitter power output, 2 dB feed line loss, 2.2 dB duplexer loss, and 7 dBd antenna gain?
Answer: 286 watts.

System Gain = (-4 dB) + (-3.2 dB) + (-0.8 dB) + (+10 dBd) = 2 dB

(dBd is dB referenced to a dipole. That is supposed to be the standard for antennas.)

ERP = 200 watts × anti-log10 (2 dB/10) = 200 × 1.584893192 = 316.9786385 watts

Question E9A16: What is the effective radiated power relative to a dipole of a repeater station with 200 watts transmitter power output, 4 dB feed line loss, 3.2 dB duplexer loss, 0.8 dB circulator loss, and 10 dBd antenna gain?
Answer: 317 watts.

System Gain = (-2 dB) + (-2.8 dB) + (-1.2 dB) + (+7 dBd) = 1 dB

(dBi is dB referenced to a isotropic antenna. If the input the power is isotropic and they do not specify a results then I assume that they want the results in isotropic power.)

ERP = 200 watts × anti-log10 (1 dB/10) = 200 × 1.258925412 = 251.7850824 watts

Question E9A17: What is the effective radiated power of a repeater station with 200 watts transmitter power output, 2 dB feed line loss, 2.8 dB duplexer loss, 1.2 dB circulator loss, and 7 dBi antenna gain?
Answer: 252 watts.

IMPEDANCE MATCHING (page 9-28)

Impedance matching at the antenna is important because it reduces power losses in the feed line. Also impedance matching hardware at the antenna is often less expensive than a piece of equipment.

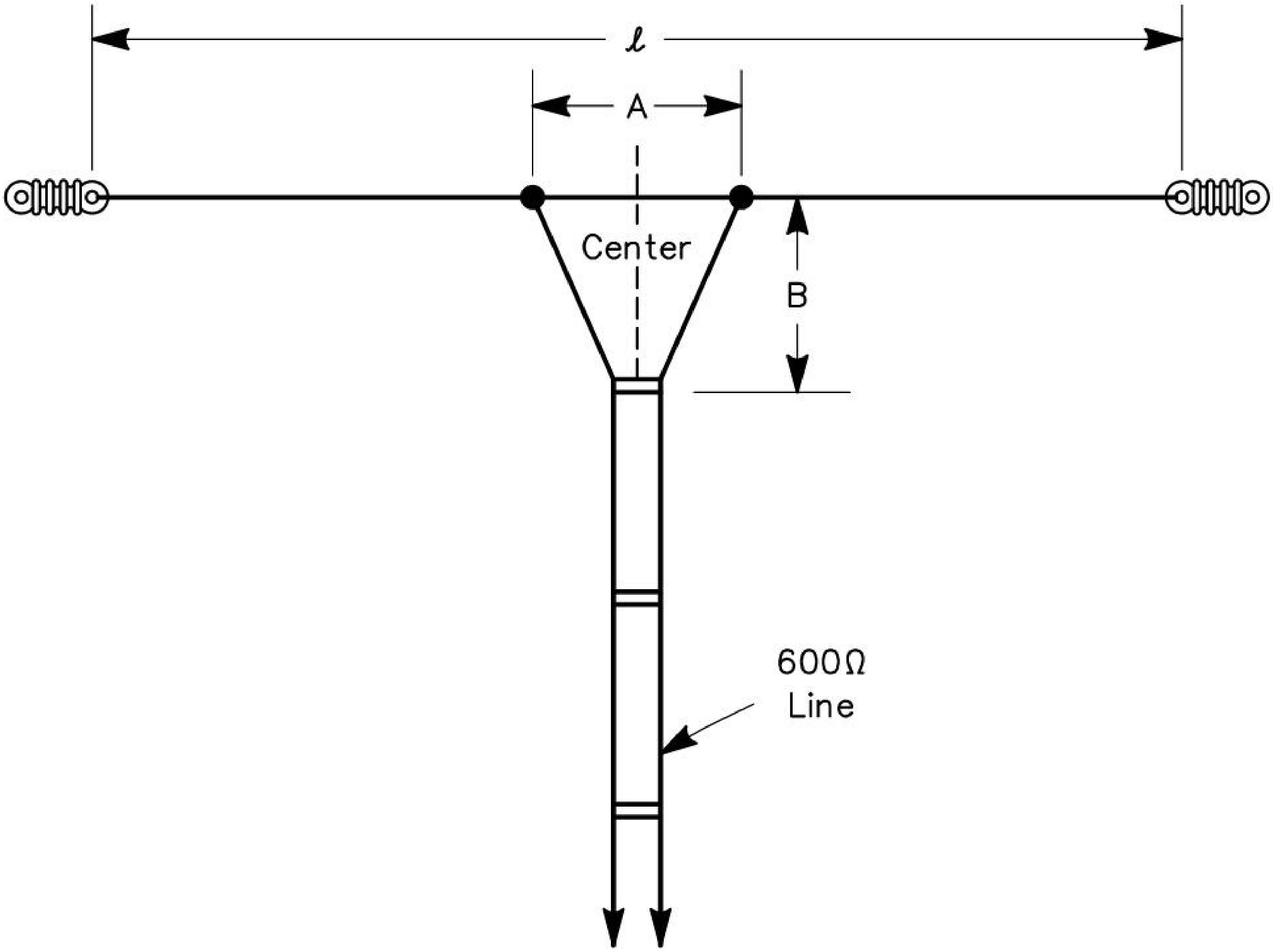
It is important to know the antenna’s feed point impedance so that a matching system can be designed. When the antenna is matched to the feed line, maximum power transfer to the antenna is achieved and Standing Wave Ratio (on the feed line) is minimized.

