Technician License Class

1

Technician Class

Chapter 4

Propagation, Antennas and Feed Lines

2

Propagation

Radio Waves.

- Radio Waves travel in straight lines.
  - Except:
    - Reflection.
      - Bouncing off reflective surface.
    - Refraction.
      - Gradual bending while traveling through atmosphere.
    - Diffraction.
      - Bending around edge of solid object.

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Propagation

Radio Waves.

- Line-of-sight.
  - Radio horizon.
    - The distance at which radio signals are blocked by curvature of the earth.
    - Slightly greater than optical horizon.
      - Refraction increases the radio horizon by about 15%.
      - Refraction causes the Earth to appear to the radio wave to be “less curved” or flatter than it actually is.

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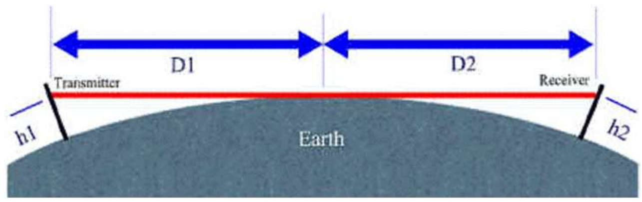
Propagation

Radio Waves.

- Line-of-sight.
  - Radio horizon.



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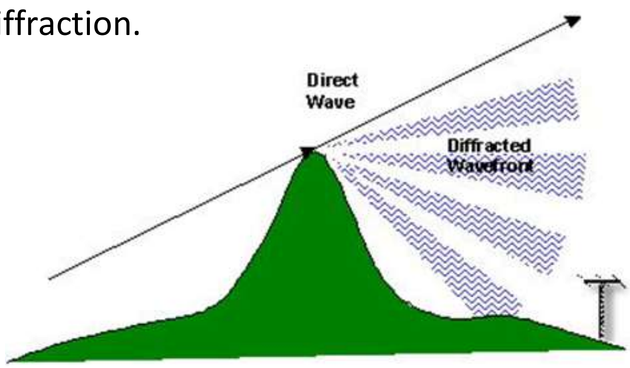
Propagation

Radio Waves.

- Diffraction.



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Propagation

Radio Waves.

- Multi-Path.
  - Radio waves reflected off of many objects arrive at receive antenna at different times.
  - Radio waves can take several different paths through the ionosphere and arrive at receive antenna at different times.

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Propagation

Radio Waves.

- Multi-Path.
  - If radio waves from the different paths arrive in phase, they will add and make the received signal stronger.
  - If radio waves from the different paths arrive out of phase, they will subtract and make the received signal weaker.
  - Since wavelengths at VHF or UHF frequencies are relatively short, you do not have to move more than a few feet or inches to change the signal strength.

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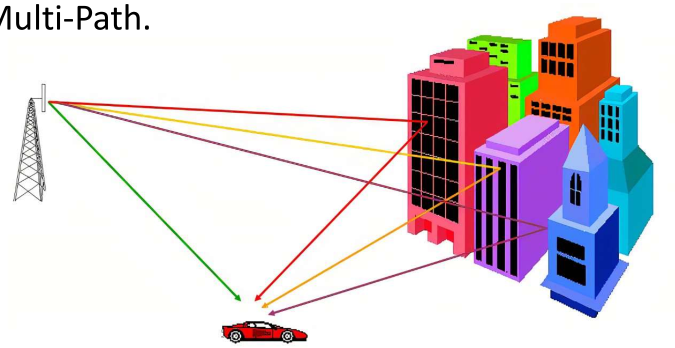
Propagation

Radio Waves.

- Multi-Path.



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Propagation

Radio Waves.

- Multi-Path.
  - If the transmitter and/or receiver are moving multi-path can cause rapid signal fading known as “picket fencing”.
  - Multi-path can cause error rates to increase on data signals.

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Propagation

Radio Waves.

- VHF & UHF radio waves are affected by obstructions in the path.
  - Buildings can block radio waves.
    - Radio waves can pass through openings in solid objects such as buildings.
      - Longest dimension of opening at least 1/2λ.
        - Because of their shorter wavelength, UHF signals can pass through buildings better than VHF signals.

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Propagation

Radio Waves.

- VHF & UHF radio waves are affected by obstructions in the path.
  - Foliage.
    - Absorbs radio waves and decreases signal strength.
    - The higher the frequency, the higher the absorption.

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Propagation

Radio Waves.

- VHF & UHF radio waves are affected by obstructions in the path.
  - Rain, fog.
    - Absorb radio waves and decrease signal strength of UHF and microwave signals.
      - Little effect on VHF and lower frequencies.

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Propagation

Radio Waves.

- Tropospheric Ducting
  - a.k.a. – Tropospheric Scatter
  - Radio waves can travel for long distances along the boundaries of different temperature air layers.
    - Caused by a temperature inversion in the atmosphere.
  - Allows propagation of 300 miles or more on VHF or UHF.

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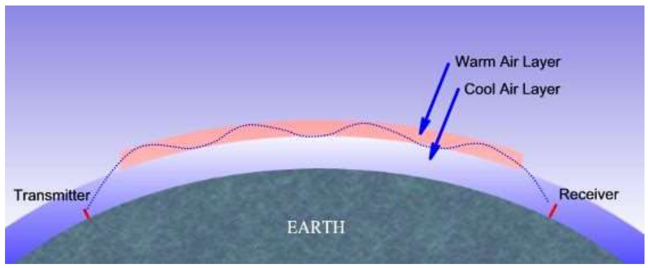
Propagation

Radio Waves.

- Tropospheric Ducting



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T3A01 -- Why do VHF signal strengths sometimes vary greatly when the antenna is moved only a few feet?

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

16

T3A02 -- What is the effect of vegetation on UHF and microwave signals?

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

17

T3A06 -- What is the meaning of the term "picket fencing"?

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

18

T3A07 -- What weather condition might decrease range at microwave frequencies?

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

19

T3A08 -- What is a likely cause of irregular fading of signals propagated by the ionosphere?

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

20

T3A10 -- What effect does multi-path propagation have on data transmissions?

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

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

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

➡ D. Error rates are likely to increase

21

T3A12 -- What is the effect of fog and rain on signals in the 10 meter and 6 meter bands?

A. Absorption

➡ B. There is little effect

C. Deflection

D. Range increase

22

T3C05 -- Which of the following effects may allow radio signals to travel beyond obstructions between the transmitting and receiving stations?

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

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T3C06 -- What type of propagation is responsible for allowing over-the-horizon VHF and UHF communications to ranges of approximately 300 miles on a regular basis?

