Introduction to Radio

A YMCA Camp Arbolado Science Activity

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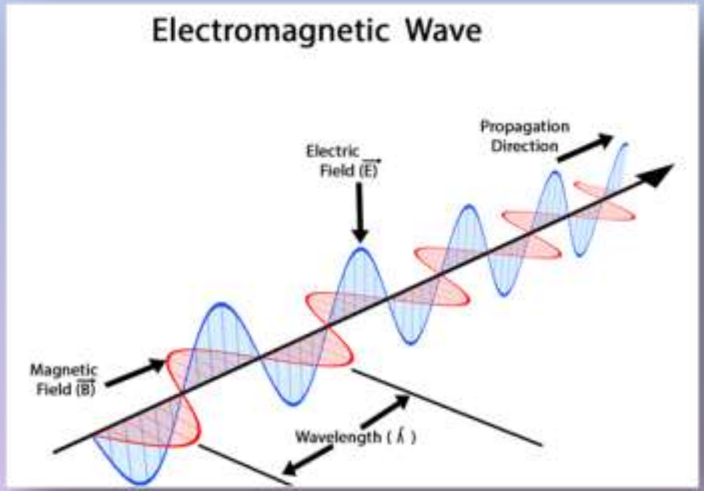
Topics

- How do cell phones work?
- Why does HAM radio matter?
- Radio signals and waves
- Harmonics and phase
- Polarization
- Radio spectrum and HAM bands
- Atmospheric effects
- Repeaters
- Antennas



Topics

- Feed lines
- SWR
- Radio types

How Do Cell Phones Work?

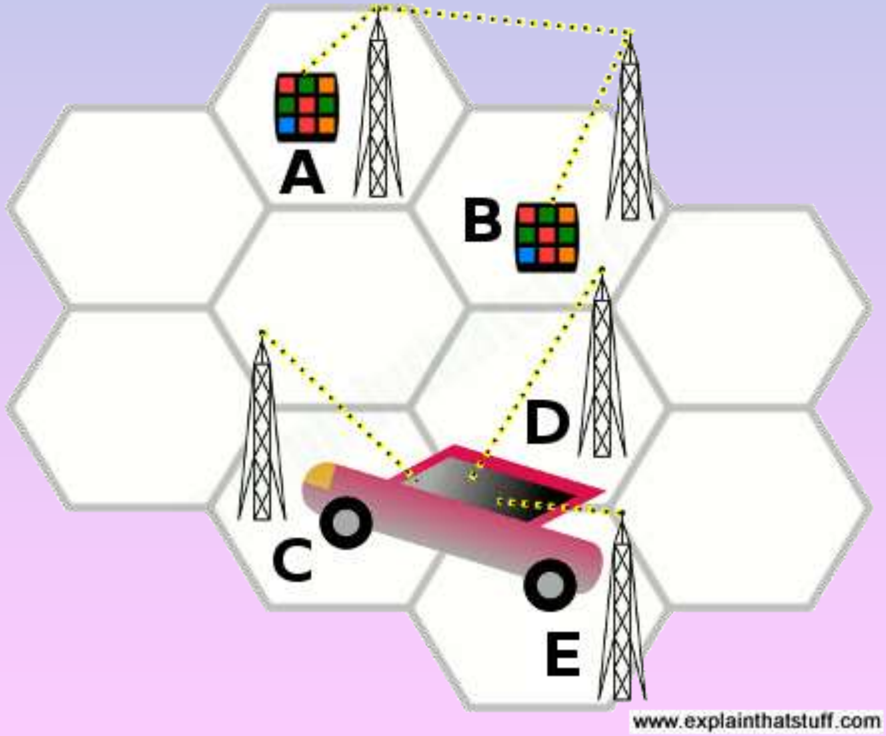
- When you speak into a cell phone a microphone turns your voice into electrical signals
- A microchip in the phone modulates (or varies) a radio wave using the electrical signal
- The radio wave is beamed out from the phone's antenna
- The radio wave travels through the air to a nearby cell tower (mast)
- The mast receives the signals and passes them on to its base station, which effectively coordinates what happens inside each local part of the cellphone network, which is called a cell

How Do Cell Phones Work?

- From the base station, the calls are routed onward to their destination
- Calls made from a cellphone to another cellphone on the same network travel to their destination by being routed to the base station nearest to the destination phone, and finally to that phone itself
- Calls made to a cellphone on a different network may have to be routed into the main telephone network before they can reach their ultimate destination

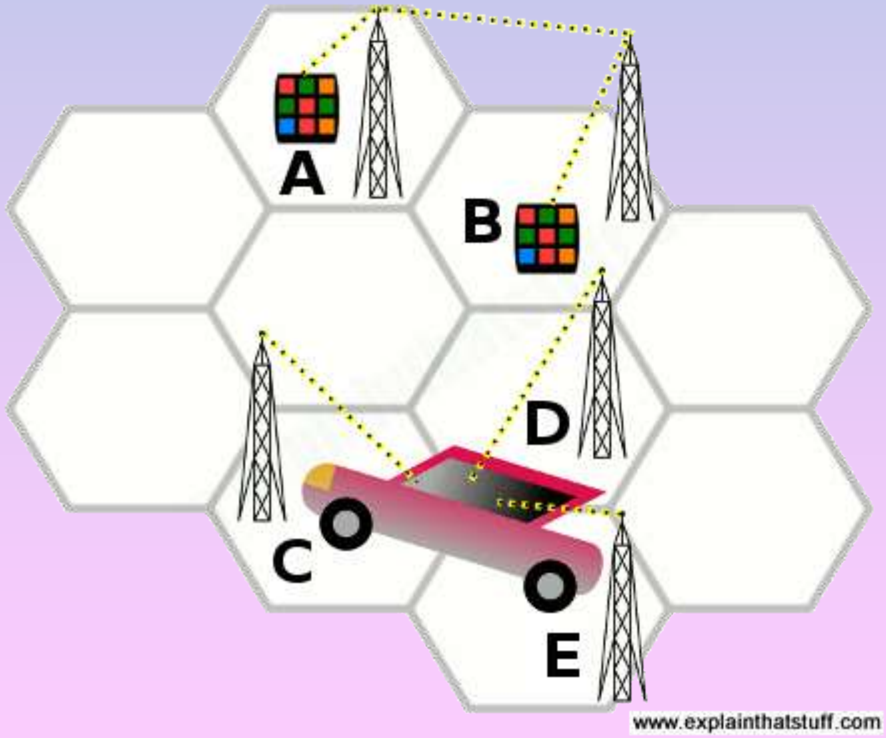
How Do Cell Phones Work?

- Simple call
  - If a phone in cell A calls a phone in cell B, the call doesn't pass directly between the phones, but from the first phone to mast A and its base station, then to mast B and its base station, and then to the second phone



How Do Cell Phones Work?

- Roaming call
  - Cellphones that are moving between cells (when people are walking or driving) are regularly sending signals to and from nearby masts so that, at any given time, the cellphone network always knows which mast is closest to which phone
  - If a car passenger is making a call and the car drives between cells C, D, and E, the phone call is automatically "handed off" (passed from cell to cell) so the call is not interrupted
  - Cellphones and the masts they communicate with are designed to send radio waves only over a limited range



Why Does HAM Radio Matter?

- If the cell phone towers are not working, communication is not possible
- A typical cellphone has enough power to reach a cell tower between 22 and 45 miles away
  - Cell phones typically have two transmit power levels: 0.6 watts and 3 watts
  - A CB radio outputs 4 watts and a HAM radio output power ranges from 5 watts to 1500 watts

Why Does HAM Radio Matter?

- Cellphone signals travel in a straight line and have limited penetration capabilities
    - Interference weakens the signal and cellphones may not be able to reach a cell tower that is quite close
    - Sources of interference are natural obstacles such as hills and trees or man-made structures such as buildings, walls and tunnels
- When the internet is down, cannot send email via cell phone, computer, etc.
    - Emails can still be sent over radio waves using amateur radio digital modes (Winlink, etc.)
- **In the end, during emergencies and natural disasters, amateur radio is the best and often only method of communication**

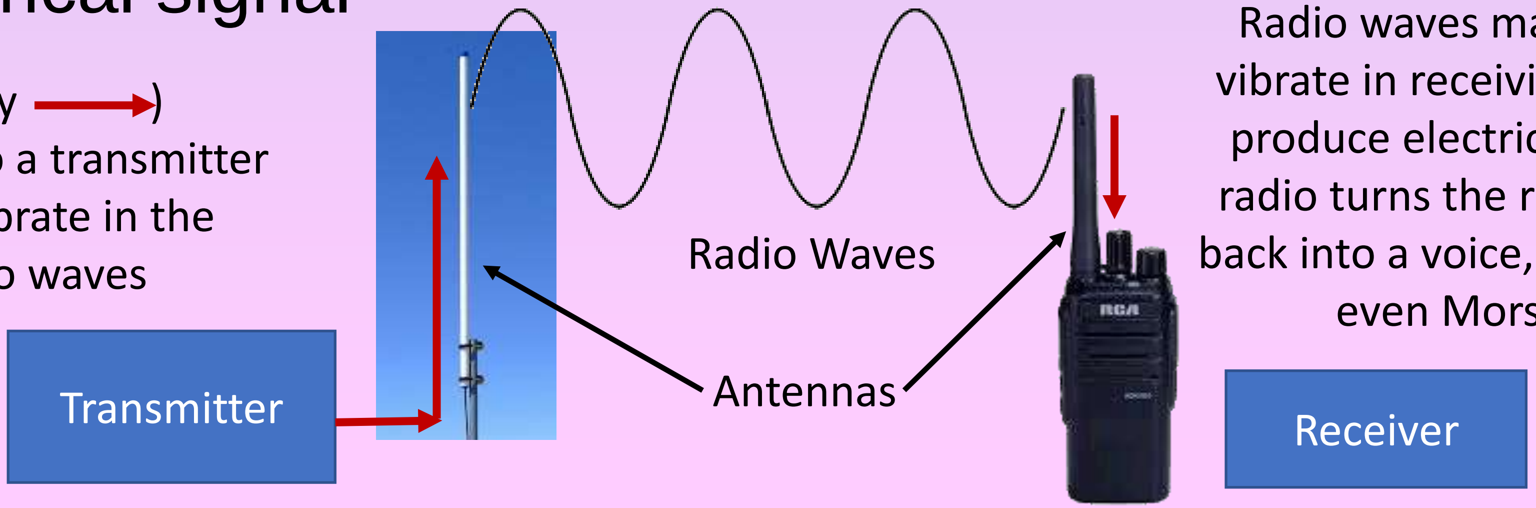
Why Does HAM Radio Matter?