Question E9A03: Why would one need to know the feed point impedance of an antenna?
Answer: To match impedances in order to minimize standing wave ratio on the transmission line.

CHAPTER 9 – ANTENNAS AND FEED LINES

THE DELTA MATCH (page 9-29)

If you try to feed a half-wave dipole antenna with an open-wire feed line you will face a problem. The center impedance of the dipole antenna is too low to be matched directly by any practical type of air-insulated parallel-conductor line. It is possible to find a value of impedance between two points on the antenna that can be matched to an open-wire line when a "fanned" section or Delta Match is used to couple the feed line and antenna. The antenna is not broken in the center, so there is no center insulator. Also, the Delta Match connection is symmetrical about the center of the antenna. The fanned-out section of the feed line is triangular, similar to the Greek letter Δ (delta) that gives the technique its name.



The Delta Match gives us a way to match a high-impedance transmission line to a lower impedance antenna. The line connects to the driven element in two places, spaced a fraction of a wavelength on each side of the element center.

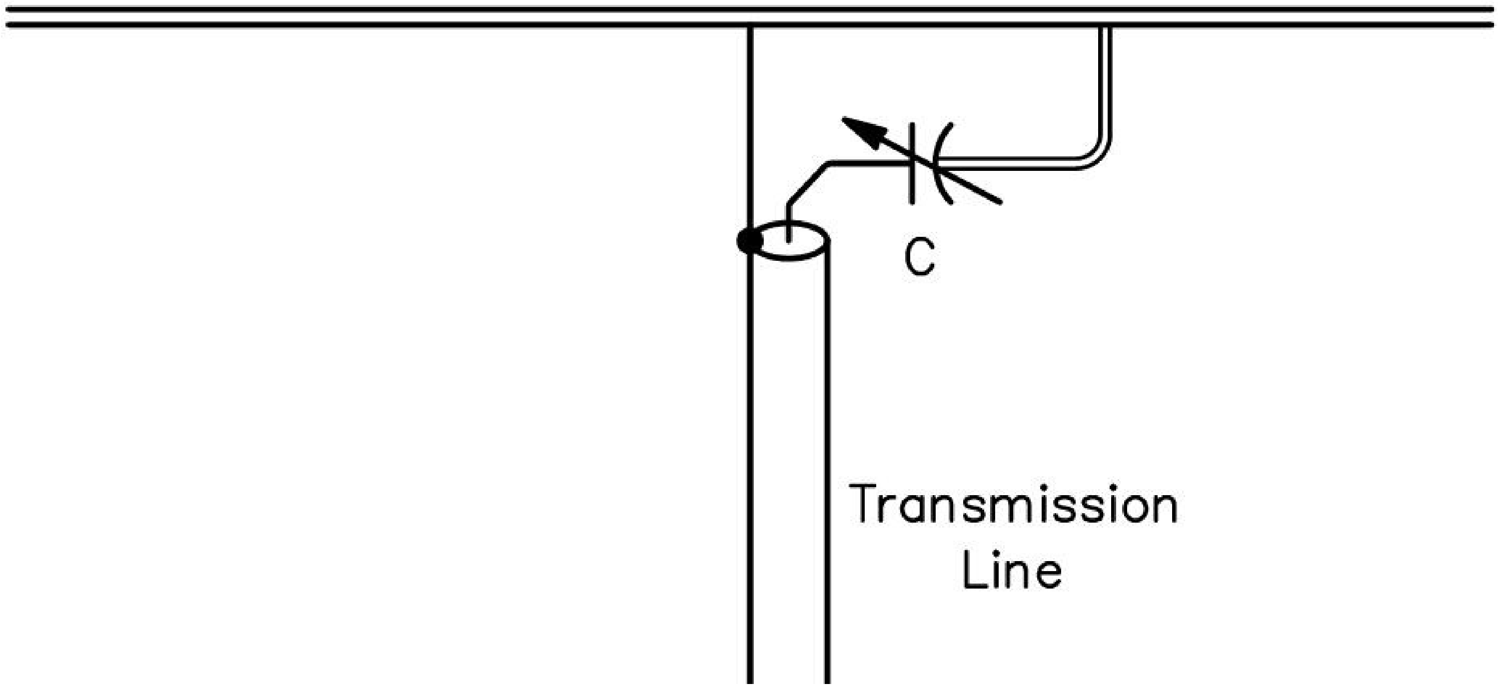
Question E9E01: What system matches a higher impedance transmission line to a lower impedance antenna by connecting the line to the driven element in two places spaced a fraction of a wavelength each side of element center?