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

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T3C08 -- What causes tropospheric ducting?

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

25

T3C11 -- Why is the radio horizon for VHF and UHF signals more distant than the visual horizon?

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

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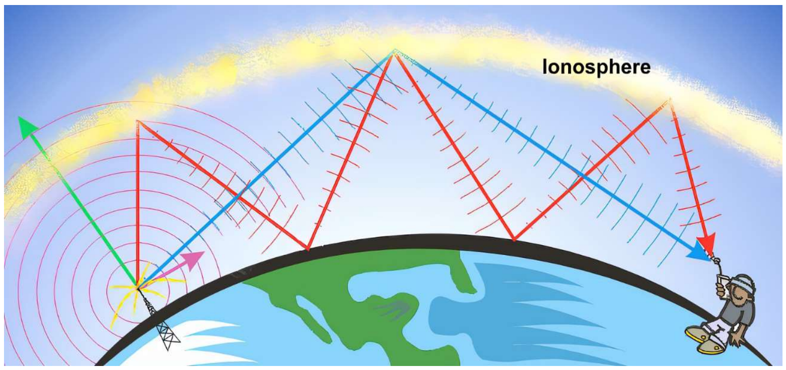
Propagation

The Ionosphere.



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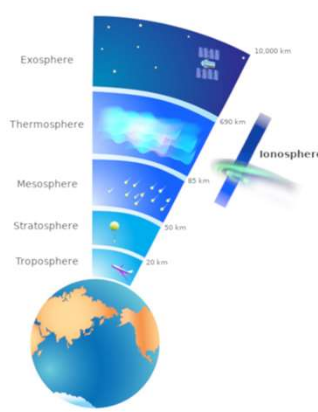
Propagation

The Ionosphere.

- The upper layers of the atmosphere are ionized by ultra-violet radiation from the sun.
  - This area is called the ionosphere.
    - 30 to 260 miles above the surface.



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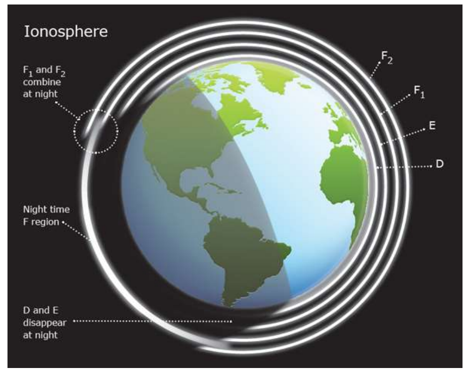
Propagation

The Ionosphere.

- The ionosphere is divided into layers or regions.
  - Each layer has its own unique characteristics.



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Propagation

The Ionosphere.

- Some radio frequency ranges (HF & lower VHF frequencies) will be reflected off the ionosphere & return to earth.
  - Called “skip”.
  - Distances well beyond the range of line-of-sight.
  - Several hundred to several thousand miles.
    - Maximum of about 2500 miles for a single hop.
    - Can have multiple hops.

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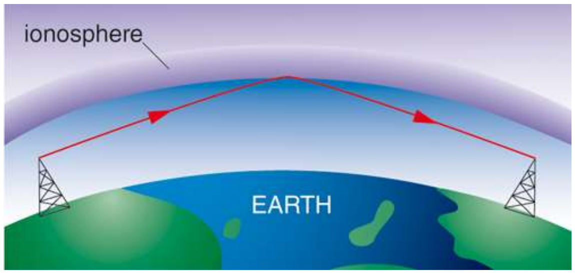
Propagation

The Ionosphere.

- The higher the amount of ionization, the better radio waves are reflected off the ionosphere.



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Propagation

The Ionosphere.

- Amount of ionization varies with time of day.
  - Sunrise to sunset → higher ionization level.
- Amount of ionization varies with sunspot activity.
  - More sunspots → higher ionization level.
  - Larger sunspots → higher ionization level.
  - Number & size of sunspots varies over an 11-year cycle.
    - Currently in Cycle 25.

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Propagation

The Ionosphere.

- Skip is not really reflection (bouncing) but rather refraction (bending).
  - The shorter the wavelength (higher frequency), the less the signal is refracted (bent).
  - At some frequency, the wave is no longer bent enough to return to earth.
    - Critical frequency.
  - Skip normally occurs in the F-layer (F1 & F2).
    - Can occur in the E-layer.

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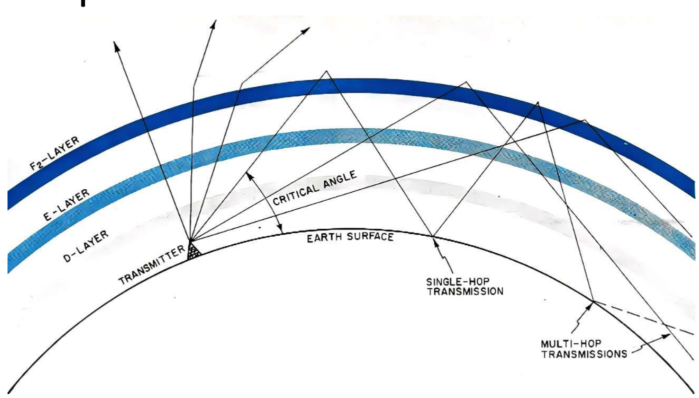
Propagation

The Ionosphere.



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Propagation

The Ionosphere.

- The highest frequency that can be used to communicate between 2 points is called the Maximum Useable Frequency (MUF).
- The lowest frequency that can be used to communicate between 2 points is called the Lowest Useable Frequency (LUF).
- MUF & LUF vary depending on amount of ionization of the ionosphere.

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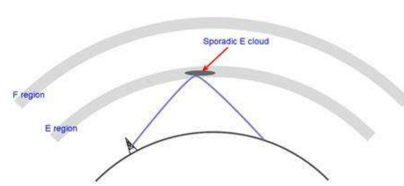
Propagation

The Ionosphere.

- E-Layer Propagation.
  - Sporadic-E.
    - Can occur at any time during solar cycle.
    - Early summer & mid-winter are best (June & December).
    - Useable on 10m, 6m, & 2m.



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Propagation

The Ionosphere.

- E-Layer Propagation.
  - In addition to sporadic-E skip, there are other types of propagation that occur in the E-layer. are unique to the 6m band.
  - These types of propagation are most useable on 6m, causing it to be often referred to as the “magic” band.

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Propagation

The Ionosphere.

- E-Layer Propagation.
  - Aurora.

