

# Technician License Course

## Chapter 4

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



**ARRL**

*The national association for  
AMATEUR RADIO*

# 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.



**ARRL** The national association for  
AMATEUR RADIO



# 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.



**ARRL** The national association for  
AMATEUR RADIO

# 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.



**ARRL** The national association for  
AMATEUR RADIO



# 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



**ARRL** *The national association for*  
**AMATEUR RADIO**

# 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



**ARRL** The national association for  
AMATEUR RADIO



# 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.



**ARRL** The national association for  
AMATEUR RADIO

# The Decibel (dB)

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



**ARRL** The national association for  
AMATEUR RADIO



# The Antenna (Some Vocabulary)

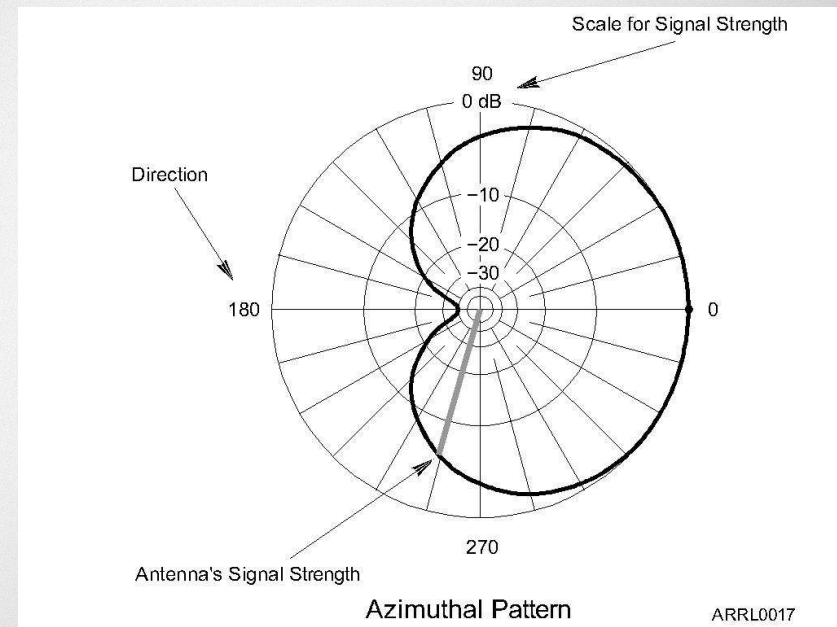
- **Gain:** Apparent increase in power in a particular direction by focusing radiation in that direction. Measured in decibels (dB).
- **Isotropic:** Equal radiation in all directions.
- **Omnidirectional:** No preferred horizontal direction.
- **Directional:** Antenna that focuses radiation in specific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



**ARRL** The national association for  
AMATEUR RADIO

# 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.



**ARRL** The national association for  
AMATEUR RADIO



# 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



**ARRL** The national association for  
AMATEUR RADIO

# Radiation Pattern Vocabulary

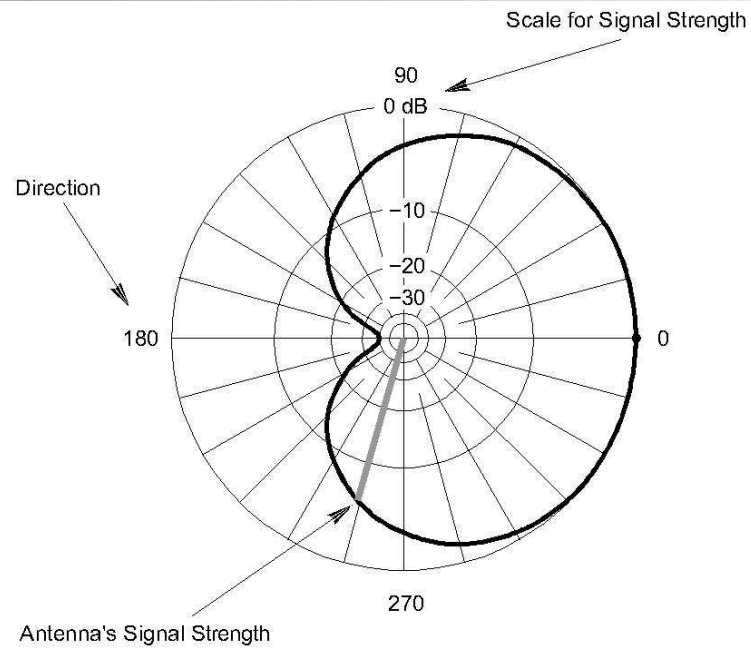
- **Azimuth pattern:** Radiation pattern showing gain in all horizontal directions around the antenna.
- **Elevation pattern:** Radiation pattern showing gain at all vertical angles from the antenna.
  - Often restricted to angles above horizontal