- Using repeater networks such as PAPA, WINSYTEM, etc., a small, inexpensive ($30 - $60) handheld amateur radio can reach across the United States and to many part of the world
  - Unlike cell phone or land line service, the amateur radio communication is free

Radio Signals and Waves

- A radio signal can be electrical energy inside radio equipment or a radio wave traveling through space
- Radio waves begin at an antenna that turns an electrical signal into radio waves that travel at the speed of light
- As the wave passes other antennas, it creates replicas of the original electrical signal

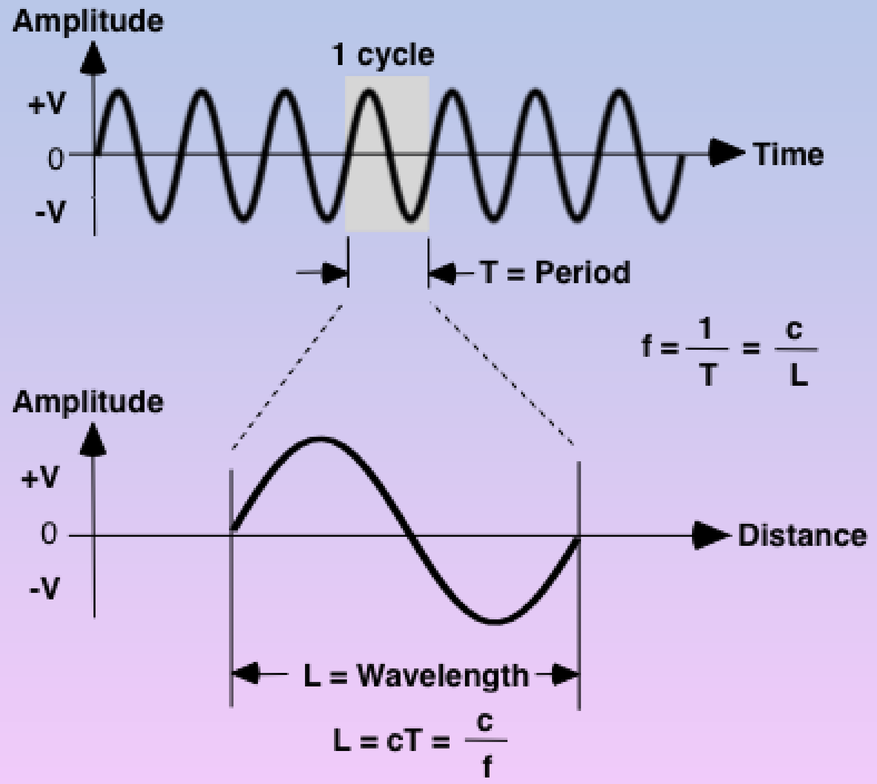
Electric current (shown by →) flowing from a transmitter into a transmitter antenna makes electrons vibrate in the antenna, producing radio waves



Radio waves make electrons vibrate in receiving antenna to produce electric current. The radio turns the received signal back into a voice, digital data, or even Morse Code.

Radio Signals and Waves

- Radio wave characteristics
  - A radio wave continuously varies in strength (*amplitude*) like a sine wave
  - The continual change is called *oscillation*
  - As the signal oscillates, each up-and-down sequence is called a *cycle*
  - The number of cycles per second is called the signal's *frequency (f),* measured in hertz (Hz)
  - The *period (T)* of the cycle is its duration
  - The *wavelength (L or λ)* is the distance a radio wave travels in during one complete cycle



f = frequency

L (λ) = wavelength. In meters, L (λ) = $\frac{300}{f \text{ in } MHz}$

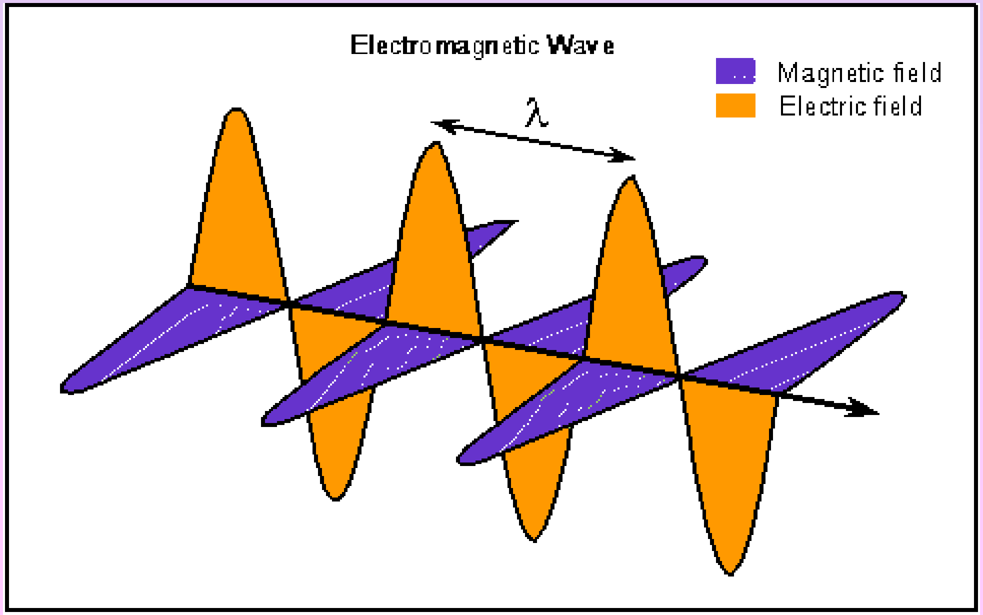
c = speed of light = 3 X 10^8 meters per second in space and air

T = period (time to complete 1 cycle)

1 Hz = 1 cycle per second

Radio Signals and Waves

- A radio wave contains both electrical and magnetic energy and is thus called an *electromagnetic wave*
  - Energy is supplied by electrons moving back and forth in the antenna
  - The wave's electric and magnetic fields oscillate at the same frequency as the radio frequency (RF) current in the antenna



Radio Signals and Waves Demo 1 of 2

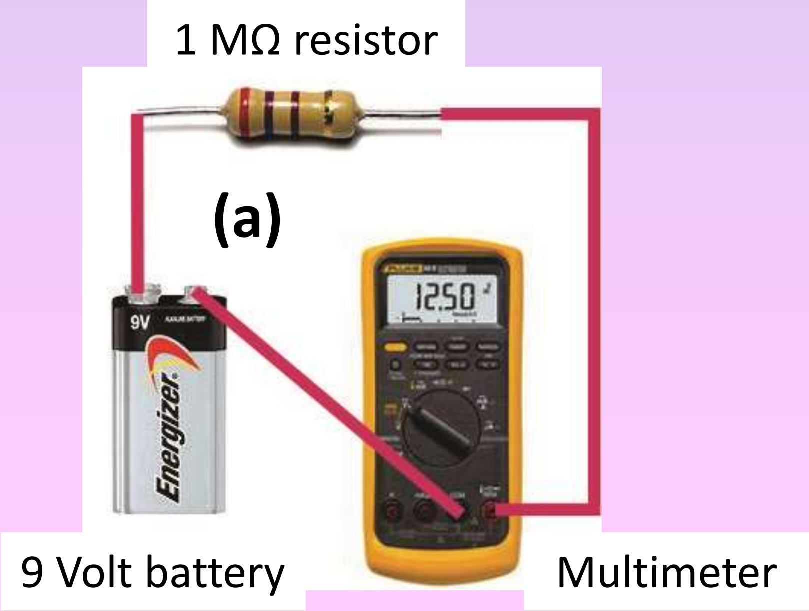
- Using a electromagnetic field radiation detector, measure the electric and magnetic field strengths of a portable HAM radio in transmit mode
  - Vary distance of radio to detector and note results
  - Vary types of antennas (high gain and whip) and frequencies and note results

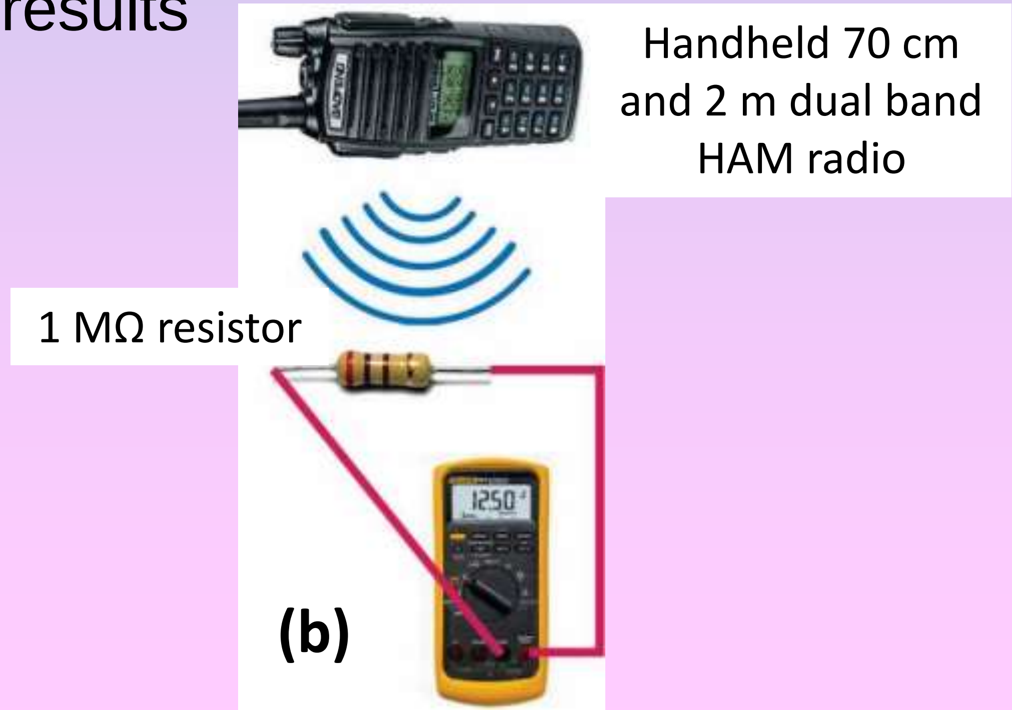
Electromagnetic field radiation detector capable of measuring electric and magnetic field strengths

Dual band 2 m and 70 cm HAM radio

Radio Signal and Waves Demo 2 of 2

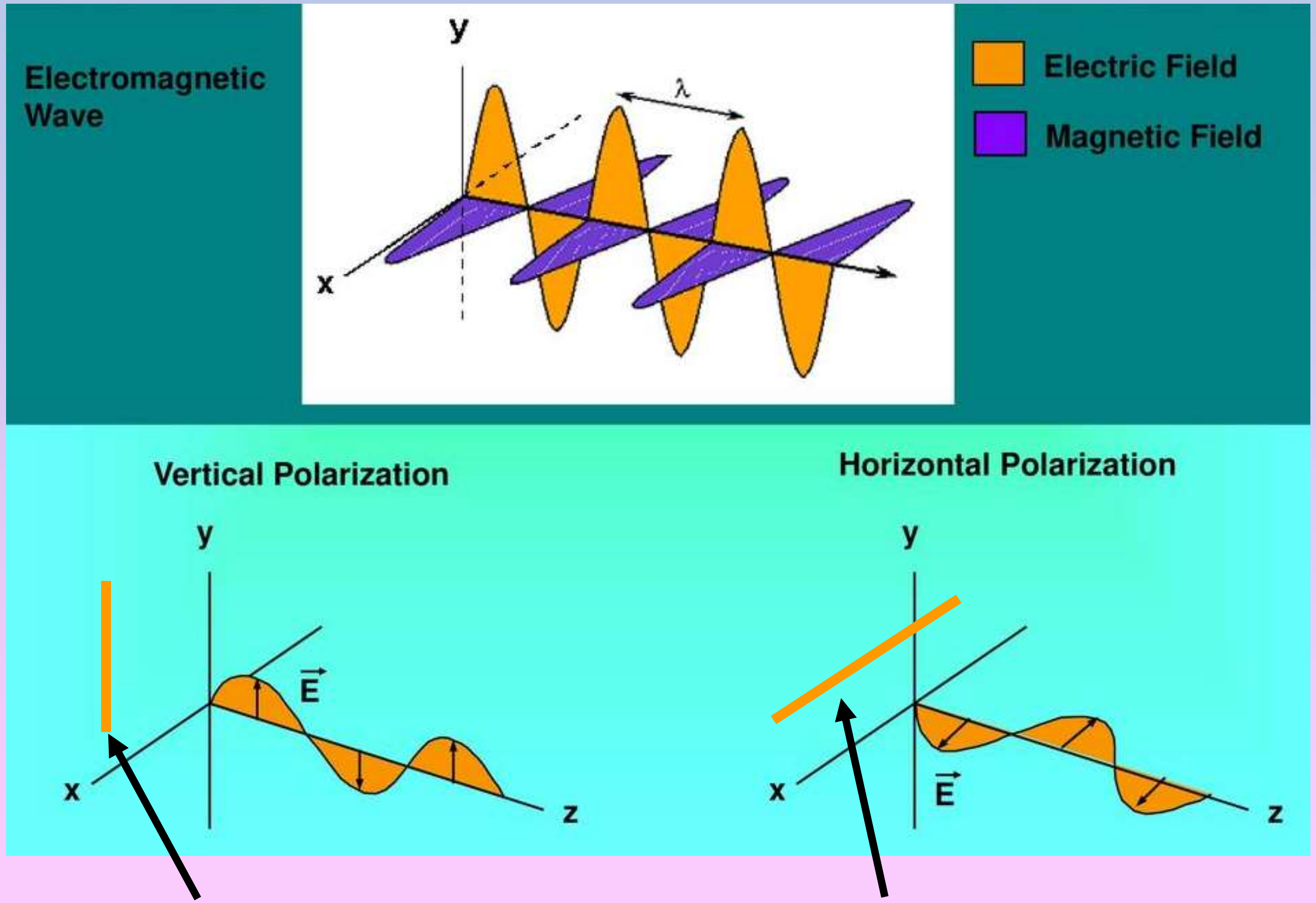
- Use a multimeter to measure current in circuit (a)
- Use a multimeter to measure current in circuit (b) when portable HAM radio is off and in transmit modes
  - Vary radio bands and distance, noting results