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Propagation

The Ionosphere.

- E-Layer Propagation.
  - Aurora.
    - Charged particles from the sun (solar wind) are captured by the Earth's magnetic field & concentrated near the poles.
    - These charges particles
      - Excite molecules in the atmosphere, causing them to emit photons (light).
      - Ionize atoms in the E-layer, allowing radio waves to be reflected.

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Propagation

The Ionosphere.

- E-Layer Propagation.
  - Aurora.
    - Rapid signal strength changes.
    - Signals sound fluttery or distorted.
    - Primarily 6m.

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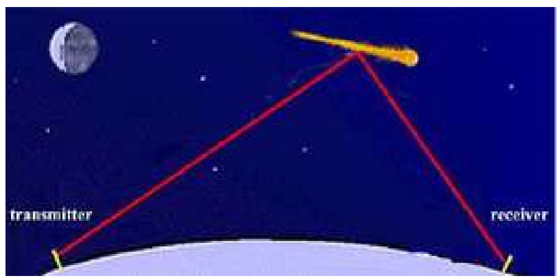
Propagation

The Ionosphere.

- E-Layer Propagation.
  - Meteor scatter.



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Propagation

The Ionosphere.

- E-Layer Propagation.
  - Meteor scatter.
    - As meteors collide with atoms in the atmosphere, they ionize those atoms.
    - Concentration of ionized atoms is greatest in the E-layer.
    - Radio signals can be reflected these trails of ionized atoms.
    - Meteor scatter propagation is best on 6m.

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Propagation

The Ionosphere.

- The lowers regions of the ionosphere absorb radio waves.
  - Primarily D-layer.
    - Some absorption in E-layer.
  - The longer the wavelength (lower frequency), the more absorption.

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T3A11 -- Which region of the atmosphere can refract or bend HF and VHF radio waves?

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

44

T3C01 -- Why are simplex UHF signals rarely heard beyond their radio horizon?

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

45

T3C02 -- What is a characteristic of HF communication compared with communications on VHF and higher frequencies?

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

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T3C03 -- What is a characteristic of VHF signals received via auroral backscatter?

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

47

T3C04 -- Which of the following types of propagation is most commonly associated with occasional strong signals on the 10, 6, and 2 meter bands from beyond the radio horizon?

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

48

T3C07 -- What band is best suited for communicating via meteor scatter?

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

49

T3C09 -- What is generally the best time for long-distance 10 meter band propagation via the F layer?

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

50

T3C10 -- Which of the following bands may provide long-distance communications via the ionosphere's F region during the peak of the sunspot cycle?

A. 6 and 10 meters
B. 23 centimeters
C. 70 centimeters and 1.25 meters
D. All these choices are correct

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Antenna and Radio Wave Basics

Antennas.

- An antenna converts an RF electrical signal into an electromagnetic wave (radio wave) or vice versa.
  - Any electrical conductor can act as an antenna.
    - Some sizes & configurations work better than others.

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Antenna and Radio Wave Basics

Antennas.

- Feed point.
  - The place where the feed-line is connected to the antenna.
- Feed Point Impedance.
  - The ratio of the RF voltage to the RF current at the feed point.
  - If the impedance is pure resistance (no reactance) then the antenna is said to be *resonant*.

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Antenna and Radio Wave Basics

Antenna Elements.

- The conductive parts of an antenna are called “elements”.
- The element that the feed-line is connected to is called the “driven” element.
- Elements that are not directly connected to the feed-line are called “parasitic” elements.
- An antenna with more than one driven element is called a “driven array”.

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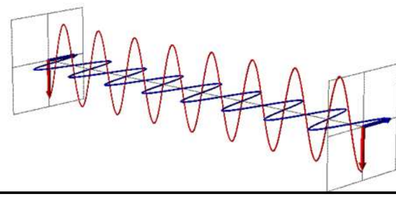
Antenna and Radio Wave Basics

Polarization.

- An electromagnetic wave consists of an electric wave & a magnetic wave at right angles to each other.
- Polarization is the orientation of the electric wave with respect to the earth.



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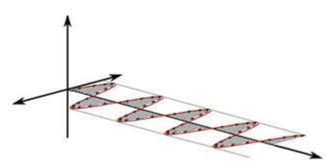
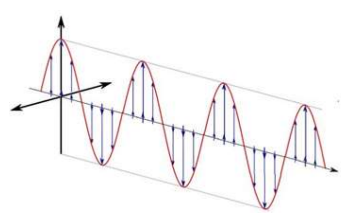
Antenna and Radio Wave Basics

Polarization.

- If the electric wave is horizontal (parallel to the ground), the wave is said to be horizontally polarized.
- If the electric wave is vertical (perpendicular to the ground), the wave is said to be vertically polarized.





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Antenna and Radio Wave Basics

Polarization.

- In most antennas, the direction of the electric field is the same as the direction of the driven element.
  - Loop antennas are exceptions.
- If polarizations are not matched, then reduced signal strength results.
  - If the polarization of the radio wave is precisely 90° from that of the antenna, **NO** signal will be received.
  - Especially important on VHF, UHF, & up.

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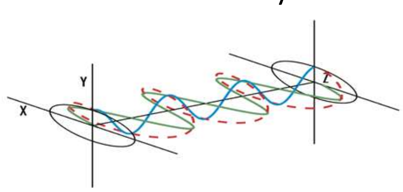
Antenna and Radio Wave Basics

Polarization.

- The polarization of signals (skip) that have been refracted in the ionosphere is random & continuously changing.
  - Signals are elliptically polarized.
  - Any polarization antenna may be used.



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T3A04 -- What happens when antennas at opposite ends of a VHF or UHF line of sight radio link are not using the same polarization?

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

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T3A09 -- Which of the following results from the fact that signals propagated by the ionosphere are elliptically polarized?

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

60

T3B01 -- What is the relationship between the electric and magnetic fields of an electromagnetic wave?

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

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T3B02 -- What property of a radio wave defines its polarization?

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

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T3B03 -- What are the two components of a radio wave?

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

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Antenna and Radio Wave Basics

Decibels.

- The difference in strength between 2 signals is often expressed in decibels (dB).
  - Ratio between 2 values
  - Logarithmic scale.
  - Commonly used to:
    - Specify the gain of an amplifier.
    - Specify the gain of an antenna.
    - Specify the loss in a feed line.

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Antenna and Radio Wave Basics

Decibels.

- Power ratio:

$$dB = 10 \log_{10}(P_1/P_2)$$

Do not worry about this formula.
You will not actually need to use it.

It is easier to use the following chart.

