Technician License Course
Chapter 4

Lesson Plan Module 9 – Antenna Fundamentals, Feed Lines & SWR

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The Antenna System

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

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The Antenna (Some Vocabulary)

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

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The Antenna (Some Vocabulary)

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

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Electromagnetic Waves

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

Wave Polarization

- Orientation of the wave's electric field component with respect to the surface of the Earth
  - *Vertical* or *horizontal* – determined by elements
  - Can be *circular* if the orientation twists as the wave spreads through space
  - Combinations of polarization are called *elliptical* polarization

Cross-Polarization

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

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The Decibel (dB)

- A ratio expressed as an power of 10 to make large numbers easier to work with.
  - dB = 10 log (power ratio)
  - dB = 20 log (voltage ratio)
- Positive values in dB indicate ratios > 1 and negative values of dB are for ratios < 1.
- Antenna gain is discussed in terms of dB.

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The Antenna (Some Vocabulary)

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

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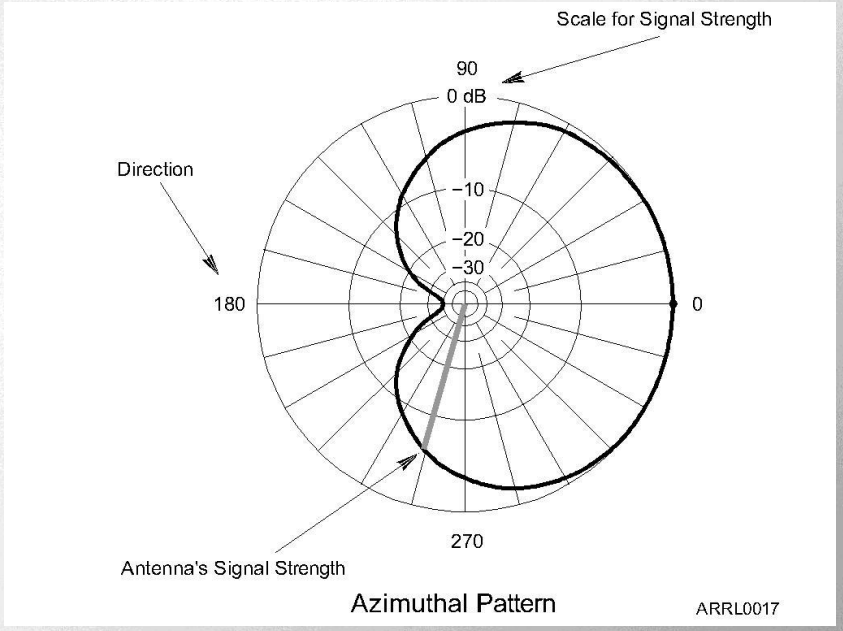
Antenna Radiation Patterns

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



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Radiation Pattern Vocabulary

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

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Radiation Pattern Vocabulary