Polarization

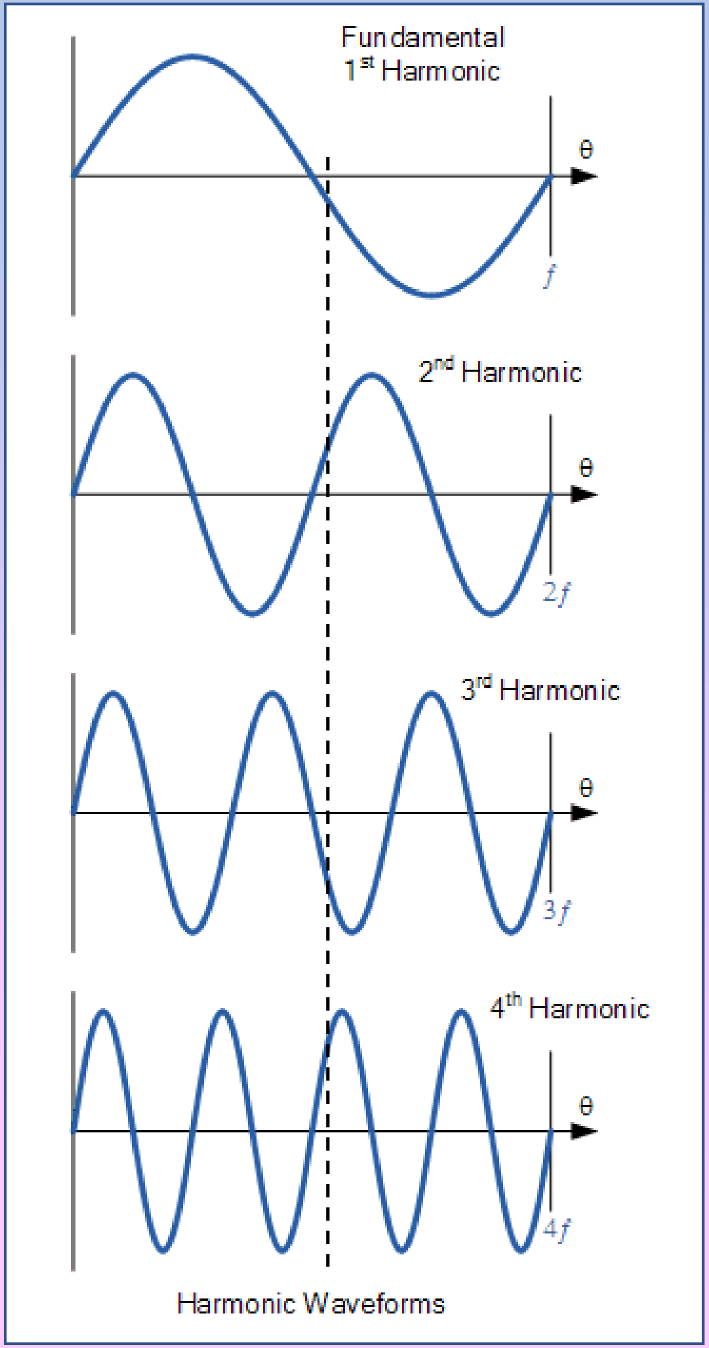
- Refers to the orientation of the radio wave's electric field
  - In a horizontally polarized radio wave, the electric field is oriented horizontally
  - In a vertically polarized radio wave, the electric field is oriented vertically



Transmitting/receiving antenna orientations

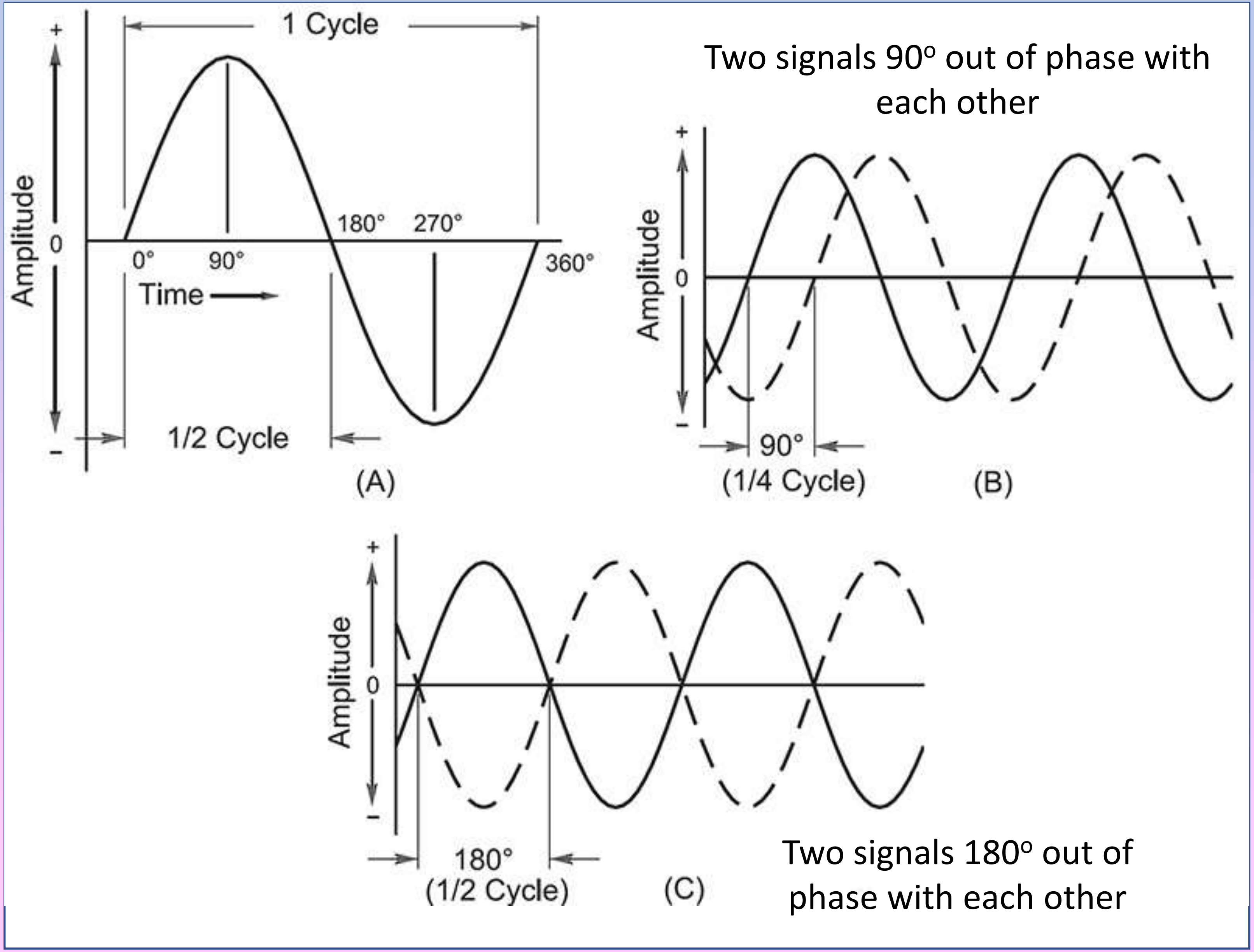
Harmonics

- A harmonic is a signal with a frequency is some multiple (x2, x3, x4, etc.) of a *fundamental* frequency
  - The harmonic at 2x the fundamental's frequency is called the *second harmonic*, at 3x the fundamental's frequency is called the *third harmonic*, and so forth
    - For example, the 2nd harmonic of a 15 MHz signal is 30 MHz and its 3rd harmonic is 45 MHz



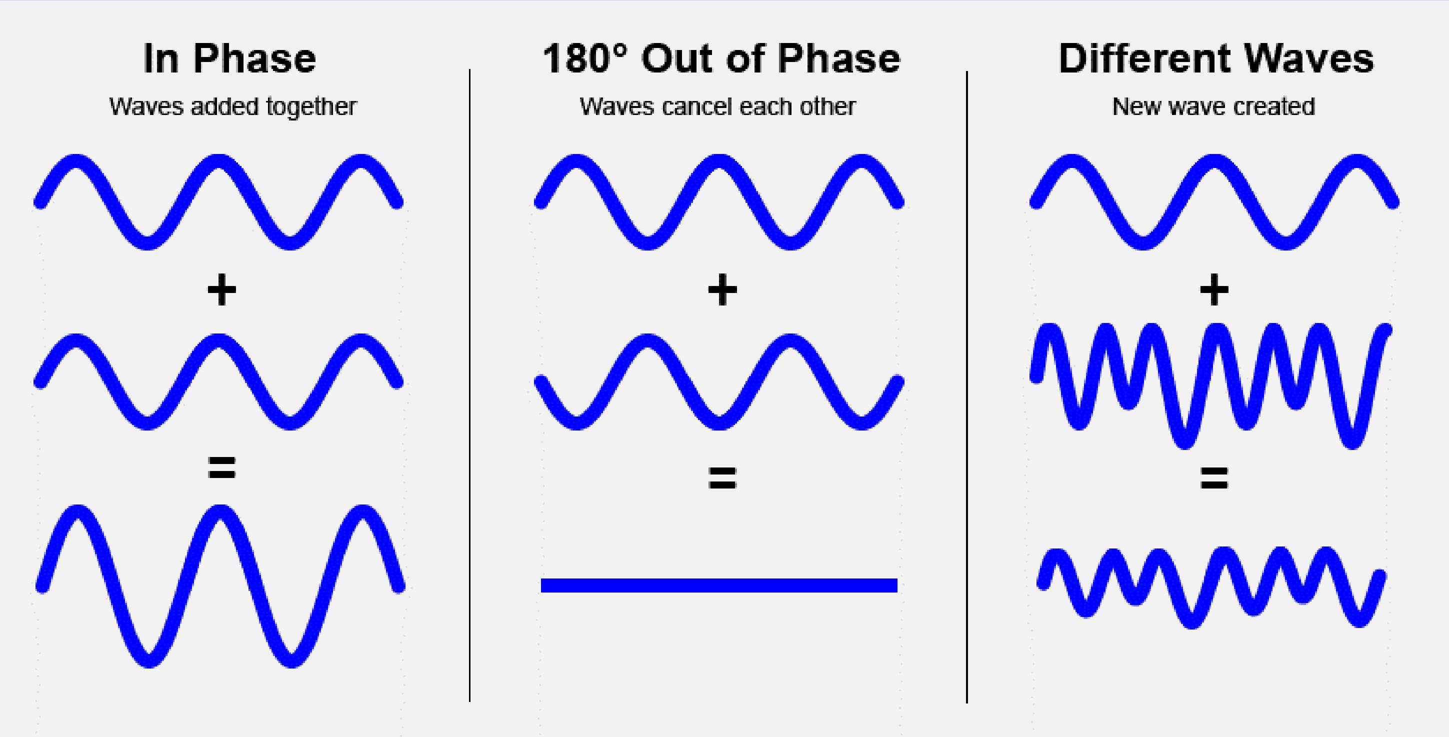
Phase

- Every cycle of a radio wave has the same basic shape: rising and falling and returning to where it started
  - Position within a cycle is called *phase*
  - Phase is used to compare how sine wave signals are aligned with time