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Antenna and Radio Wave Basics

dB	Ratio
0	1.000
-1	0.794
-2	0.631
-3	0.501
-4	0.398
-5	0.316
-6	0.250
-7	0.200
-8	0.159
-9	0.126
-10	0.100

dB	Ratio
0	1.000
1	1.259
2	1.585
3	1.995
4	2.512
5	3.162
6	4.000
7	5.012
8	6.310
9	7.943
10	10.00

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Antenna and Radio Wave Basics

Decibels.

- Adding 2 dB values is the equivalent of multiplying the ratios represented by those dB values.
- For example:
  - 6 dB = 3 dB + 3 dB = 4:1
    - Since 3 dB = 2:1, 6 B = (2:1) x (2:1) = 4:1.
  - 13 dB = 10 dB + 3 dB = 20:1
    - Since 10 dB = 10:1 & 3 dB = 2:1, 13 B = (10:1) x (2:1) = 20:1.

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T5B09 -- Which decibel value most closely represents a power increase from 5 watts to 10 watts?

A. 2 dB

B. 3 dB

C. 5 dB

D. 10 dB

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T5B10 -- Which decibel value most closely represents a power decrease from 12 watts to 3 watts?

A. -1 dB
B. -3 dB
➡ C. -6 dB
D. -9 dB

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T5B11 -- Which decibel value represents a power increase from 20 watts to 200 watts?

➡ A. 10 dB
B. 12 dB
C. 18 dB
D. 20 dB

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Antenna and Radio Wave Basics

Antenna Gain.

- Omni-directional antennas radiate equally in all directions.
- Directional antennas focus radiation in one or more specific directions.
  - a.k.a. – Beam antennas.

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Antenna and Radio Wave Basics

Antenna Gain.

- Gain is the apparent increase in power in a particular direction because energy is focused in that direction.
  - Compared to a reference antenna.
    - Isotropic antenna,
    - Dipole.
  - Measured in decibels (dB).

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Antenna and Radio Wave Basics

Antenna Gain.

- Isotropic antenna.
  - Theoretical point radiator.
    - Imaginary – cannot be constructed in the real world.
  - Radiates equally well in all directions.
    - Perfect sphere.
  - Used as reference for antenna gain specifications.

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Antenna and Radio Wave Basics

Antenna Gain.

- Omni-directional antenna.
  - Radiates equally well in all horizontal directions.
- Directional antenna (beam).
  - Has more radiation in one horizontal direction than in other directions.
  - The direction with the most radiation is called the "main lobe".
  - Lobes in other directions are called "side lobes".

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Antenna and Radio Wave Basics

Antenna Gain.

- Directional antenna (beam).
  - The ratio of the power in the forward direction to the power in the opposite direction is called the "front-to-back ratio".
  - The ratio of power in the forward direction to the power at 90° from the forward direction is called the "front-to-side ratio".
  - Directional antennas are useful in rejecting interference from an unwanted direction.

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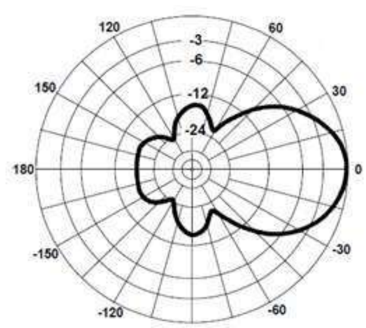
Antenna and Radio Wave Basics

Radiation Patterns.

- A way of visualizing antenna performance.
- The further the line is away from the center of the graph, the stronger the signal in that direction.



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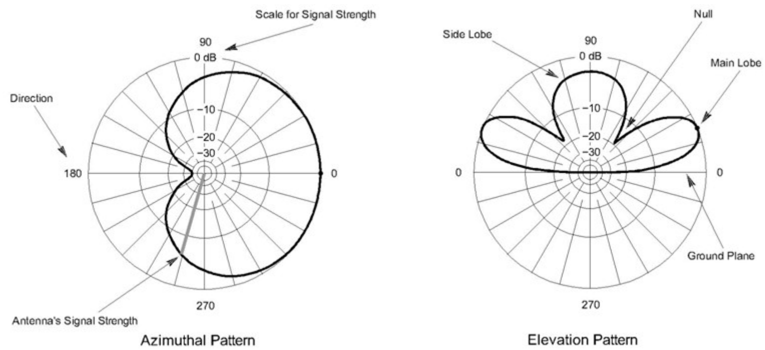
Antenna and Radio Wave Basics

Radiation Patterns.



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T9A11 -- What is antenna gain?

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

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

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

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

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Feed Lines and SWR

Feed Lines.

- a.k.a. – Transmission line.
- Connect RF signals between radio and antenna.
- Connect RF signals between pieces of equipment.

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Feed Lines and SWR

Feed Lines.

- Constructed using special materials and configurations.
  - Maintain constant impedance.
  - Minimize losses.
- Power lost in the feed line is converted to heat and is called "feed line loss".
  - Feed line loss **always** increases with frequency.
  - Measured in decibels (dB).

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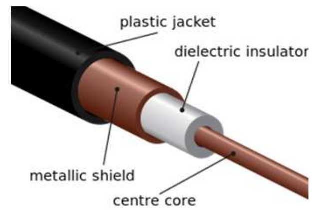
Feed Lines and SWR

Coaxial cable.

- Coaxial cable.
  - Usually shortened to "coax".
  - Most popular type.
  - Easy to work with.
  - Low characteristic impedance.
    - Typically 50Ω or 75Ω.
  - Moderate to high loss.
    - Higher frequency → higher loss.



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Feed Lines and SWR

Coaxial cable.

- Coaxial cable.
  - Energy lost in feed line is converted to heat.
  - Loss is primarily determined by size of cable & by insulating material.
    - Larger diameter → Lower loss.
    - Air is lowest loss insulator.
      - Foam dielectric coax has lower loss than solid dielectric coax because it contains bubbles of air.
      - Air-insulated hard line has lowest loss.

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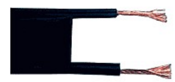
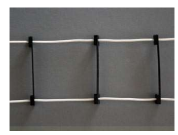
Feed Lines and SWR

Parallel-Wire Transmission Line.

- Open-wire (ladder) line, window line, twin lead.
- More difficult to work with.
- High characteristic impedance.
  - Typically 300Ω to 600Ω.
- Very low loss.





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Feed Lines and SWR

Characteristic Impedance.