Answer: The delta matching system.

CHAPTER 9 – ANTENNAS AND FEED LINES

THE GAMMA MATCH (page 9-29)

A commonly used method for matching a coaxial feed line to the driven element of a parasitic array (like a Yagi) is the Gamma Match. The Gamma Match is named for the Greek letter Γ (gamma). The Gamma Match has considerable flexibility in impedance matching ratio. Because this match is inherently unbalanced, no balun is needed.



The Gamma Match gives us a way to match the unbalanced feed line to an antenna. The feed line attaches at the center of the driven element and at a fraction of a wavelength to one side of the center.

Question E9E02: What is the name of an antenna matching system that matches an unbalanced feed line to an antenna by feeding the driven element both at the center of the element and at a fraction of a wavelength to one side of center?
Answer: The gamma match.

Electrically speaking the gamma conductor and the associated antenna conductor can be considered as a section of transmission line sorted at the end. Since it is shorter than ¼ wavelength the gamma matching section has an inductive reactance. (See my rule 6 and question E9F10 from the Transmission Line Stubs on page 9-39 of the Extra Manual.) This means that if the antenna itself is exactly resonate at the operating frequency, the input impedance of the gamma section will show inductive reactance as well as resistance. The reactance must be tuned out to present a good match to the transmission line. The antenna can be shortened so that its impedance contains capacitive reactance to cancel the inductive reactance of the gamma section. **OR** a capacitor of the proper value can be inserted in series at the input terminals.

Question E9E04: What is the purpose of the series capacitor in a gamma-type antenna matching network?
Answer: To cancel the inductive reactance of the matching network.

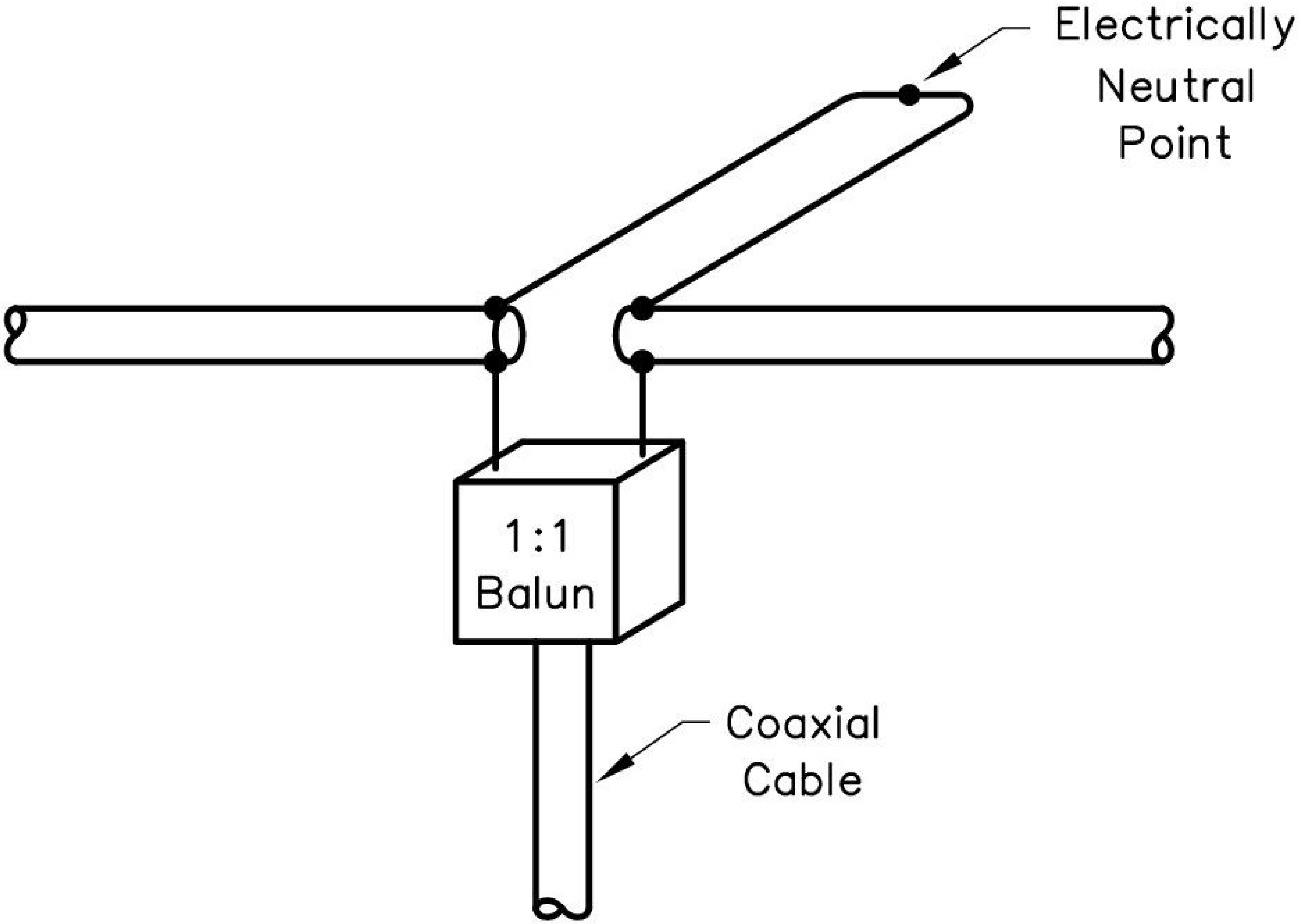
Gamma Matches can be used to match the impedance at the base of a grounded tower to be used as a vertical antenna.