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

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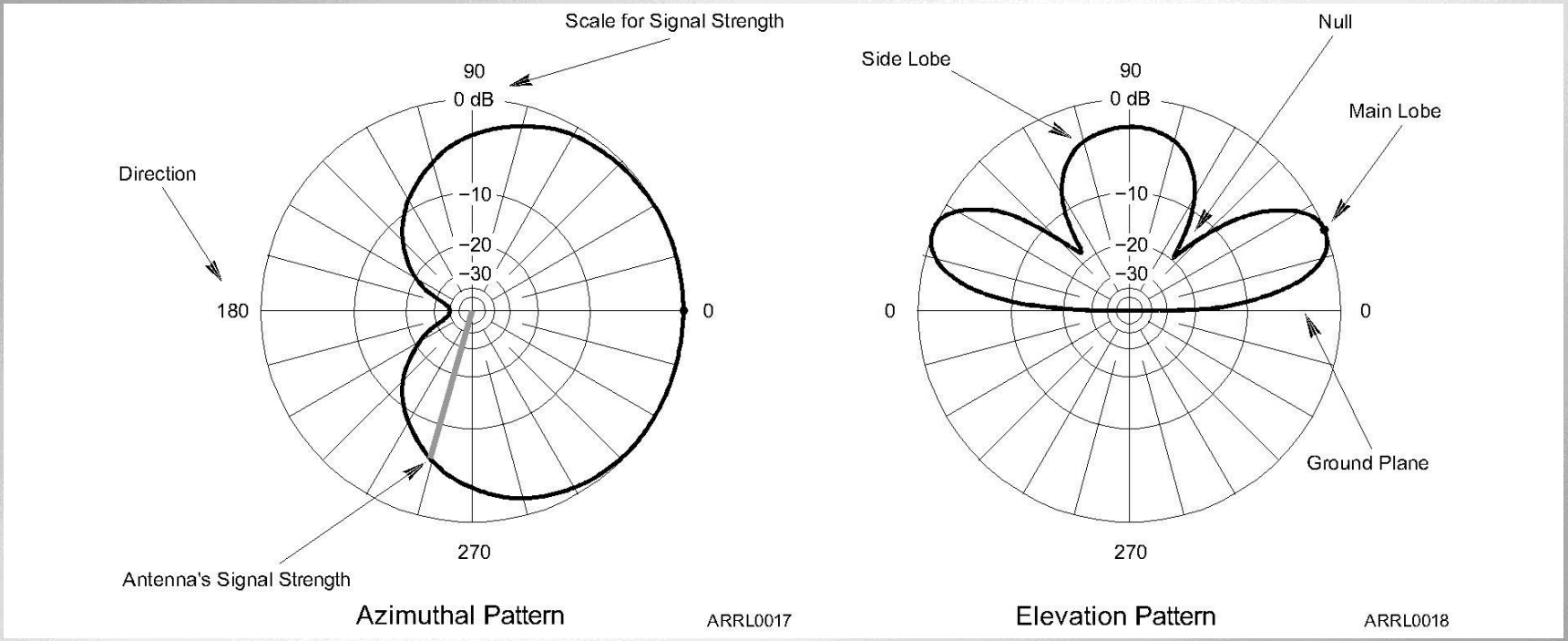
Azimuth Pattern

Elevation Pattern



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Radiation Pattern Vocabulary

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

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Feed Lines

- The purpose of the feed line is to get RF power from your station to the antenna.
- Basic feed line types
  - *Coaxial cable* (coax)
  - *Open-wire line* (OWL) also called ladder line or window line
- Power lost as heat in the feed line is called *loss* and it increases with frequency.

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Feed Line Vocabulary

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

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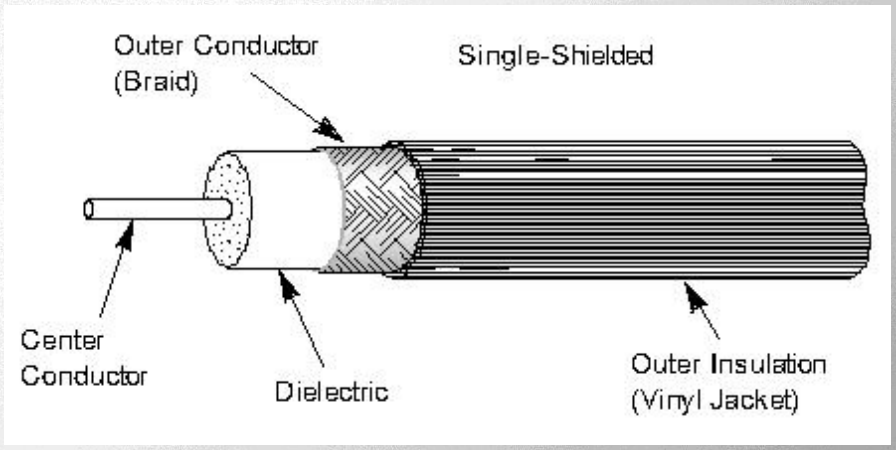
Coaxial Cable