- Coaxial cable.
  - Characteristic impedance primarily determined by ratio of diameter of shield to diameter of center conductor.
    - Larger ratio → higher impedance.
  - 50Ω = RG-8, RG-8X, RG-58, RG-174.
    - 50Ω most common impedance used in amateur installations.
  - 75Ω = RG-11, RG-6, RG-59.
    - 75Ω used in TV installations.

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Feed Lines and SWR

Characteristic Impedance.

- Parallel-wire transmission line.
  - Characteristic impedance determined by ratio of diameter of conductors to distance between them.
    - Larger distance → higher impedance.
    - Smaller diameter → higher impedance.

85

T7C07 -- What happens to power lost in a feed line?

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

86

T9B02 -- What is the most common impedance of coaxial cables used in amateur radio?

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

87

T9B03 -- Why is coaxial cable the most common feed line for amateur radio antenna systems?

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

88

T9B05 -- What happens as the frequency of a signal in coaxial cable is increased?

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

89

T9B11 -- Which of the following types of feed line has the lowest loss at VHF and UHF?

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

90

Feed Lines and SWR

Standing Wave Ratio -- SWR.

- If the feed line impedance **exactly** matches the load (antenna) impedance all of the energy is delivered to the load.
- If the feed line impedance does **not** exactly match the load impedance, then some of the power is reflected back towards the source (transmitter).

91

Feed Lines and SWR

Standing Wave Ratio (SWR).

- Forward power
  - Power traveling towards the load.
- Reverse power
  - Power reflected back towards the source.

92

Feed Lines and SWR

Standing Wave Ratio (SWR).

- The forward and reflected powers combine to form an interference pattern with peaks and valleys.
- The ratio of the maximum value (peak) to the minimum value (valley) is called the standing wave ratio (SWR).
  - Normally we use the maximum & minimum voltage values (VSWR).

93

Feed Lines and SWR

Standing Wave Ratio (SWR).

- SWR is equal to the ratio of the load impedance to the feed line impedance, or the ratio of the feed line impedance to the load impedance, whichever is greater than 1.
  - $SWR = Z_{Line} / Z_{Ant}$ or $SWR = Z_{Ant} / Z_{Line}$

94

Feed Lines and SWR

Standing Wave Ratio (SWR).

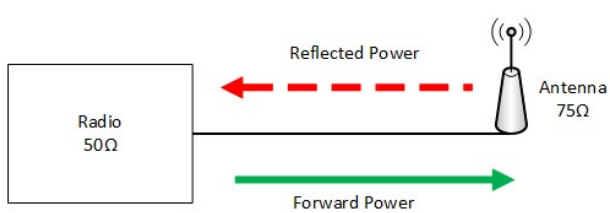
- Rule-of-thumb guidelines:
  - 1:1 = Perfect.
  - 1:1 to 2:1 = Acceptable.
    - Most modern transmitters will automatically reduce transmitter output power when SWR is above 2:1.
  - 2:1 to 3:1= Useable (with tuner).
    - Many transceivers have an internal antenna tuner which will match SWR's up to 3:1.
  - 3:1 or more = Really bad.

95

Feed Lines and SWR

Standing Wave Ratio (SWR).

- SWR is constant anywhere along the feed line.
  - Normally measured at the source (transmitter) end of the feed line.



96

Feed Lines and SWR

Standing Wave Ratio (SWR).

- Why does SWR matter?
  - Some power is always lost in the feed line. A high SWR will increase the loss.
  - The voltage peaks created by a high SWR can cause damage to the transmitter output devices.
    - Nearly all modern, solid-state transmitters include protective circuitry that reduces power or shuts a transmitter down completely if a high SWR is detected.

97

Feed Lines and SWR

Standing Wave Ratio (SWR).

- What causes high SWR?
  - High SWR is caused by an impedance mismatch.
    - Antenna too long for the frequency being used.
    - Antenna too short for the frequency being used.
    - Incorrect impedance feed line.
    - Faulty feed line.
    - Faulty connection.
  - An intermittent, high SWR is often caused by a loose feed line connection.

98

Feed Lines and SWR

Standing Wave Ratio (SWR).

- SWR Meters are used to measure the SWR of an antenna system.
  - SWR meters are designed for specific frequency ranges.
  - SWR meters are designed for specific power levels.

99

T4A02 -- Which of the following should be considered when selecting an accessory SWR meter?

A. The frequency and power level at which the measurements will be made

B. The distance that the meter will be located from the antenna

C. The types of modulation being used at the station

D. All these choices are correct

100

T7C04 -- What reading on an SWR meter indicates a perfect impedance match between the antenna and the feed line?

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

101

T7C05 -- Why do most solid-state transmitters reduce output power as SWR increases beyond a certain level?

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

102

T7C06 -- 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

103

T9B01 -- What is a benefit of low SWR?

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

104

T9B09 -- What can cause erratic changes in SWR?

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

105

T9B12 -- What is standing wave ratio (SWR)?

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

106

Break

107

Practical Antenna Systems

Dipoles and Ground Planes.

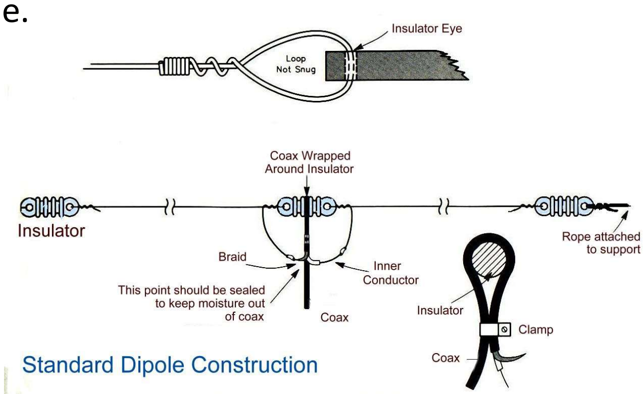
- Dipole.
  - Most basic antenna.
    - Two conductors, equal length.
    - Feed line connected in the middle.
  - Total length is 1/2 wavelength (1/2 λ).
    - Length (feet) = 468 / Frequency (MHz).

108

Practical Antenna Systems

Dipoles and Ground Planes.

- Dipole.



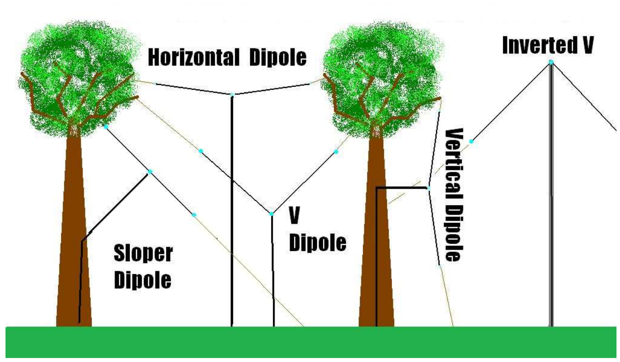
Standard Dipole Construction

109

Practical Antenna Systems

Dipoles and Ground Planes.