Question E9E09: Which of these matching systems is an effective method of connecting a 50 ohm coaxial cable feed line to a grounded tower so it can be used as a vertical antenna?
Answer: Gamma match.

CHAPTER 9 – ANTENNAS AND FEED LINES

THE HAIRPIN MATCH (page 9-30)

The Hairpin Match is also referred to as a Beta Match. The center point of the hairpin is electrically neutral and is often attached to an antenna's metal boom for mechanical stability.



To use the Hairpin Match, the driven element must be split in the middle and insulated from its supporting structure. The driven element is tuned so it has a capacitive reactance at the desired operating frequency.

Question E9E05: How must the driven element in a 3-element Yagi be tuned to use a hairpin matching system?
Answer: The driven element reactance must be capacitive.

The Hairpin is an inductor that is placed in shunt, parallel, with the antenna – shunt inductor.

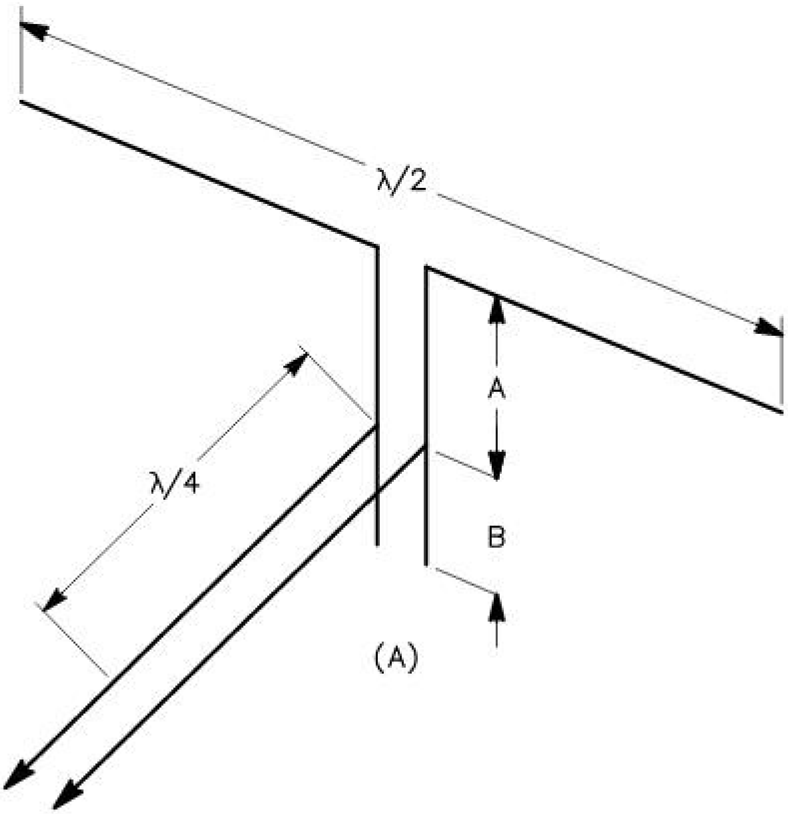
Question E9E06: What is the equivalent lumped-constant network for a hairpin matching system of a 3-element Yagi?
Answer: A shunt inductor.

THE STUB MATCH (page 9-31)

In some cases, it is possible to match a transmission line and antenna by connecting an appropriate reactance in parallel with them at the antenna feed point. Reactance formed from sections of transmission line are called Matching Stubs. Those stubs are designated either as open or closed, depending on whether the free end is open or short circuit.