**ARRL** The national association for  
AMATEUR RADIO



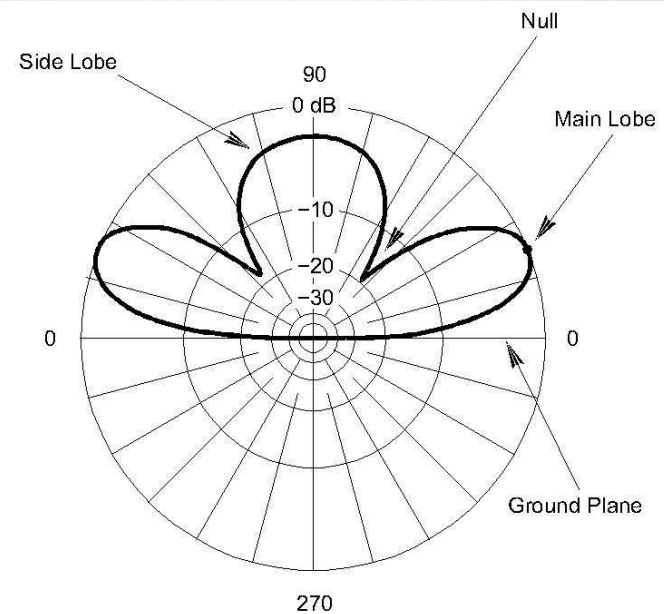
# Azimuth Pattern



Azimuthal Pattern

ARRL0017

# Elevation Pattern



Elevation Pattern

ARRL0018



**ARRL** The national association for  
AMATEUR RADIO

# Radiation Pattern Vocabulary

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



# Feed Lines

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



**ARRL** The national association for  
AMATEUR RADIO

# 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

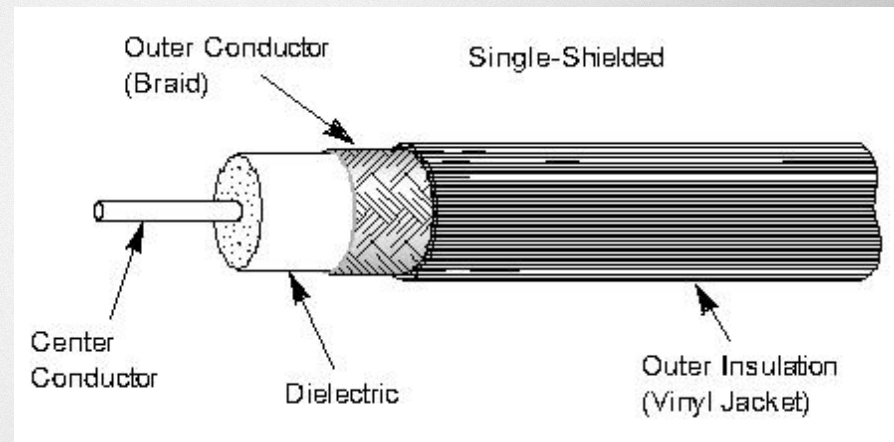


**ARRL** The national association for  
AMATEUR RADIO



# Coaxial Cable

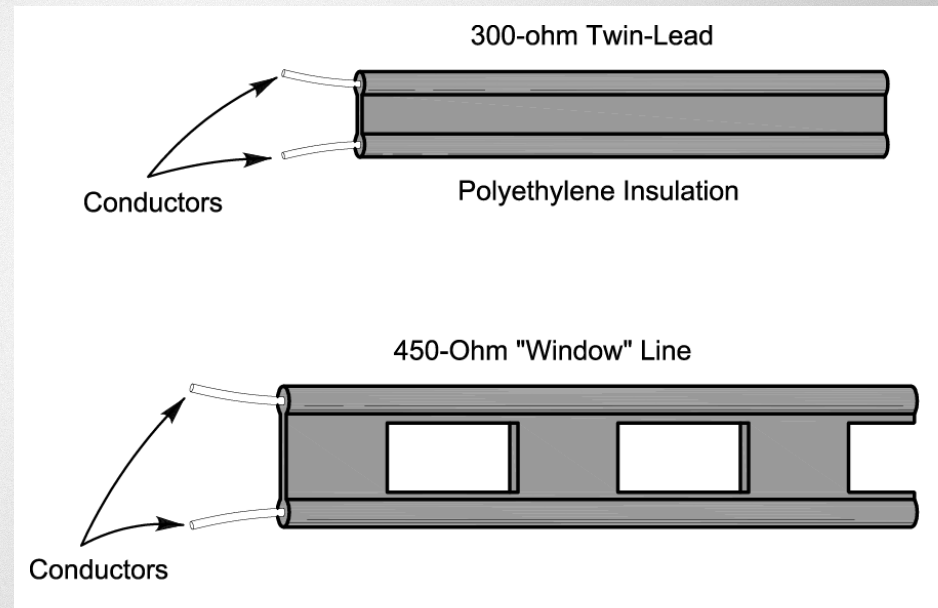
- Most common feed line
- Easy to use
- Not affected by nearby materials
- Has higher loss than open-wire line at most frequencies
- Air-insulated “hard line” has lowest loss



**ARRL** The national association for  
AMATEUR RADIO

# 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



**ARRL** The national association for  
AMATEUR RADIO



# Characteristic Impedance

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



**ARRL** The national association for  
AMATEUR RADIO

# 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*.



**ARRL** The national association for  
AMATEUR RADIO



# 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).



**ARRL** The national association for  
AMATEUR RADIO

# 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



**ARRL** The national association for  
AMATEUR RADIO



# 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

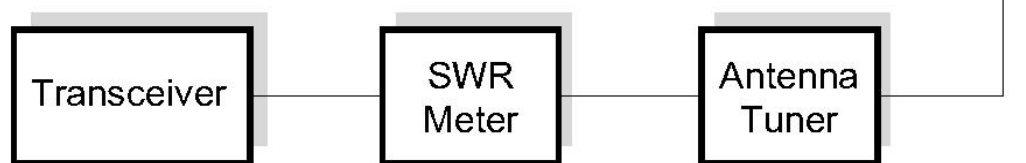


**ARRL** The national association for  
AMATEUR RADIO

# 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.

ARRL0021



**ARRL** The national association for  
AMATEUR RADIO



# 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



**ARRL** The national association for  
AMATEUR RADIO

# Practice Questions



**ARRL** *The national association for*  
**AMATEUR RADIO**

2014 Technician License Course



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)



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)



**ARRL** *The national association for*  
**AMATEUR RADIO**



# 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)



**ARRL** *The national association for  
AMATEUR RADIO*

# 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)





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)



**ARRL** The national association for  
AMATEUR RADIO

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)



**ARRL** The national association for  
AMATEUR RADIO



# 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)



**ARRL** The national association for  
AMATEUR RADIO

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)



**ARRL** *The national association for  
AMATEUR RADIO*



# 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)



**ARRL** *The national association for*  
**AMATEUR RADIO**

# 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)





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)



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)