Phase

- Depending on their phase, when two waves interact with each other they will cancel each other, result in a amplified/reduced signal, or create a different wave



Phase (Practical Application & Demo)

Using phase shifting techniques, active noise-canceling headphones actively erase lower-frequency sound waves

Components

- A **microphone** "listens" to external sounds that cannot be blocked passively
- **Noise-Cancelling electronics** sense the input from the microphone and generate a "fingerprint" of the noise, noting the frequency and amplitude of the incoming wave. Then they create a new wave that is 180º out of phase with the waves associated with the noise.
- The "anti-sound" created by the noise-canceling circuitry is fed into the headphones' **speakers** along with the normal audio; the anti-sound erases the noise by destructive interference, but does not affect the desired sound waves in the normal audio.
- A **battery** provides the energy needed for the electronics and speakers

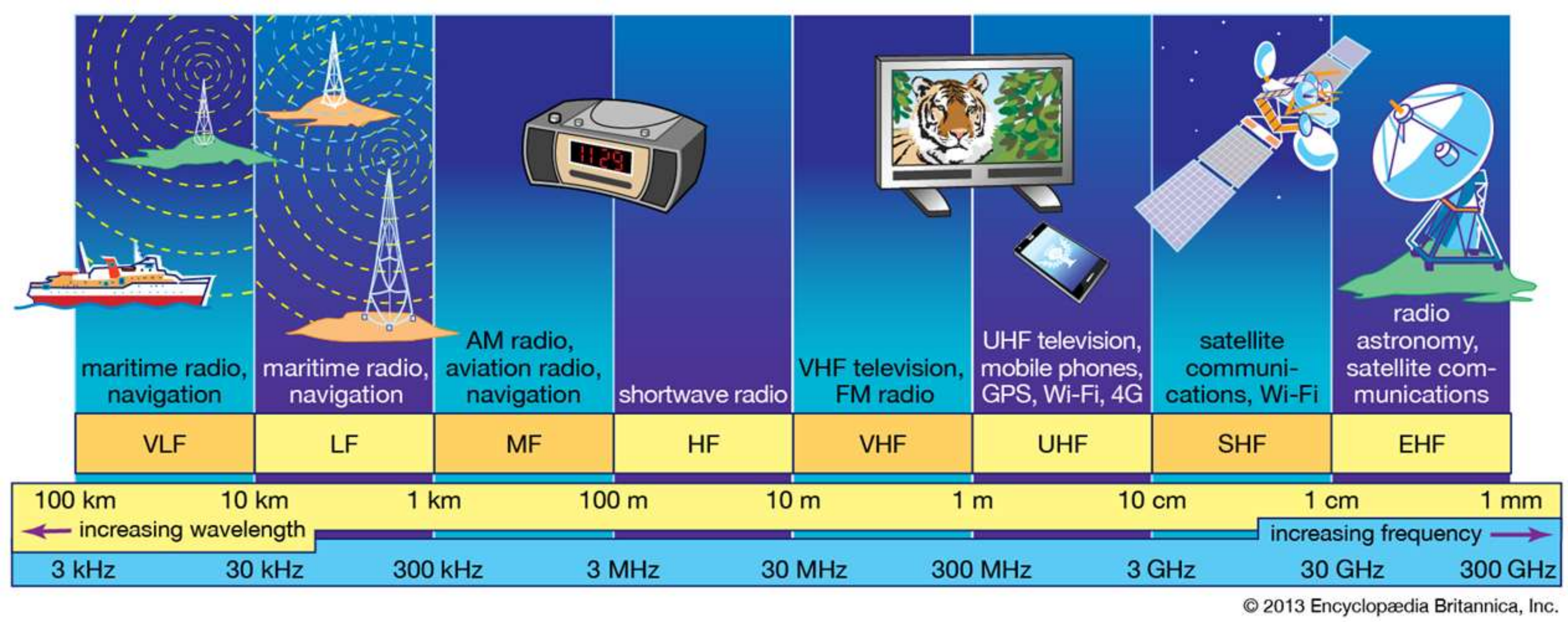
Phase – Instructor Demo

- Demonstrate how much quieter an active noise-cancelling headphone is than a traditional noise-isolation headphone

Traditional noise-isolation headphone

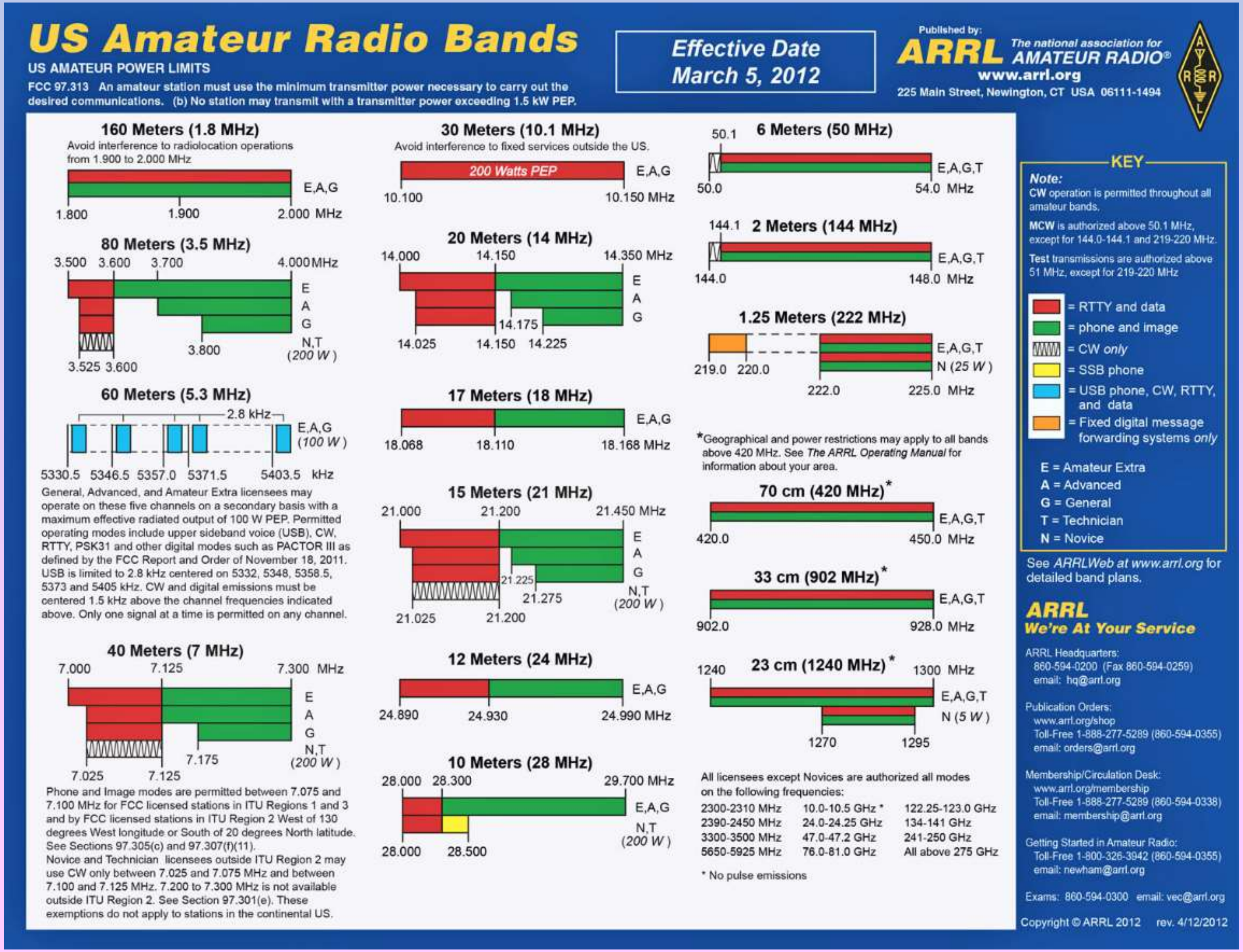
Active noise-cancellation headphone

Radio Spectrum



- 1,000,000 Hz = 1 X 10^6 Hz = 1 MHz
- Signals < 20,000 Hz (20 kHz) produce sound waves that humans can hear and are thus called *audio frequency* or *AF* signals. Signals that have a frequency > 20kHz are *radio frequency* or *RF* signals.