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



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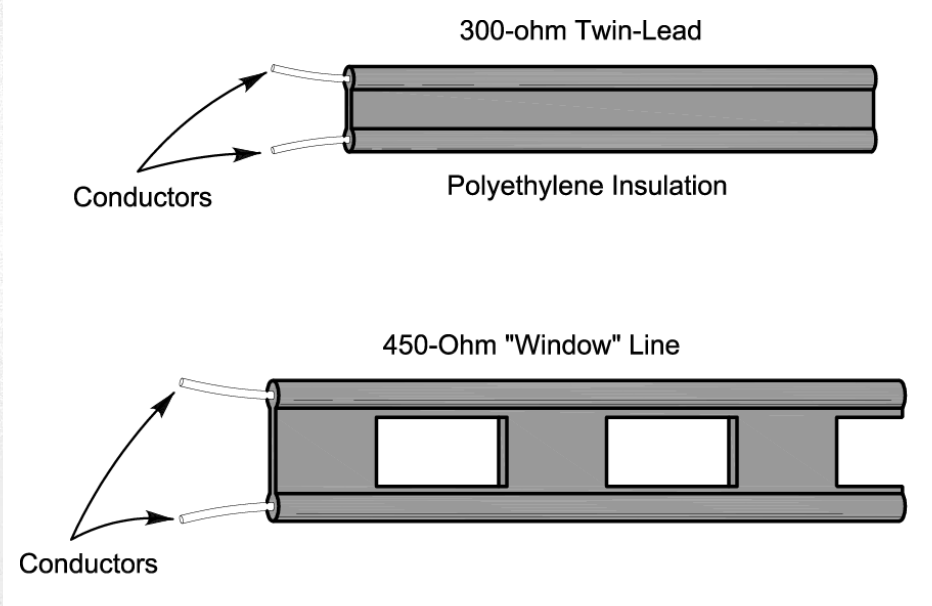
Open-Wire Line

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



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Characteristic Impedance

- The impedance presented to a wave traveling through a feed line
- Given in ohms (Ω), symbolized as Z_0
- Depends on how the feed line is constructed and what materials are used
  - Coax: 50 and 75 Ω
  - OWL: 300, 450, and 600 Ω

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Standing Wave Ratio (SWR)

- If the antenna feed point and feed line impedances are not identical, some RF power is reflected back toward the transmitter.
  - Called a *mismatch*
  - Forward and reflected waves create a pattern of *standing waves* of voltage and current in the line
  - SWR is the ratio of standing wave max to min
- Measured with an *SWR meter* or *SWR bridge*.

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Standing Wave Ratio (SWR)

- Reflected power is re-reflected at the transmitter and bounces back and forth.
  - Some RF power is lost as heat on each trip back and forth through the feed line
  - All RF power is eventually lost as heat or transferred to the antenna or load
- High SWR means more reflections and more loss of RF power (less transferred to the antenna or load).

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Nothing Is Perfect

- SWR equals the ratio of feed point (or *load*) and feed line impedance, whichever is greater than 1 (SWR always greater than 1:1).
- What is an acceptable SWR?
  - 1:1 SWR is perfect – no power reflected
  - Up to 2:1 SWR is normal
  - Modern radios lower transmitter output power for protection when SWR is above 2:1

Nothing Is Perfect

- SWR above 3:1 is considered high in most cases.
- Erratic SWR readings may indicate a faulty feed line, faulty feed line connectors, or a faulty antenna.
- High SWR can be corrected by
  - Tuning or adjusting the antenna or
  - With impedance matching equipment at the transmitter
    - Called an *antenna tuner* or *transmatch*
    - Does not change SWR in the feed line