Using a stub in this way is called a Stub Match.

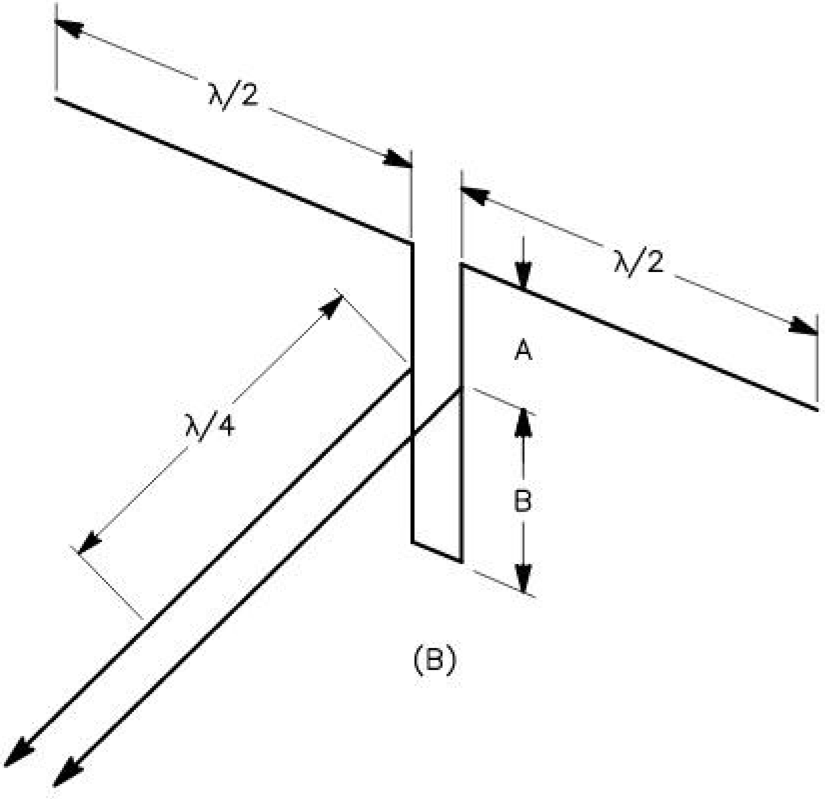
Question E9E03: What is the name of the matching system that uses a section of transmission line connected in parallel with the feed line at or near the feed point?
Answer: The stub match.



(A)

An impedance match can be obtained by connecting the feed line at an appropriate point along the matching stub. This Universal Stub is used mostly at VHF and Higher frequencies. This allows a feed line and antenna impedance to be matched, even if both impedances are unknown.

Question E9E11: What is an effective way of matching a feed line to a VHF or UHF antenna when the impedances of both the antenna and feed line are unknown?
Answer: Use the universal stub matching technique.



(B)

CHAPTER 9 – ANTENNAS AND FEED LINES

9.4 TRANSMISSION LINES (page 9-31)

WAVELENGTH IN A FEED LINE (page 9-31)

VELOCITY OF PROPAGATION (page 9-32)

$$\text{VF} = \text{Velocity Factor} = \frac{\text{Speed of Wave in a Transmission Line}}{\text{Speed of Light in a Vacuum}}$$

Question E9F02: Which of the following determines the velocity factor of a transmission line?
Answer: Dielectric materials used in the line.

Question E9F01: What is the velocity factor of a transmission line?
Answer: The velocity of the wave in the transmission line divided by the velocity of light in a vacuum.

Question E9F08: What is the term for the ratio of the actual speed at which a signal travels through a transmission line to the speed of light in a vacuum?
Answer: Velocity factor.

See Table 9.1 on page 9-33. VF of solid polyethylene = 66% = 0.66

Question E9F04: What is the typical velocity factor for a coaxial cable with solid polyethylene dielectric?
Answer: 0.66.

ELECTRICAL LENGTH (OF A TRANSMISSION LINE) (page 9-32)

Measured in wavelengths, the physical length of a transmission line is shorter than its electrical length.

LENGTH IN METERS = VF * WAVELENGTH
(in a transmission line) (in free space)

Question E9F03: Why is the physical length of a coaxial cable transmission line shorter than its electrical length?
Answer: Electrical signals move more slowly in a coaxial cable than in air.

Given: coax is RG-8 the VF is 0.66, 14.1 MHz, 1/4 Wavelength

Coax Length = VF * (300/frequency) * ¼ = 0.66 * (300/14.1) * ¼ = 3.52 meters

Question E9F05: What is the approximate physical length of a solid polyethylene dielectric coaxial transmission line that is electrically one-quarter wavelength long at 14.1 MHz?
Answer: 3.5 meters.