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)



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)





# 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)



**ARRL** *The national association for*  
**AMATEUR RADIO**

# 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)



**ARRL** *The national association for*  
**AMATEUR RADIO**



# 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)



# 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)





# 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)



# 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)





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)



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)



**ARRL** *The national association for*  
**AMATEUR RADIO**



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)



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)





# 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)



**ARRL** *The national association for  
AMATEUR RADIO*

# 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)





# 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)



# 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*



# 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)



**ARRL** *The national association for  
AMATEUR RADIO*

# 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)



**ARRL** *The national association for*  
**AMATEUR RADIO**



# 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)



**ARRL** *The national association for  
AMATEUR RADIO*

# 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)



**ARRL** *The national association for*  
**AMATEUR RADIO**



# 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)



**ARRL** *The national association for*  
**AMATEUR RADIO**

# 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)



**ARRL** *The national association for*  
**AMATEUR RADIO**



# 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)



# 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)



**ARRL** *The national association for*  
**AMATEUR RADIO**



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)



**ARRL** *The national association for  
AMATEUR RADIO*

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)



**ARRL** *The national association for  
AMATEUR RADIO*



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)



**ARRL** *The national association for  
AMATEUR RADIO*

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)





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)



**ARRL** *The national association for  
AMATEUR RADIO*

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)





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)



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)



**ARRL** *The national association for  
AMATEUR RADIO*



# 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)



**ARRL** *The national association for  
AMATEUR RADIO*

# 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)





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)



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)