- Dipole.



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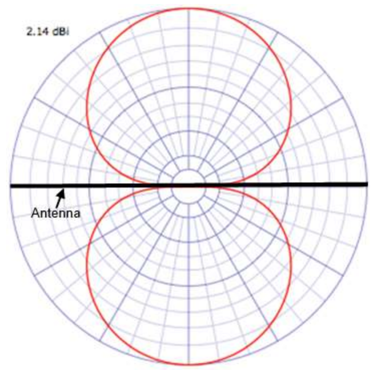
Practical Antenna Systems

Dipoles and Ground Planes.

- Dipole.



111

Practical Antenna Systems

Dipoles and Ground Planes.

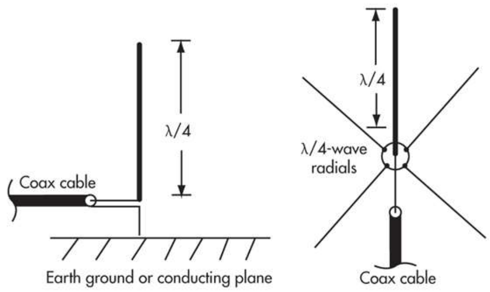
- Ground plane.
  - One half of a dipole that is oriented perpendicular to the Earth's surface.
    - Often called "verticals".
  - The other half is replaced by a ground-plane.
    - Earth
    - Car roof, trunk lid, or other metal surface.
    - Radial wires (>1/4λ long in all directions).
  - Length (feet) = 234 / Frequency (MHz).
  - Omni-directional.

112

Practical Antenna Systems

Dipoles and Ground Planes.

- Ground plane.



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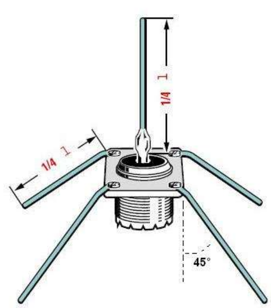
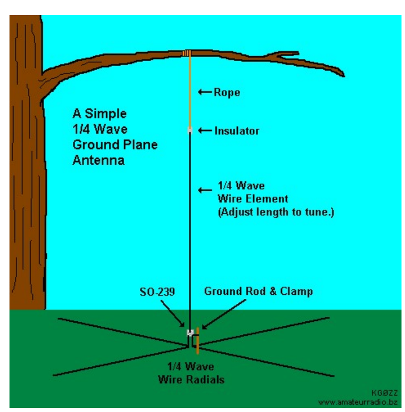
Practical Antenna Systems

Dipoles and Ground Planes.

- Ground plane.





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Practical Antenna Systems

Dipoles and Ground Planes.

- Ground Plane.
  - On frequencies below 24 MHz, length of a full-size ground plane makes it impractical for mobile or portable use.
  - Need a way to the antenna physically sorter while maintaining the same resonant electrical length.
    - a.k.a. – Loading.

115

Practical Antenna Systems

Dipoles and Ground Planes.

- Mobile antennas.
  - Most mobile antennas are a variation of the ground plane.
  - If the antenna cannot be a full 1/4λ long, an inductor (coil) is added to make the antenna electrically longer.
    - This is known as "inductive loading"
  - Mounting the antenna in center of the roof gives the most uniform radiation pattern.

116

Practical Antenna Systems

Dipoles and Ground Planes.

- Mobile antennas.
  - A popular mobile antenna for VHF & UHF is the 5/8λ vertical.
  - Lower angle of radiation.
  - Provides a gain of 1.5 dB over a 1/4λ vertical.

117

Practical Antenna Systems

Dipoles and Ground Planes.

- "Rubber Duck" Antennas.
  - Variation of the ground-plane.
  - Commonly used on hand-held transceivers.
  - Coil of wire enclosed in rubber (plastic) covering.
    - Shorter than normal ground-plane.
    - Much less efficient than full-sized ground-plane.

Side note: Using a rubber duck antenna inside your vehicle is not a good idea because….

Signals are weaker due to shielding by car body.

118

T9A02 -- Which of the following describes a type of antenna loading?

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

119

T9A03 -- Which of the following describes a simple dipole oriented parallel to the Earth's surface?

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

120

T9A04 -- What is a disadvantage of the short, flexible antenna supplied with most handheld radio transceivers, compared to a full-sized quarter-wave antenna?

A. It has low efficiency
B. It transmits only circularly polarized signals
C. It is mechanically fragile
D. All these choices are correct

121

T9A05 -- Which of the following increases the resonant frequency of a dipole antenna?

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

122

T9A07 -- What is a disadvantage of using a handheld VHF transceiver with a flexible antenna inside a vehicle?

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

123

T9A08 -- What is the approximate length, in inches, of a quarter-wavelength vertical antenna for 146 MHz?

A. 112
B. 50
C. 19
D. 12

124

T9A09 -- What is the approximate length, in inches, of a half-wavelength 6 meter dipole antenna?

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

125

T9A10 -- In which direction does a half-wave dipole antenna radiate the strongest signal?

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

126

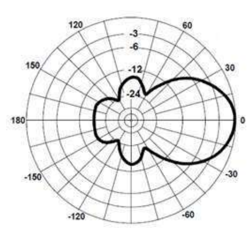
T9A12 -- What is an advantage of a 5/8 wavelength whip antenna for VHF or UHF mobile service?

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

Practical Antenna Systems

Directional Antennas.

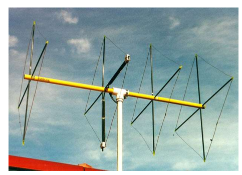
- Directional antennas focus or direct RF energy in a desired direction.
  - Gain -- Apparent increase in power in the desired direction.
    - Applies to both transmit and receive.



Practical Antenna Systems

Directional Antennas.

- The most common type of directional antenna is the beam.
- All beam antennas have parts called elements.
  - Metal rods.
  - Loops of wire.



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Practical Antenna Systems

Directional Antennas.