CHAPTER 9 – ANTENNAS AND FEED LINES

Given: coax is RG-8 the VF is 0.66, 7.2 MHz, 1/.4 Wavelength

Coax Length = VF * (300/frequency) * ¼ = 0.66 * (300/7.2) * ¼ = 6.9 meters

Question E9F09: What is the approximate physical length of a solid polyethylene dielectric coaxial transmission line that is electrically one-quarter wavelength long at 7.2 MHz?
Answer: 6.9 meters.

From table 9.1 on page 9-33. VF of Open Wire Transmission Line = 95% = 0.95.

Given: transmission line is “Parallel Conductors” the VF is 0.95, 14.1 MHz, 1/.2 Wavelength

Coax Length = VF * (300/frequency) * ½ = 0.95 * (300/14.1) * ½ = 10 meters

Question E9F06: What is the approximate physical length of an air-insulated, parallel conductor transmission line that is electrically one-half wavelength long at 14.10 MHz?
Answer: 10 meters.

FEED LINE LOSS (page 9-34)

From table 9.1 on page 9-33. The table shows a loss in dB per 100 feet at 100 MHz.

Ladder line has less loss at any frequency.

Question E9F07: How does ladder line compare to small-diameter coaxial cable such as RG-58 at 50 MHz?
Answer: Lower Loss.

Question E9F16: Which of the following is a significant difference between foam dielectric coaxial cable and solid dielectric cable, assuming all other parameters are the same?
Answer: Foam dielectric has lower safe operating voltage limits, Foam dielectric has lower loss per unit of length, Foam dielectric has higher velocity factor.

REFLECTION COEFFICIENT AND SWR (page 9-34)

$$\text{Voltage Reflection Coefficient} = \frac{\text{Reflected Voltage}}{\text{Incident Voltage}} \quad \text{or} \quad \frac{\text{Reflected Current}}{\text{Incident Current}}$$

The reflection coefficient is a good parameter to describe the interactions at the load end of a mismatched transmission line.

Question E9E07: What term best describes the interactions at the load end of a mismatched transmission line?
Answer: Reflection coefficient.

(SWR) (page 9-34)

Question E9E08: Which of the following measurements is characteristic of a mismatched transmission line?
Answer: An SWR greater than 1:1.

CHAPTER 9 – ANTENNAS AND FEED LINES

POWER MEASUREMENT (page 9-35)

Question E4B06: How much power is being absorbed by the load when a directional power meter connected between a transmitter and a terminating load reads 100 watts forward power and 25 watts reflected power?
Answer: 75 Watts.

Questions E4B09, What is indicated if the current reading on an RF ammeter placed in series with the antenna feed line of a transmitter increases as the transmitter is tuned to resonance?
Answer: There is more power going into the antenna.

SMITH CHART (page 9-36)

SMITH CHART CONSTRUCTION (page 9-36)

Question E9G01: Which of the following can be calculated using a Smith chart?
Answer: Impedance along transmission lines.

Question E9G02: What type of coordinate system is used in a Smith chart?
Answer: Resistance circles and reactance arcs.

Question E9G03: Which of the following is often determined using a Smith chart?
Answer: Impedance and SWR values in transmission lines.

Question E9G04: are the two families of circles and arcs that make up a Smith chart?
Answer: Resistance and reactance.

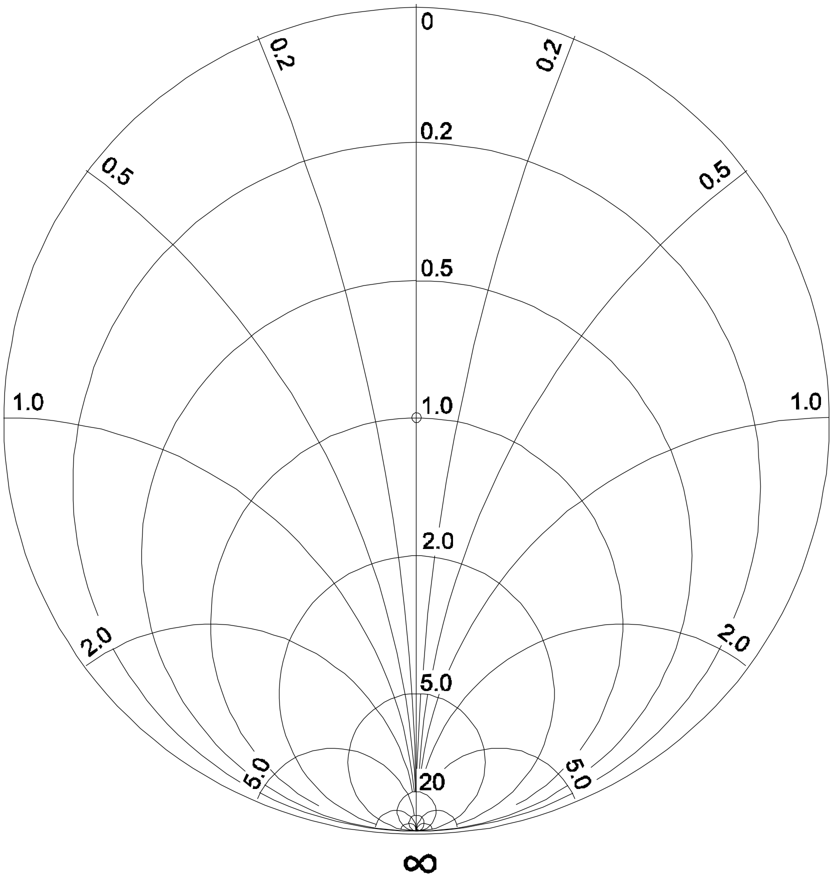
Question E9G05: What type of chart is shown in Figure E9-3?
Answer: Smith chart.