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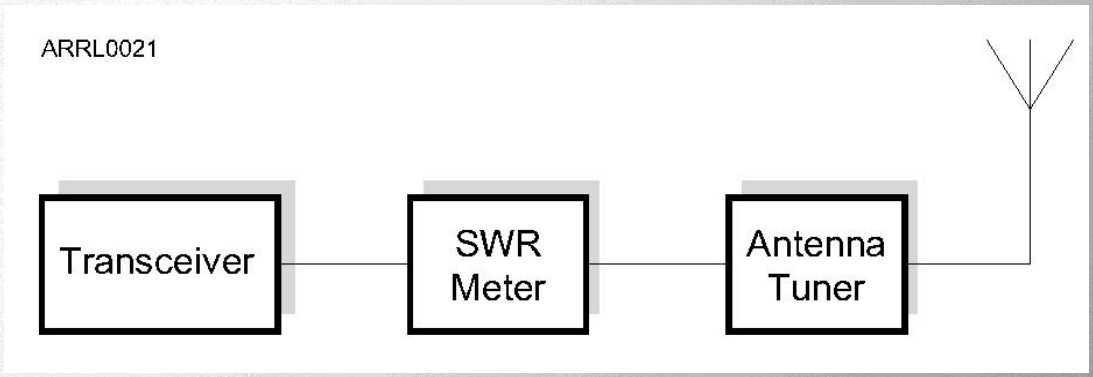
Adjusting SWR

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



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Dummy Loads

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

Practice Questions

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

A. The modulation sidebands might become inverted

B. Signals could be significantly weaker

C. Signals have an echo effect on voices

D. Nothing significant will happen

T3A04 HRLM (4-6)

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T3A04 HRLM (4-6)

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What type of wave carries radio signals between transmitting and receiving stations?

A. Electromagnetic

B. Electrostatic

C. Surface acoustic

D. Magnetostrictive

T3A07 HRLM (4-6)

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T3A07 HRLM (4-6)

Which of the following is a common effect of "skip" reflections between the Earth and the ionosphere?

A. The sidebands become reversed at each reflection

B. The polarization of the original signal is randomized

C. The apparent frequency of the received signal is shifted by a random amount

D. Signals at frequencies above 30 MHz become stronger with each reflection

T3A09 HRLM (4-6)

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T3A09 HRLM (4-6)

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What property of a radio wave is used to describe its polarization?

A. The orientation of the electric field

B. The orientation of the magnetic field

C. The ratio of the energy in magnetic field to the energy in the electric field

D. The ratio of the velocity to the wavelength

T3B02 HRLM (4-6)

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T3B02 HRLM (4-6)

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What are the two components of a radio wave?

A. AC and DC

B. Voltage and current

C. Electric and magnetic fields

D. Ionizing and non-ionizing radiation

T3B03 HRLM (4-6)

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T3B03 HRLM (4-6)

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What is the approximate amount of change, measured in decibels (dB), of a power increase from 5 watts to 10 watts?

A. 2 dB

B. 3 dB

C. 5 dB

D. 10 dB

T5B09 HRLM (4-7)

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C. 5 dB

D. 10 dB

T5B09 HRLM (4-7)

What is the approximate amount of change, measured in decibels (dB), of a power decrease from 12 watts to 3 watts?

A. -1 dB

B. -3 dB

C. -6 dB

D. -9 dB

T5B10 HRLM (4-7)

What is the approximate amount of change, measured in decibels (dB), of a power decrease from 12 watts to 3 watts?

A. -1 dB

B. -3 dB

C. -6 dB

D. -9 dB

T5B10 HRLM (4-7)

What is the approximate amount of change, measured in decibels (dB), of a power increase from 20 watts to 200 watts?

A. 10 dB

B. 12 dB

C. 18 dB

D. 28 dB

T5B11 HRLM (4-7)

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D. 28 dB

T5B11 HRLM (4-7)

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What is a usual name for electromagnetic waves that travel through space?

A. Gravity waves

B. Sound waves

C. Radio waves

D. Pressure waves

T5C07 HRLM (4-6)

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T5C07 HRLM (4-6)

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What is the primary purpose of a dummy load?

A. To prevent the radiation of signals when making tests

B. To prevent over-modulation of your transmitter

C. To improve the radiation from your antenna

D. To improve the signal to noise ratio of your receiver

T7C01 HRLM (5-4)

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T7C01 HRLM (5-4)

ARRL The national association for AMATEUR RADIO

What, in general terms, is standing wave ratio (SWR)?