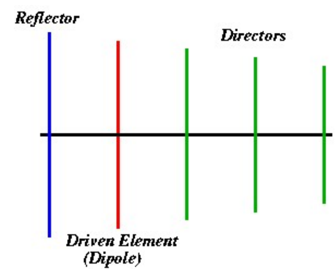
- The most common type of beam antenna is the Yagi-Uda array.
  - Normally just called a “Yagi”.
  - Invented in 1926 by Dr. Shintaro Uda in collaboration with Dr. Hidetsugu Yagi.
  - Rod-like elements.
    - Similar to TV antennas.

130

Practical Antenna Systems

Directional Antennas.

- Yagi antennas.
  - Driven element.
    - Connected to the radio by the feed line.
  - Reflector element.
    - Behind the driven element.
  - Director element(s).
    - In front of the driven element.
    - Can have more then one director.



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Practical Antenna Systems

Directional Antennas.

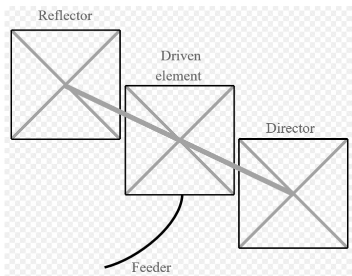
- Yagi antennas.
  - Horizontally-polarized Yagi antennas are commonly used for long distance, weak signal CW & SSB communications on VHF & UHF.

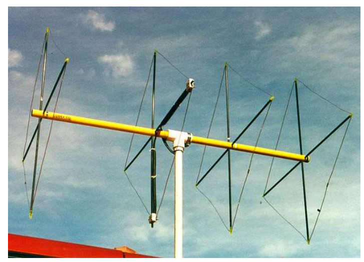
132

Practical Antenna Systems

Directional Antennas.

- Quad Antennas.
  - Square wire loop elements.



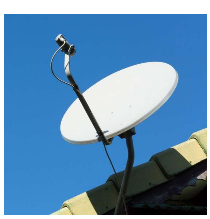


133

Practical Antenna Systems

Directional Antennas.

- Parabolic Dish.
  - Large, round, curved reflector.
  - Very high gain.



134

T3A03 -- What antenna polarization is normally used for long-distance CW and SSB contacts on the VHF and UHF bands?

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

135

T3A05 -- When using a directional antenna, how might your station be able to communicate with a distant repeater if buildings or obstructions are blocking the direct line of sight path?

A. Change from vertical to horizontal polarization
➡ B. Try to find a path that reflects signals to the repeater
C. Try the long path
D. Increase the antenna SWR

136

T9A01 -- What is a beam antenna?

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

137

T9A06 -- Which of the following types of antenna offers the greatest gain?

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

138

Practical Feed Lines and Associated Equipment

Feed Line Selection and Maintenance.

- Coax vs. Open Wire.
  - Coax easier to use.
    - VHF & UHF installations almost always use coaxial cable.
  - Open wire has lower loss.
    - Normally used only with HF wire antennas.

139

Practical Feed Lines and Associated Equipment

Feed Line Selection and Maintenance.

- Need to consider:
  - Frequency.
  - Length of cable.
  - Power level.
  - Budget.
- Loss.
  - Larger cable generally has lower loss.
  - Foam dielectric has lower loss.

140

Practical Feed Lines and Associated Equipment

Type	Impedance	Loss @ 30MHz (dB/100ft)	Loss @ 150MHz (dB/100ft)	Cost (per foot)
RG-174	50Ω	4.6 dB	10.3 dB	$0.20
RG-58	50Ω	2.5 dB	5.6 dB	$0.28
RG-8X	50Ω	2.0 dB	4.5 dB	$0.30
RG-8	50Ω	1.1 dB	2.5 dB	$1.00
RG-213	50Ω	1.1 dB	2.5 dB	$0.89
LMR-400	50Ω	0.7 dB	1.5 dB	$1.11

Type	Impedance	Loss @ 30MHz (dB/100ft)	Loss @ 150MHz (dB/100ft)	Cost (per foot)
RG-59	75Ω	1.8 dB	4.1 dB	$0.16
RG-6	75Ω	1.4 dB	3.3 dB	$0.24
RG-11A	75Ω	0.7 dB	1.6 dB	$0.97

141

Practical Feed Lines and Associated Equipment

Feed Line Selection and Maintenance.

- Coaxial cable must be protected.
  - Worst enemy is moisture getting into the cable.
    - Moisture increases loss in cable.
    - Avoid nicks or cuts in outer jacket.
    - Prolonged exposure to sunlight can result in tiny cracks in outer jacket which can admit moisture.
    - Seal all outside connections against moisture.
    - Air-core coaxial cable requires special techniques to keep moisture from entering the cable.

142

Practical Feed Lines and Associated Equipment

Feed Line Selection and Maintenance.

- Coaxial cable must be protected.
  - Avoid sharp bends or turns.
    - Insulating material will cold flow causing a short-circuit between the center conductor and the shield.

143

Practical Feed Lines and Associated Equipment

Coaxial Feed Line Connectors.

- UHF Connectors.
  - Most common type.
  - Useable up to 150 MHz.
  - High power (>1.5 kW).
  - Not constant impedance.
  - Not weather resistant.
  - Inexpensive.
  - Plug = PL-259, Socket = SO-239.

144

Practical Feed Lines and Associated Equipment

Coaxial Feed Line Connectors.

- Type “N” Connectors.
  - Useable up to 10 GHz.
  - High power (>1.5 kW).
  - Constant impedance.
    - 50Ω and 75Ω versions available.
  - Weather resistant.
  - Relatively expensive.
  - Relatively difficult to install.

145

Practical Feed Lines and Associated Equipment

Coaxial Feed Line Connectors.

- BNC Connectors.
  - Useable up to 4 GHz.
  - Low power.
  - Constant impedance.
    - 50Ω and 75Ω versions available.
  - Commonly used on:
    - Older hand-held radios.
    - Test equipment.

146

Practical Feed Lines and Associated Equipment

Coaxial Feed Line Connectors.

- SMA Connectors.
  - Useable up to 18 GHz.
  - Low power.
  - Constant impedance.
    - Only 50Ω available.
  - Used on most new hand-held radios.

147

Practical Feed Lines and Associated Equipment

Soldering.

- A process in which two or more metal items are joined together by melting and flowing a filler metal into the joint.
- The filler metal is called solder.
- Flux is a material used to prevent the formation of oxides during the soldering process.

148

Practical Feed Lines and Associated Equipment

Soldering.

- Types of solder.
  - Standard solder.
    - Mixture of tin & lead.
    - Ratio of tin to lead is adjusted for lowest melting temperature.
      - 63/37 or 60/40.
      - Melting point is about 183°C (361°F).