Question E9G06: On the Smith chart shown in Figure E9-3, what is the name for the large outer circle on which the reactance arcs terminate?
Answer: Reactance axis.

Question E9G07: On the Smith chart shown in Figure E9-3, what is the only straight line shown?
Answer: The resistance axis.

Question E9G10: What do the arcs on a Smith chart represent?
Answer: Points with constant reactance.

Figure E9-3



CHAPTER 9 – ANTENNAS AND FEED LINES

NORMALIZATION (page 9-37)

Question E9G08: What is the process of normalization with regard to a Smith chart?
Answer: Reassigning impedance values with regard to the prime center.

CONSTANT-SWR CIRCLES (page 9-37)

Question E9G09: What third family of circles is often added to a Smith chart during the process of solving problems?
Answer: Standing wave ratio circles.

WAVELENGTH SCALES (page 9-39)

Question E9G11: How are the wavelength scales on a Smith chart calibrated?
Answer: In fractions of transmission line electrical wavelength.

TRANSMISSION LINE STUBS AND TRANSFORMERS (page 9-39)

(TRANSMISSION LINE STUBS) (page 9-39)

Rule 1: Every 1/2 wavelength (1/2. 1. 1-1/2, 2) along the transmission line the impedance repeats.

Rule 2: When a transmission line is odd 1/4 wavelengths long (1/4, 3/4, 1-1/4, 1-3/4, etc) the impedance at one end is inverted from that at the other end.

Rule 3: A very short open circuit transmission line appears as an open circuit.

Rule 4: A 1/8 wavelength open circuit transmission line appears as a ***capacitor*** (capacitive reactance) because of the two parallel wires.

Rule 5: A very short shorted circuit transmission line appears as short-circuit.

Rule 6: A 1/8 wavelength shorted circuit transmission line appears as an ***inductor*** inductive reactance) because of the continuous wires.

Question E9F10: What impedance does a 1/8 wavelength transmission line present to a generator when the line is ***shorted*** at the far end?
Answer: It appears as an inductive reactance – see rule 6.

Question E9F11: What impedance does a 1/8 wavelength transmission line present to a generator when the line is ***open (not shorted)*** at the far end?
Answer: It appears as a capacitive reactance – see rule 4.

Question E9F12: What impedance does a 1/4 wavelength transmission line present to a generator when the line is ***open (not shorted)*** at the far end?
Answer: It appears as a very low impedance (shorted, not open) – see rule 2.

Question E9F13: What impedance does a 1/4 wavelength transmission line present to a generator when the line is ***shorted*** at the far end?
Answer: It appears as a very high impedance (not shorted, open) – see rule 2.

CHAPTER 9 – ANTENNAS AND FEED LINES

Question E9F14: What impedance does a 1/2 wavelength transmission line present to a generator when the line is ***shorted*** at the far end?
Answer: It appears as a very low impedance (shorted, not open) – see rule 1.

Question E9F15: What impedance does a 1/4 wavelength transmission line present to a generator when the line is ***open (not shorted)*** at the far end?
Answer: It appears as a very high impedance (not shorted, open) – see rule 1.

SYNCHRONOUS TRANSFORMERS (page 9-40)

You match the impedance between an antenna and a transmission line by placing a different transmission line, of 1/4 wavelength, of a different impedance, in series between the antenna and the primary transmission line.