A. A measure of how well a load is matched to a transmission line

B. The ratio of high to low impedance in a feed line

C. The transmitter efficiency ratio

D. An indication of the quality of your station's ground connection

T7C03 HRLM (4-10)

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T7C03 HRLM (4-10)

ARRL The national association for AMATEUR RADIO

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

A. 2 to 1

B. 1 to 3

C. 1 to 1

D. 10 to 1

T7C04 HRLM (4-10)

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C. 1 to 1

D. 10 to 1

T7C04 HRLM (4-10)

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What is the approximate SWR value above which the protection circuits in most solid-state transmitters begin to reduce transmitter power?

A. 2 to 1

B. 1 to 2

C. 6 to 1

D. 10 to 1

T7C05 HRLM (4-10)

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B. 1 to 2

C. 6 to 1

D. 10 to 1

T7C05 HRLM (4-10)

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What does an SWR reading of 4:1 indicate?

A. Loss of -4 dB

B. Good impedance match

C. Gain of +4 dB

D. Impedance mismatch

T7C06 HRLM (4-10)

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T7C06 HRLM (4-10)

What happens to power lost in a feed line?

A. It increases the SWR

B. It comes back into your transmitter and could cause damage

C. It is converted into heat

D. It can cause distortion of your signal

T7C07 HRLM (4-8)

ARRL The national association for AMATEUR RADIO

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T7C07 HRLM (4-8)

Which of the following is a common use of coaxial cable?

A. Carrying dc power from a vehicle battery to a mobile radio

B. Carrying RF signals between a radio and antenna

C. Securing masts, tubing, and other cylindrical objects on towers

D. Connecting data signals from a TNC to a computer

T7C12 HRLM (4-9)

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T7C12 HRLM (4-9)

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What does a dummy load consist of?

A. A high-gain amplifier and a TR switch

B. A non-inductive resistor and a heat sink

C. A low voltage power supply and a DC relay

D. A 50 ohm reactance used to terminate transmission

T7C13 HRLM (4-9)

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T7C13 HRLM (4-9)

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Which of the following is true regarding vertical antennas?

A. The magnetic field is perpendicular to the Earth
B. The electric field is perpendicular to the Earth
C. The phase is inverted
D. The phase is reversed

T9A02 HRLM (4-6)

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T9A02 HRLM (4-6)

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What is meant by the gain of an antenna?

A. The additional power that is added to the transmitter power

B. The additional power that is lost in the antenna when transmitting on a higher frequency

C. The increase in signal strength in a specified direction when compared to a reference antenna

D. The increase in impedance on receive or transmit compared to a reference antenna

T9A11 HRLM (4-6)

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T9A11 HRLM (4-6)

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Why is it important to have a low SWR in an antenna system that uses coaxial cable feed line?

A. To reduce television interference

B. To allow the efficient transfer of power and reduce losses

C. To prolong antenna life

D. All of these choices are correct

T9B01 HRLM (4-10)

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T9B01 HRLM (4-10)

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What is the impedance of the most commonly used coaxial cable in typical amateur radio installations?

A. 8 ohms

B. 50 ohms

C. 600 ohms

D. 12 ohms

T9B02 HRLM (4-9)

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T9B02 HRLM (4-9)

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Why is coaxial cable used more often than any other feed line for amateur radio antenna systems?

A. It is easy to use and requires few special installation considerations

B. It has less loss than any other type of feed line

C. It can handle more power than any other type of feed line

D. It is less expensive than any other types of feed line

T9B03 HRLM (4-9)

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T9B03 HRLM (4-9)

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What generally happens as the frequency of a signal passing through coaxial cable is increased?

A. The apparent SWR increases
B. The reflected power increases
C. The characteristic impedance increases
D. The loss increases

T9B05 HRLM (4-8)

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T9B05 HRLM (4-8)

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What might cause erratic changes in SWR readings?

A. The transmitter is being modulated
B. A loose connection in an antenna or a feed line
C. The transmitter is being over-modulated
D. Interference from other stations is distorting your signal

T9B09 HRLM (4-10)

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T9B09 HRLM (4-10)

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

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

T9B11 HRLM (4-9)

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