HAM Bands



US Amateur Radio Bands
US AMATEUR POWER LIMITS
FCC 97.313 An amateur station must use the minimum transmitter power necessary to carry out the desired communications. (b) No station may transmit with a transmitter power exceeding 1.5 kW PEP.
Effective Date March 5, 2012
Published by: ARRL The national association for AMATEUR RADIO® www.arrl.org 225 Main Street, Newington, CT USA 06111-1494
160 Meters (1.8 MHz)
Avoid interference to radiolocation operations from 1.900 to 2.000 MHz
E,A,G
1.800 1.900 2.000 MHz
80 Meters (3.5 MHz)
3.500 3.600 3.700 4.000 MHz
E A G N,T (200 W)
3.800
3.525 3.600
60 Meters (5.3 MHz)
2.8 kHz
E,A,G (100 W)
5330.5 5346.5 5357.0 5371.5 5403.5 kHz
General, Advanced, and Amateur Extra licensees may operate on these five channels on a secondary basis with a maximum effective radiated output of 100 W PEP. Permitted operating modes include upper sideband voice (USB), CW, RTTY, PSK31 and other digital modes such as PACTOR III as defined by the FCC Report and Order of November 18, 2011. USB is limited to 2.8 kHz centered on 5332, 5348, 5358.5, 5373 and 5405 kHz. CW and digital emissions must be centered 1.5 kHz above the channel frequencies indicated above. Only one signal at a time is permitted on any channel.
40 Meters (7 MHz)
7.000 7.125 7.300 MHz
E A G N,T (200 W)
7.175
7.025 7.125
Phone and Image modes are permitted between 7.075 and 7.100 MHz for FCC licensed stations in ITU Regions 1 and 3 and by FCC licensed stations in ITU Region 2 West of 130 degrees West longitude or South of 20 degrees North latitude. See Sections 97.305(c) and 97.307(f)(11).
Novice and Technician licensees outside ITU Region 2 may use CW only between 7.025 and 7.075 MHz and between 7.100 and 7.125 MHz. 7.200 to 7.300 MHz is not available outside ITU Region 2. See Section 97.301(e). These exemptions do not apply to stations in the continental US.
30 Meters (10.1 MHz)
Avoid interference to fixed services outside the US.
200 Watts PEP
E,A,G
10.100 10.150 MHz
20 Meters (14 MHz)
14.000 14.150 14.350 MHz
E A G
14.175
14.025 14.150 14.225
17 Meters (18 MHz)
E,A,G
18.068 18.110 18.168 MHz
15 Meters (21 MHz)
21.000 21.200 21.450 MHz
E A G N,T (200 W)
21.225
21.275
21.025 21.200
12 Meters (24 MHz)
E,A,G
24.890 24.930 24.990 MHz
10 Meters (28 MHz)
28.000 28.300 29.700 MHz
E,A,G
N,T (200 W)
28.000 28.500
6 Meters (50 MHz)
50.1
E,A,G,T
50.0 54.0 MHz
2 Meters (144 MHz)
144.1
E,A,G,T
144.0 148.0 MHz
1.25 Meters (222 MHz)
E,A,G,T
N (25 W)
219.0 220.0
222.0 225.0 MHz
*Geographical and power restrictions may apply to all bands above 420 MHz. See The ARRL Operating Manual for information about your area.
70 cm (420 MHz)*
E,A,G,T
420.0 450.0 MHz
33 cm (902 MHz)*
E,A,G,T
902.0 928.0 MHz
23 cm (1240 MHz)*
1240 1300 MHz
E,A,G,T
N (5 W)
1270 1295
All licensees except Novices are authorized all modes on the following frequencies:
2300-2310 MHz 10.0-10.5 GHz * 122.25-123.0 GHz
2390-2450 MHz 24.0-24.25 GHz 134-141 GHz
3300-3500 MHz 47.0-47.2 GHz 241-250 GHz
5650-5925 MHz 76.0-81.0 GHz All above 275 GHz
* No pulse emissions
KEY
Note:
CW operation is permitted throughout all amateur bands.
MCW is authorized above 50.1 MHz, except for 144.0-144.1 and 219-220 MHz.
Test transmissions are authorized above 51 MHz, except for 219-220 MHz.
= RTTY and data
= phone and image
= CW only
= SSB phone
= USB phone, CW, RTTY, and data
= Fixed digital message forwarding systems only
E = Amateur Extra
A = Advanced
G = General
T = Technician
N = Novice
See ARRLWeb at www.arrl.org for detailed band plans.
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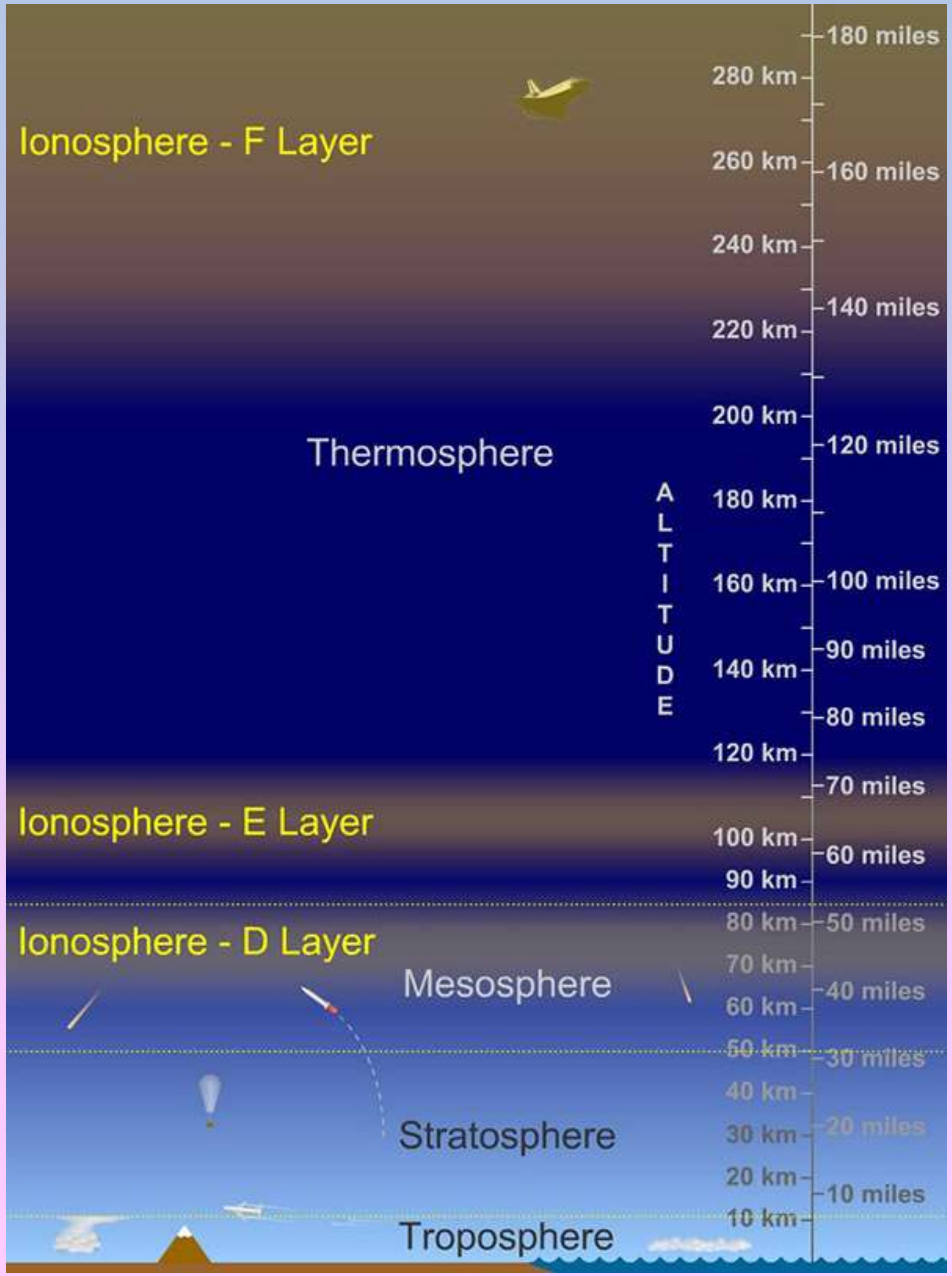
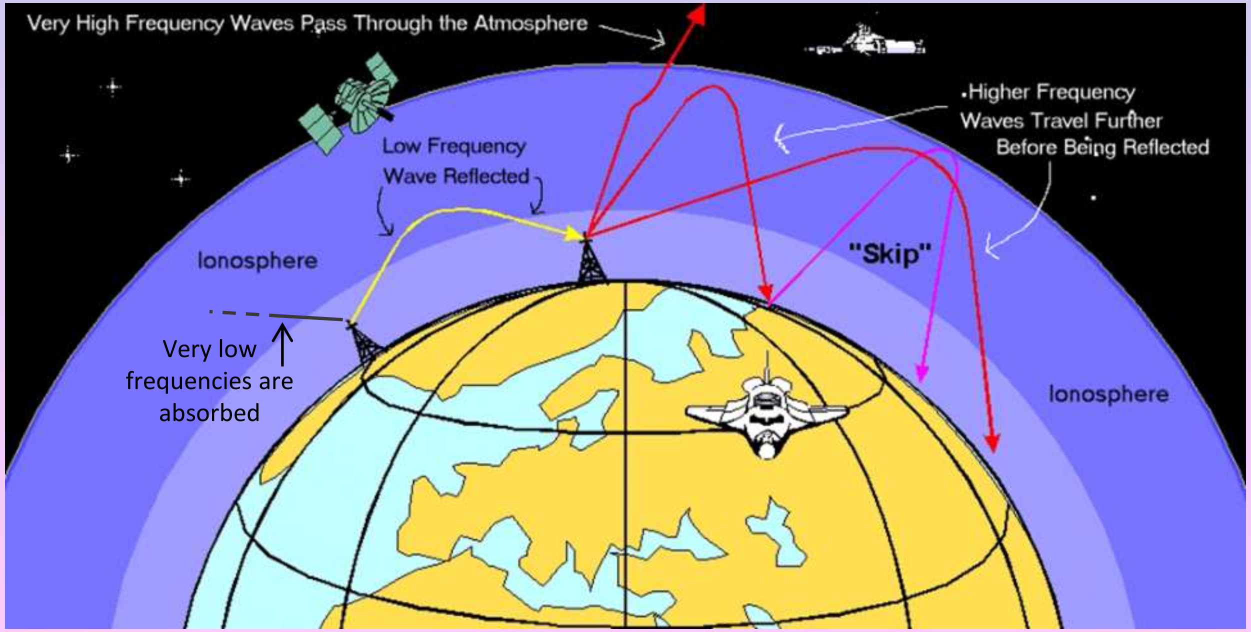
Atmospheric Effects

- The earth's atmosphere is divided into distinct regions
- The ionosphere plays a major role in the propagation of radio signals
  - This region occupies a zone 30 to 260 miles above the Earth
  - Exposure to intense ultraviolet (UV) light from the sun causes the ionosphere to become weakly conducting



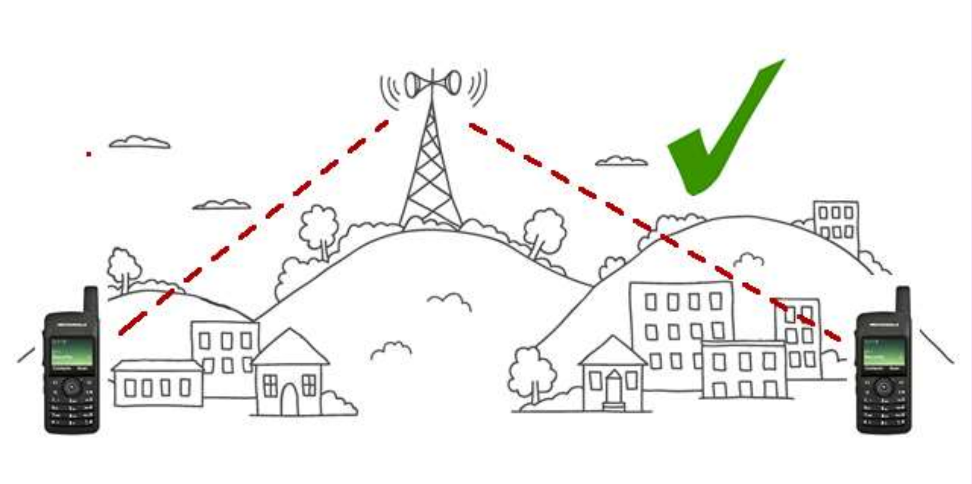
Atmospheric Effects

- Radio waves are: 1) absorbed by or pass through the ionosphere, or 2) are reflected by the ionosphere back to earth
  - Very low frequencies (≤ 30 kHz) are usually absorbed
  - Lot to medium frequency signals (30kHz to 3 MHz) bounce back
  - High frequency signals (3 MHz to 30 MHz) travel further before being bounced back
  - Very high and higher frequencies (≥ 30 MHz) usually pass through the ionosphere