The book says:

$$Z_1 = \text{square root of } (Z_0 \times Z_{\text{load}})$$

The book means:

$$Z_{\text{Characteristic Impedance}} = \text{square root of } (Z_{\text{Line Impedance}} \times Z_{\text{Load Impedance}})$$

Question E9E10: Which of these choices is an effective way to match an antenna with a 100 ohm feed point impedance to a 50 ohm coaxial cable feed line?
Answer: Insert a 1/4-wavelength piece of 75 ohm coaxial cable transmission line in series between the antenna terminals and the 50 ohm feed cable.

$$Z_1 = \text{square root of } (Z_0 \times Z_{\text{load}}) = \text{square root of } (50 \times 100) = \text{square root of } (5000) = 70.71$$

(75 ohm cable is the closest match to 71 ohms)

SCATTERING (S) PARAMETERS (pages 9-94)

I really do not know anything about this stuff. I know that if you have an electrical circuit, either simple or complex, it can have ports: one port, two ports, three ports, etc. Here we are discussing two port systems like a transmission line with a port going out (responding port) and a port going in (incident port.) Each port has an input called “a” and an output called “b”. The “S” parameter is defined as $S_{(\text{Output})(\text{Input})}$.or $S_{(\text{Responding})(\text{Incident})}$. Thus S_{11} refers to the ratio of the amplitude of the signal that reflects from port one to the amplitude of the signal incident on port one. When both numbers are the same the “S” values are referred to as reflection coefficients because they only refer to what happens at a single port. These reflection coefficients can be plotted on a Smith Chart. While for different numbers “S” values are referred to as transmission coefficients, because they refer to what happens at one port when it is excited by a signal incident at another port. The “S” values may be complex numbers.

Let’s just simply look at the definitions.

Rule 1: S11 = b1/a1 = is the input port voltage reflection coefficient.

Rule 2: S12 = b1/a2 = is the reverse voltage gain.

Rule 3: S21 = b2/a1 = is the forward voltage gain.

Rule 4: S22 = b2/a2 = is the output voltage reflection coefficient.

CHAPTER 9 – ANTENNAS AND FEED LINES

Question E4B07: What do the subscripts of S parameters represent?
Answer: The port or ports at which measurements are made.

Question E4B13: Which S parameter is equivalent to forward gain?
Answer S21 – rule 3.

ANTENNA AND NETWORK ANALYZERS (page 9-42)

I assume that everyone is familiar with antenna analyzers like the very portable hand held Rig Expert analyzer. They provide their own RF energy and are connected directly to the device being tested.

If you are lucky you have access to a Network Analyzer. To calibrate on you need to connect across the test port an short, a open and 50 ohms.

Question E4A08: Which of the following instruments would be best for measuring the SWR of a beam antenna?
Answer: An antenna analyzer.

Question E4B11: How should an antenna analyzer be connected when measuring antenna resonance and feed point impedance?
Answer: Connect the antenna feed line directly to the analyzer's connector.

Question E4A07: Which of the following is an advantage of using an antenna analyzer compared to an SWR bridge to measure antenna SWR?
Answer: Antenna analyzers do not need an external RF source.

Question: E4B17: What three test loads are used to calibrate a standard RF vector network analyzer?
Answer: Short circuit, open circuit, and 50 ohms.

9.5 ANTENNA DESIGN (page 9-43)

ANTENNA MODELING AND DESIGN (page 9-43)

There are a number of programs in common use for antenna analysis. Most of them are derived from a program developed at US government laboratories, called NEC, short for Numerical Electromagnetic Code.

Question E9B13: What does the abbreviation NEC stand for when applied to antenna modeling programs?
Answer: Numerical Electromagnetic Code.

This complex program uses a modeling technique called the Method of Moments.

Question E9B09: What type of computer program technique is commonly used for modeling antennas?
Answer: Method of Moments.

In the method of moments, the antenna wires (or tubing elements) are modeled as a series of segments and a uniform value of current in each segment is computed.

Question E9B10: What is the principle of a Method of Moments analysis?
Answer: A wire is modeled as a series of segments, each having a uniform value of current.

A lower number of segments will reduce the time for model calculations but the outputs, such as pattern shape or feed point impedance, will not be as accurate.

Question E9B11: What is a disadvantage of decreasing the number of wire segments in an antenna model below the guideline of 10 segments per half-wavelength?
Answer: The computed feed point impedance may be incorrect.

The programs compute, at a minimum, antenna gain, beamwidth, all the pattern ratios, feed point impedance, and SWR versus frequency 'sweep' graphs.

Question E9B14: What type of information can be obtained by submitting the details of a proposed new antenna to a modeling program?
Answer: A. SWR vs frequency charts B. Polar plots of the far field elevation and azimuth patterns
C. Antenna gain D. All of these choices are correct.

DESIGN TRADEOFFS AND OPTIMIZATION (page 9-44)

You should evaluate an antenna across the entire frequency band for which it is designed You may discover that gain may change as you move away from its design frequency.

Question E9B04: What may occur when a directional antenna is operated at different frequencies within the band for which it was designed?
Answer: The gain may change depending on frequency.

You may decide to optimize a Yagi antenna for maximum forward gain, but in that case the front-to-back ratio usually decreases, feed point impedance becomes very low, and the SWR bandwidth will decrease.

Question E9D13: What usually occurs if a Yagi antenna is designed solely for maximum forward gain?
Answer: The front-to-back ratio decreases.