149

Practical Feed Lines and Associated Equipment

Soldering.

- Types of solder.
  - Lead-free solder.
    - Mixture of tin & silver or tin, silver, & copper.
    - Melting point is about 40°C (72°F) hotter than standard solder.

150

Practical Feed Lines and Associated Equipment

Soldering.

- Types of flux.
  - Resin.
    - Used for electrical/electronic connections.
  - Acid.
    - Used for plumbing.

NEVER use acid–core solder or acid flux to solder electronic connections!

151

Practical Feed Lines and Associated Equipment

Soldering.

- It takes a little bit of skill to make a good solder joint.
  - A good solder joint is bright & shiny.
  - If the joint is not heated enough or if it is moved before it cools, it can result in a “cold solder joint”.
    - A cold solder joint is dull & grainy-looking.

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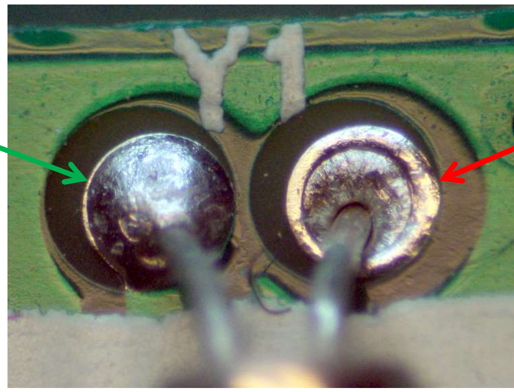
Practical Feed Lines and Associated Equipment

Soldering.



153

T7C09 -- Which of the following causes failure of coaxial cables?

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

154

T7C10 -- Why should the outer jacket of coaxial cable be resistant to ultraviolet light?

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

155

T7C11 -- What is a disadvantage of air core coaxial cable when compared to foam or solid dielectric types?

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

156

T7D08 -- Which of the following types of solder should not be used for radio and electronic applications?

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

157

T7D09 -- What is the characteristic appearance of a cold tin-lead solder joint?

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

158

T9B06 -- Which of the following RF connector types is most suitable for frequencies above 400 MHz?

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

159

T9B07 -- Which of the following is true of PL-259 type coax connectors?

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

160

T9B08 -- Which of the following is a source of loss in coaxial feed line?

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

161

T9B10 -- What is the electrical difference between RG-58 and RG-213 coaxial cable?

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

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Practical Feed Lines and Associated Equipment

SWR Meters and Wattmeters.

- SWR meters.
  - a.k.a. – SWR bridge.
  - Connects between transmitter & feed line.
  - Displays amount of mismatch (SWR) between transmitter & antenna system.
    - Antenna system = antenna + feed line.
  - Make adjustments to antenna system to minimize mismatch.

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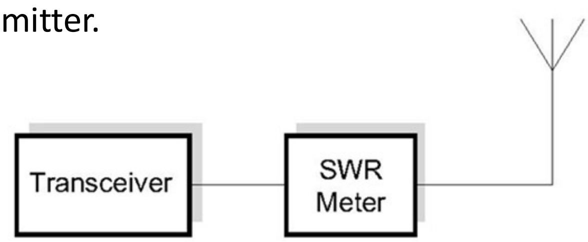
Practical Feed Lines and Associated Equipment

SWR Meters and Wattmeters.

- SWR meters are installed in the feedline, usually close to the transmitter.



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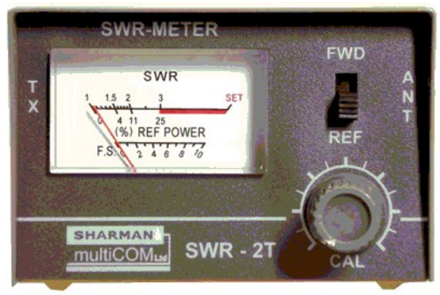
Practical Feed Lines and Associated Equipment

SWR Meters and Wattmeters.

- SWR meters.
  - Simple SWR Meter.
    - Set to “FWD”.
    - Adjust “CAL” for full scale reading (SET).
    - Set to “REF” & read SWR.



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Practical Feed Lines and Associated Equipment

SWR Meters and Wattmeters.

- Cross-needle SWR meter.
  - Measures both forward and reflected power.
  - No adjustments necessary.

166

Practical Feed Lines and Associated Equipment

SWR Meters and Wattmeters.

- Directional wattmeters.
  - Measures both forward power (P_F) & reflected power (P_R).
  - SWR can then be calculated from P_F & P_R.

$$SWR = \frac{\sqrt{P_F} + \sqrt{P_R}}{\sqrt{P_F} - \sqrt{P_R}}$$

167

Practical Feed Lines and Associated Equipment

Antenna Tuner.

- One way to make antenna matching adjustments is to use an antenna tuner.
  - a.k.a. -- Transmatch.
- Antenna tuners are impedance transformers.
  - When used appropriately they are effective.
  - When used inappropriately all they do is make a bad antenna look good to the transmitter…the antenna is still bad.

168

Practical Feed Lines and Associated Equipment

Antenna Tuner.

- An antenna tuner does **NOT** “tune” the antenna.
  - It only makes the transmitter think that all impedances are matched.

169

Practical Feed Lines and Associated Equipment

Antenna Analyzer.

- Antenna analyzers measure antenna system impedance (Z).
  - Resistance (R).
  - Reactance (X).
- Several other useful functions.
  - Calculate SWR.

170

Practical Feed Lines and Associated Equipment

Dummy Load.

- A non-radiating load used for testing.
  - Non-inductive resistor & heatsink.
  - Typically 50Ω.

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Practical Feed Lines and Associated Equipment

Dummy Load.

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T4A05 -- Where should an RF power meter be installed?

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

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T7C01 -- What is the primary purpose of a dummy load?

A. To prevent transmitting signals over the air when making tests
B. To prevent over-modulation of a transmitter
C. To improve the efficiency of an antenna
D. To improve the signal-to-noise ratio of a receiver

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T7C02 -- Which of the following is used to determine if an antenna is resonant at the desired operating frequency?

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

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T7C03 -- What does a dummy load consist of?

A. A high-gain amplifier and a TR switch
B. A non-inductive resistor mounted on a heat sink
C. A low-voltage power supply and a DC relay
D. A 50-ohm reactance used to terminate a transmission line

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T7C08 -- Which instrument can be used to determine SWR?

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

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T9B04 -- What is the major function of an antenna tuner (antenna coupler)?

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

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Questions?

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Technician Class

Next Week

Chapter 5

Amateur Radio Equipment

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