Repeaters

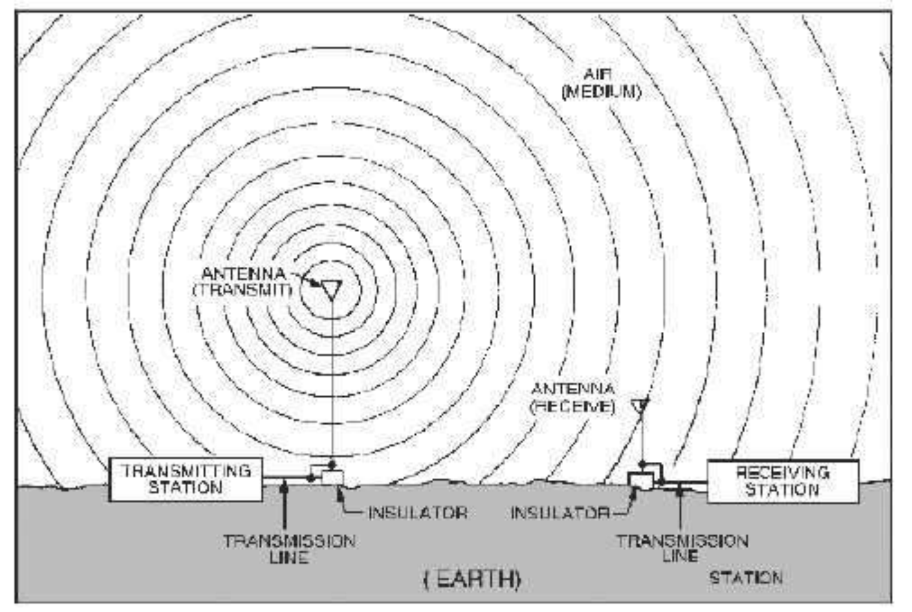
- Repeater towers greatly increase the range of a portable hand-held radio, no matter the wattage
- Act as both a radio receiver and transmitter, receiving low powered signals and then blasting them out with even more power and covering longer distances without degradation of the origin signal, allowing users to communicate clearly while miles apart



Repeater towers are usually placed at high locations, such as on top of hills or mountains

Antennas – Introduction

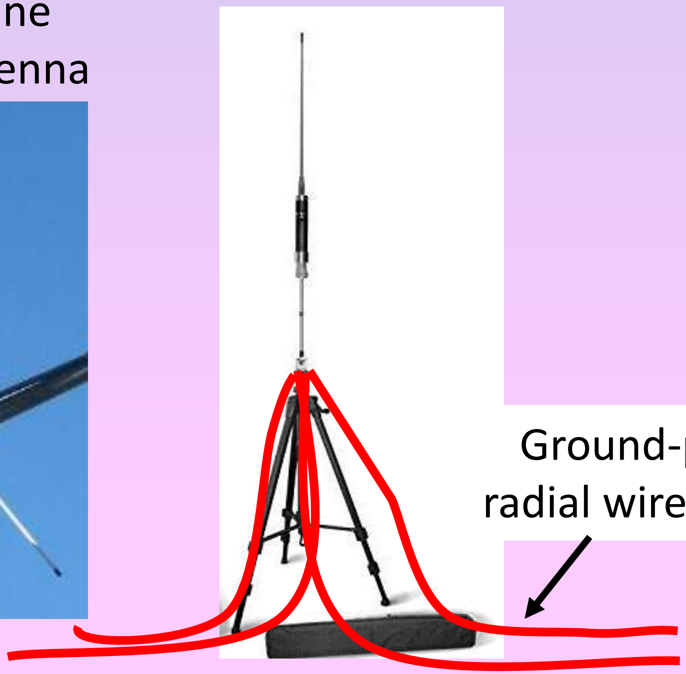
- Consists of an electrical conductor, usually a wire, rod, or pipe that radiates and receives radio signals
- For an antenna to work properly, its dimensions must be an appropriate fraction of the signal's wavelength
- Radio frequency (RF) current in an antenna creates radio waves that travel away from the antenna, spreading out into space like ripples traveling across water



Antennas – Simple Systems

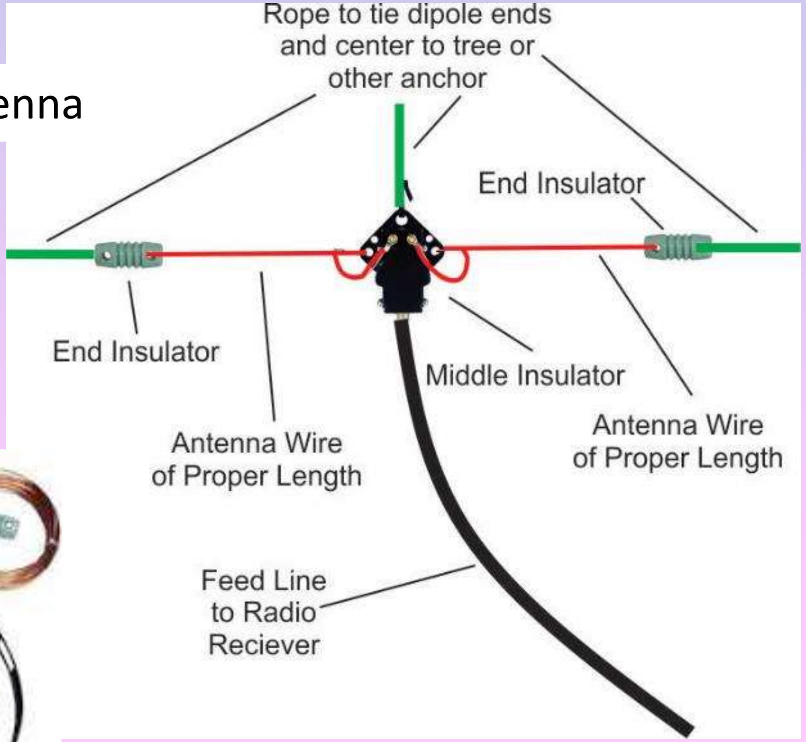
- Practical simple antenna systems
  - Dipole, which is normally oriented horizontally and thus radiates a horizontally polarized signal
  - Ground-plane (vertical)

Ground-plane (vertical) Antenna



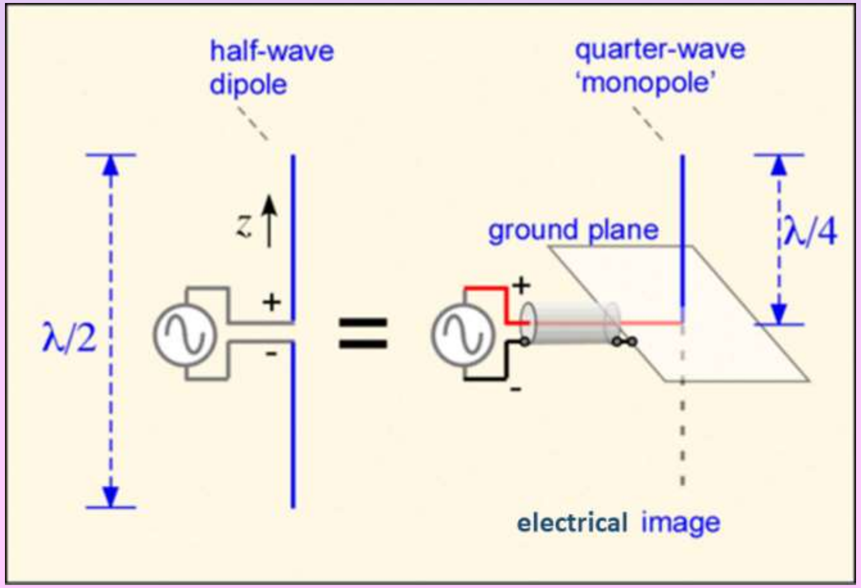
Ground-plane radial wire screen

Dipole Antenna



Antennas – Ground-Plane

- In a ground-plane (vertical) antenna, the ground-plane makes up an electrical mirror that creates an image of the missing half of the antenna
  - The result is an antenna that acts very much like a dipole
  - Ground-plane can be made up of a screen or wires or a metal surface



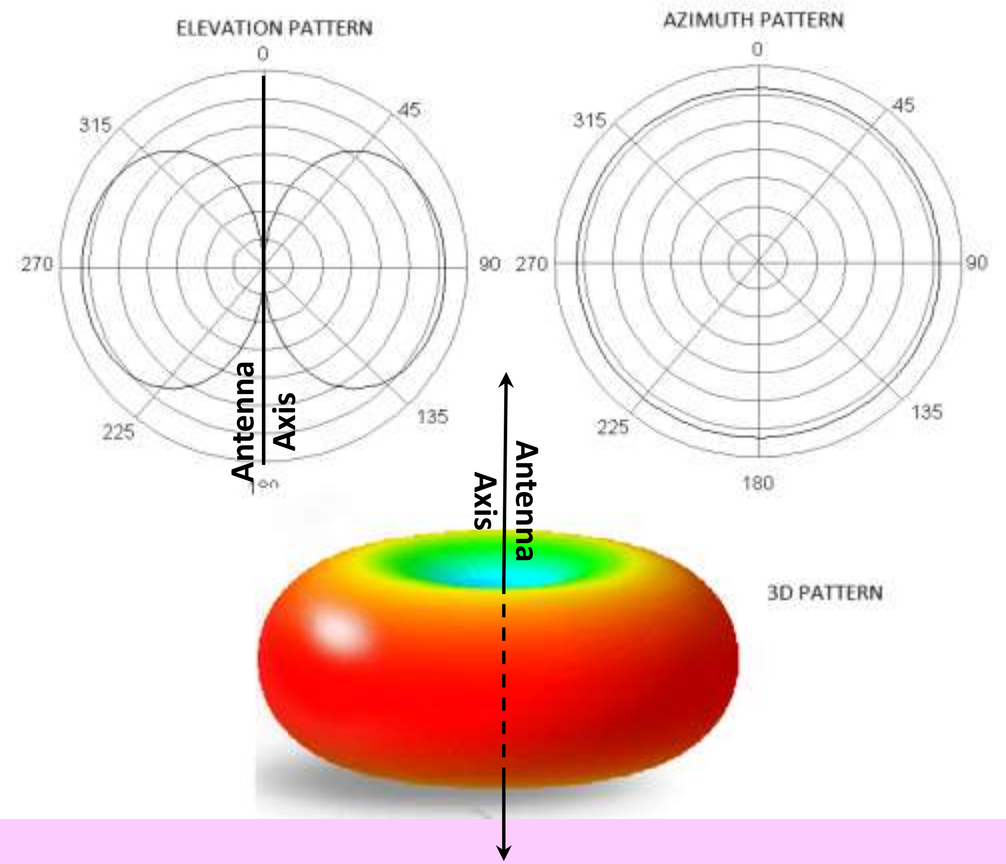
Antennas – Gain

- Concentrating an antenna's radiated signals in a specific direction is called *gain*
  - Antenna gain increases signal strength in a specific direction when compared to a reference antenna
  - Gain aids communication in the preferred direction by increasing transmitted and received signal strengths
- Antenna gain is measured in decibels (dB) with respect to some type of reference antenna
  - dB = 10 log (power ratio) or dB = 10 log (voltage ratio)
  - Examples
    - ❖A power increase from 5 watts to 15 watts = 10 log ($\frac{15}{5}$) = 10 log (3) = 4.77 dB
    - ❖A power reduction to 2 watts from 10 watts = 10 log ($\frac{2}{10}$) $=$ 10 log (0.2) = -7 dB)

Antennas – Radiation

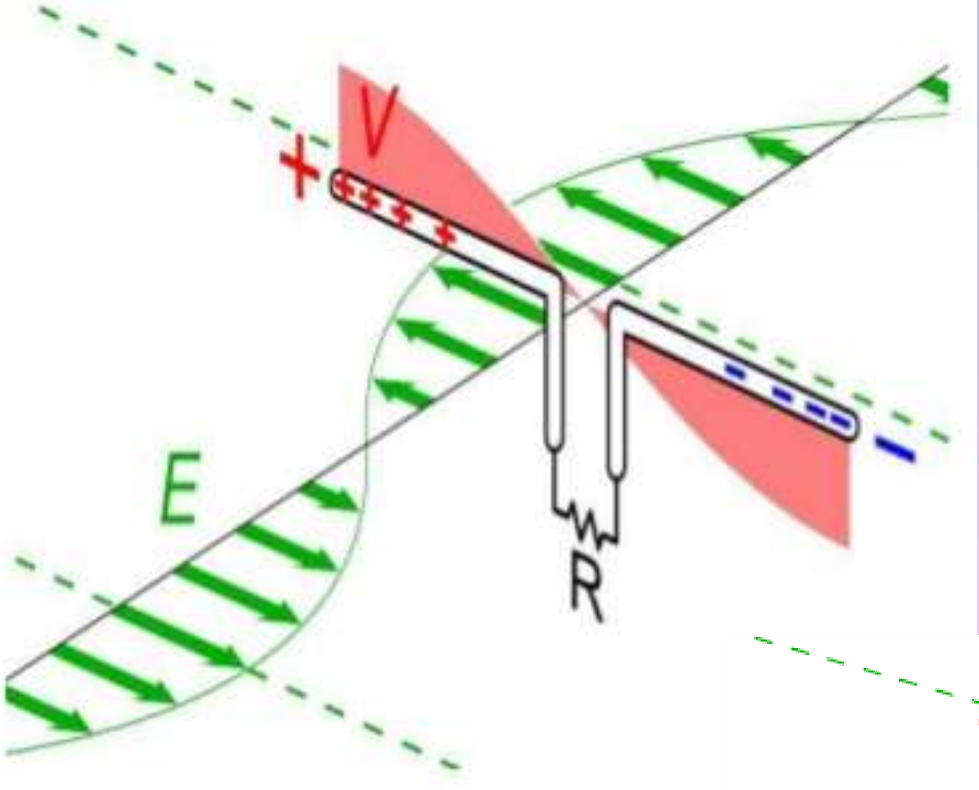
- The easiest way to describe how an antenna distributes its signals is a graph showing the antenna's gain (radiation pattern) in any direction around the antenna
  - Looking down on the antenna from above, azimuth radiation pattern shows how well the antenna transmits or receives in all horizontal directions
  - The elevation pattern looks at the antenna from the side to see how well it receives and transmits at different angles above the horizon plane

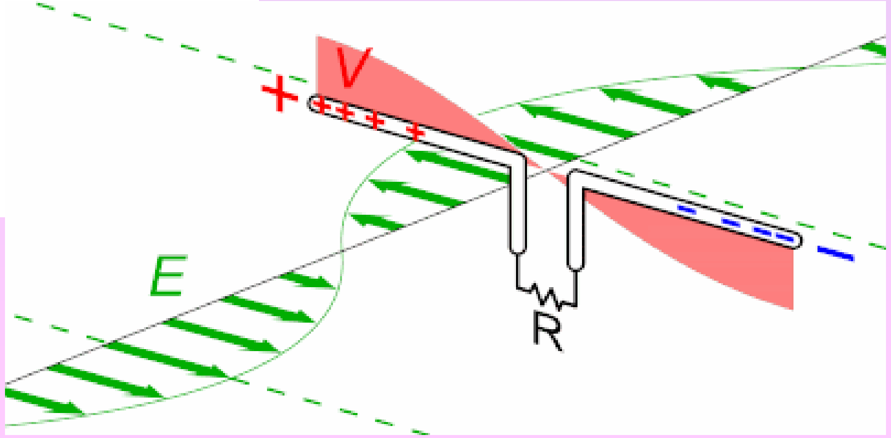
The radiation pattern of a dipole antenna far from the ground (in free space). Note that it radiates strongest perpendicular to the axis of the antenna and weakest off its end.



Antennas – Simple Dipoles

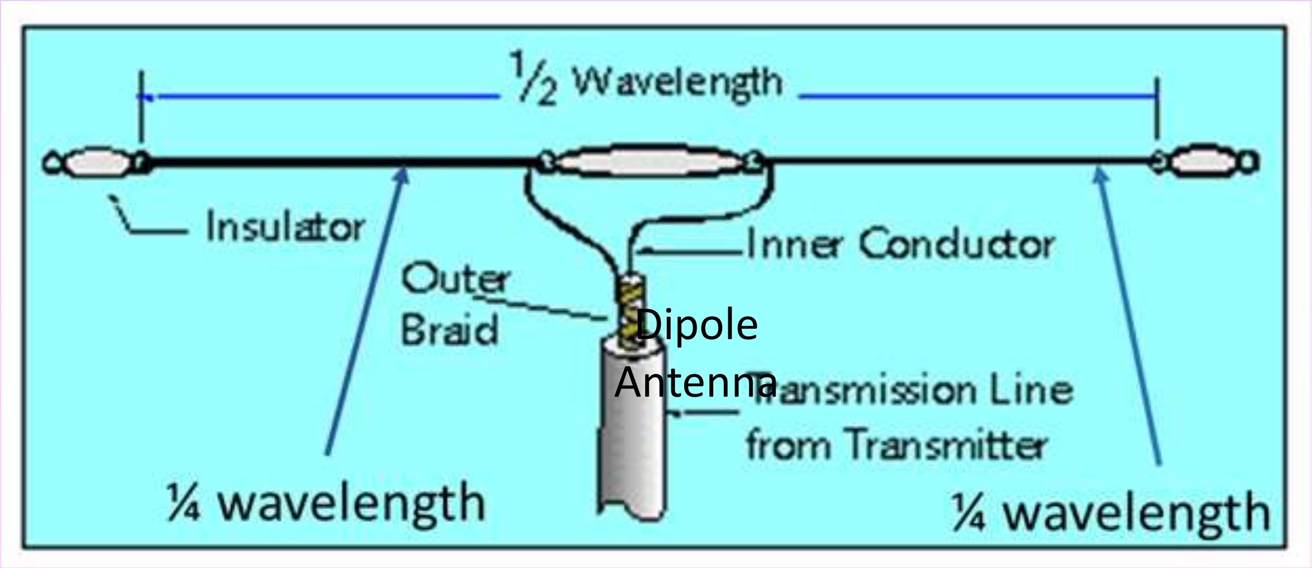
A half-wave dipole antenna receiving power from a radio wave. The electric field of the wave (E, green arrows) pushes the electrons in the antenna elements back and forth (black arrows), charging the ends of the antenna alternately positive and negative. Since the antenna is a half-wavelength long at the radio wave's frequency, it excites standing waves of voltage (V, red) and current in the antenna. These oscillating currents flow down the transmission line into the radio receiver (represented by the resistor R). The action is shown slowed down in this animation.

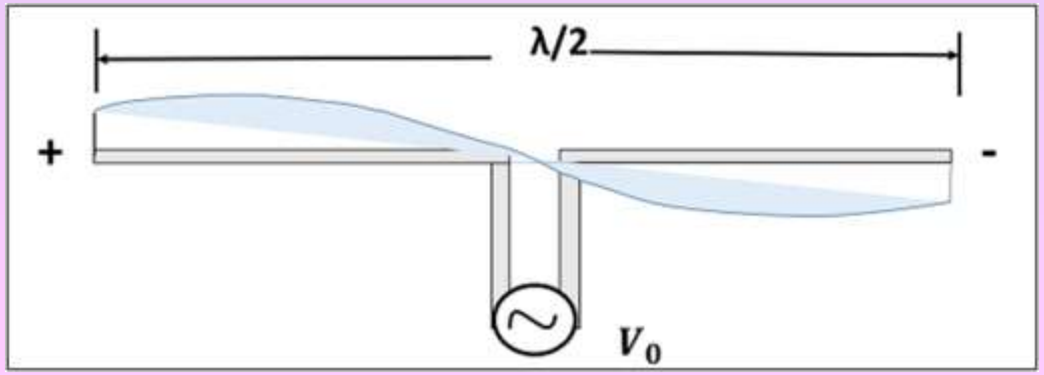




Antennas – Simple Dipoles

- A resonate dipole antenna is ½ λ long
  - In feet, ½ λ = $\frac{468}{f\ in\ MHz}$
  - For example, a 10 MHz dipole antenna is $\frac{468}{10}$ = 46.8 feet long total, so each leg is ¼ λ = $\frac{46.8}{2}$ = 23.4 feet long





Antennas – Ground-Plane (Vertical)

- The length of a ground-plane (vertical) antenna in feet = $\frac{234}{f\ in\ MHz}$
  - For example, at 50 MHz, a ground-plane antenna is $\frac{234}{50}$ = 4.68 feet long
- The ground-plane should extend at least ¼ λ from the base of the antenna in all directions

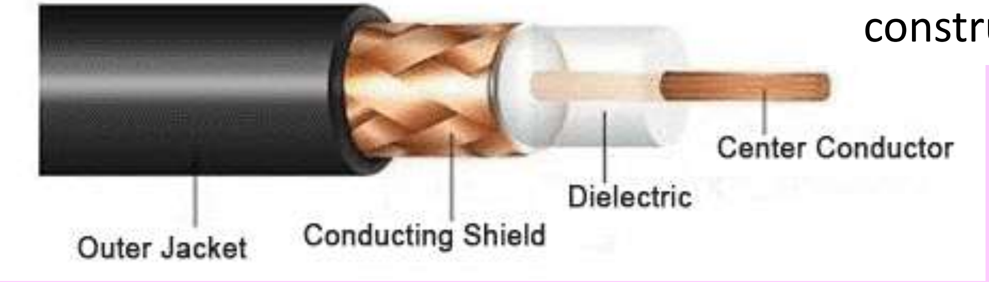
Feed Lines – Introduction

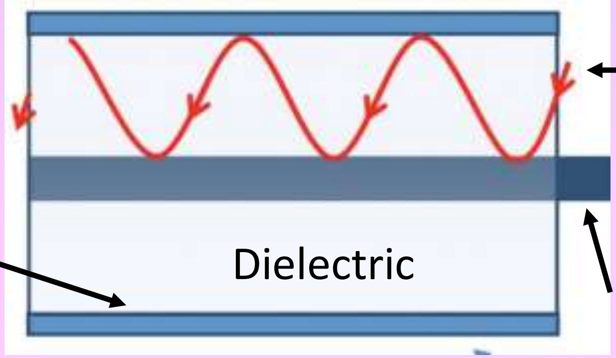
- Used to connect the radio to the antenna and when an RF signal must be conducted from one piece of equipment to another
- Made from two conductors separated by an insulating material
- The radio signal is carried on the conductors and in the space between them
- Use special materials and construction methods to minimize power being dissipated as heat by *feed line loss* to avoid signals leaking in or out

Feed Lines – Coax Cable

- *Coaxial cable (coax)* is the most popular feed line
  - A wire *center conductor* is surrounded by insulation (dielectric)
  - The insulation is covered by a tubular *shield* of braided wire or foil
    - ❖Hence the name "coaxial" comes from the common central axis of the center conductor and the shield
  - The cable is protected by a plastic sheath called the *jacket*
  - Coaxial cable carries the radio signal on the surface of the center conductor and the inside surface of the shield

Coaxial cable construction

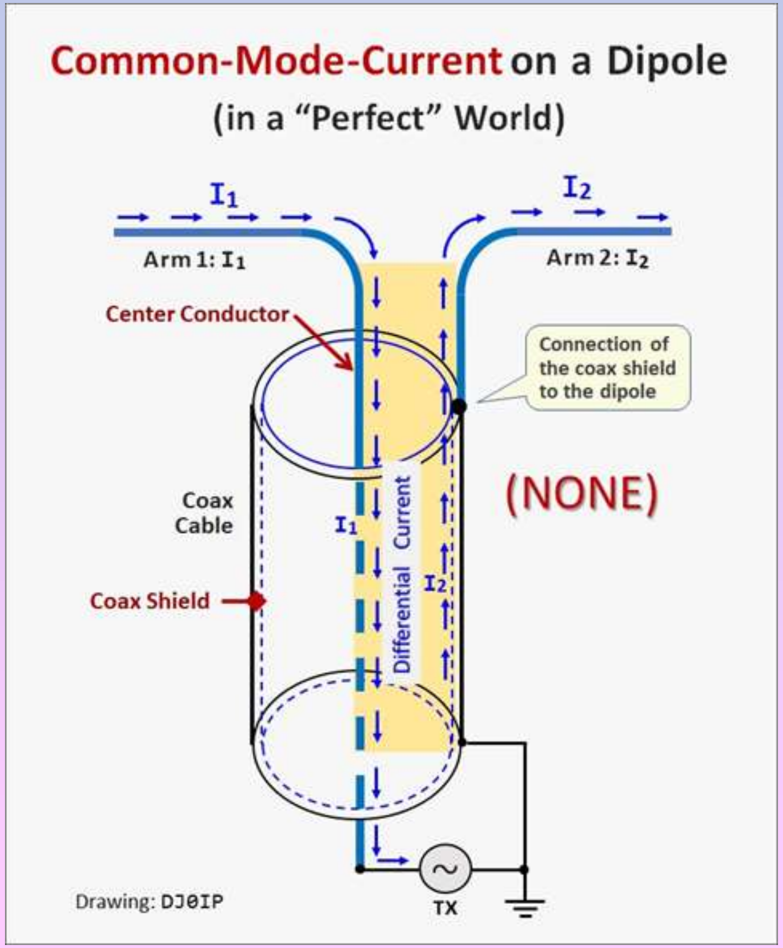


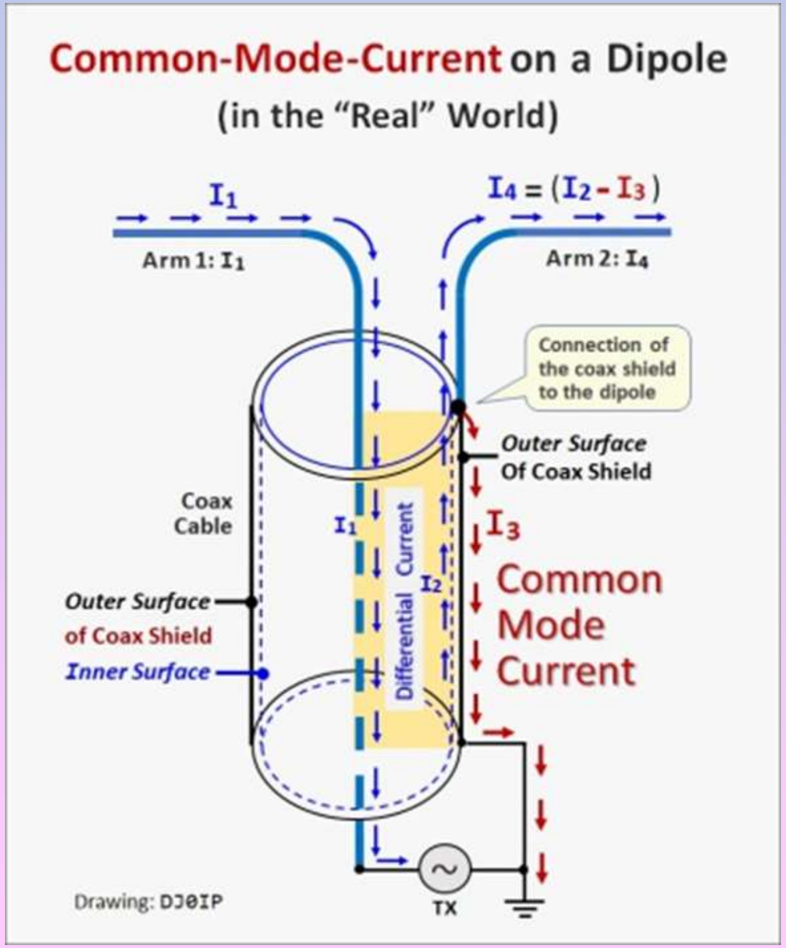


Coax Cable Feed Lines – Balun

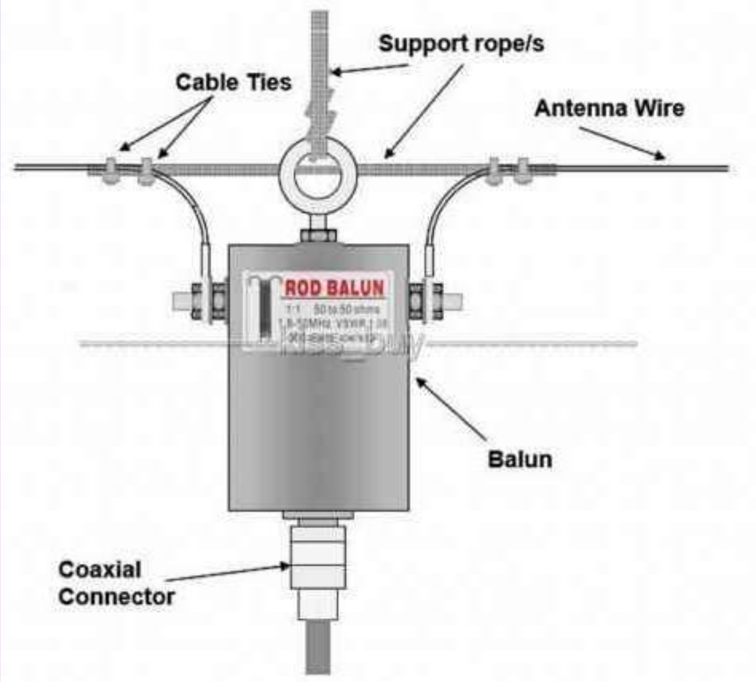
- We want RF Current to flow *inside* of the coax feed line, from the transmitter to the antenna, and then be radiated by (*and only by*) the antenna.
  - In reality, there is always a little bit of RF flowing along the *outside* of the coax shield (known as *Common-Mode-Current*)
  - A little bit of RF flowing on the *outside* of the shield usually does not harm anything and is unnoticeable
  - Unfortunately there is often a lot of RF flowing on the *outside* of the shield and this can have many significant consequences:
    - ❖Burning of the operator's fingers or lips on the radio equipment, such microphone
    - ❖Erroneous readings of instruments
    - ❖False equipment faults
    - ❖RF Interference to consumer products, (i.e., telephone, computer, TV, etc.)

Coax Cable Feed Lines – Balun



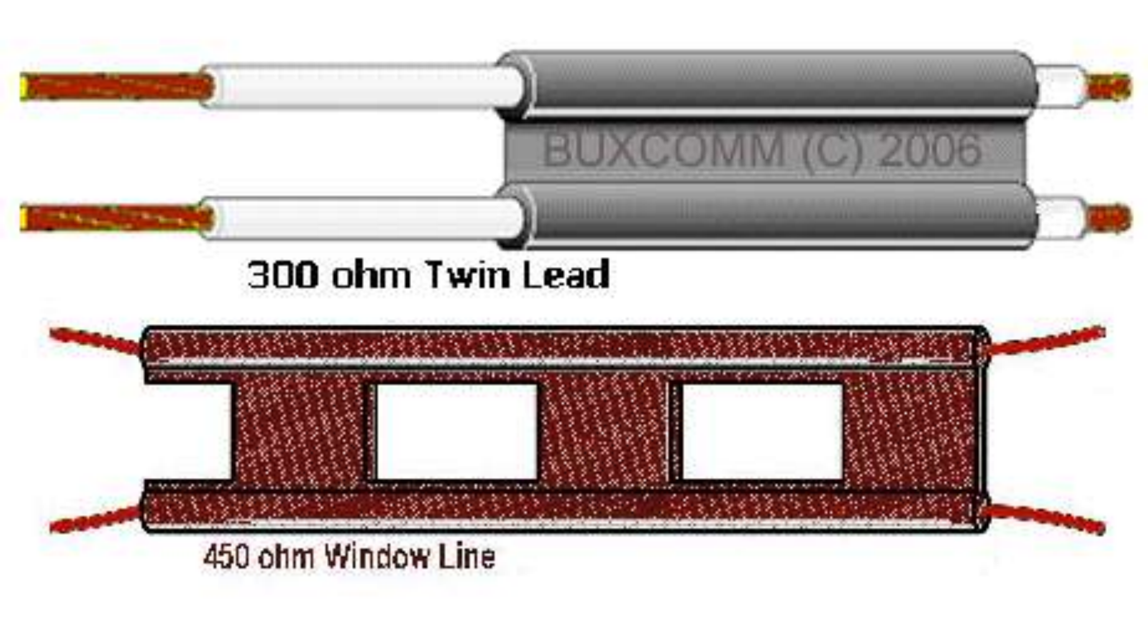


A *balun* forces an unbalanced transmission line to properly feed a balanced component. This is done by forcing the common-mode-current to be zero (often called choking the current or a current choke).



Feed Lines – Open-Wire

- Open-wire lines are also used as feed lines for dipole antennas
  - Consist of two parallel conductors separated by insulation
  - Often referred to as a open-wire, ladder line, window line, or *twin-lead*



Feed Lines - Impedance

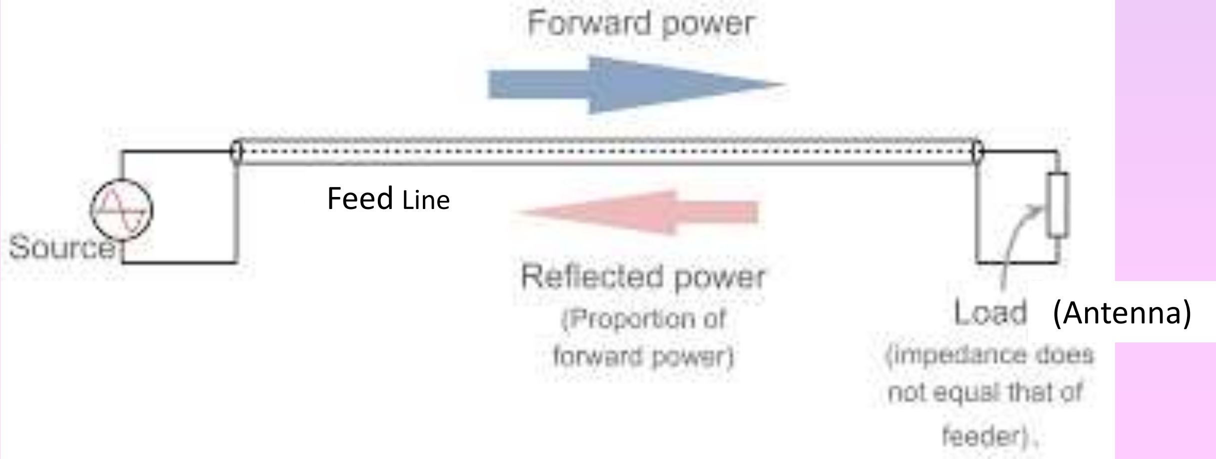
- Feed lines have a *characteristic impedance* (Z_o), which is a measurement of how energy is carried by the feed line
  - Impedance is the amount of resistance that a device offers to current flow in a circuit at a specific frequency

    - Reactive components such as capacitors and inductors change the amount of resistance they offer in a circuit depending on the input signal’s frequency
    - Impedance varies according to the frequency of the signal entering the device

  - Just like resistance, the unit to measure impedance is ohms(Ω)
  - Resistance is a value and measure which is independent of frequency
    - Frequency doesn't affect the resistance of nonreactive devices such as resistors and conductors

Standing Wave Ratio (SWR)

- The power of a feed line is transferred completely to a load, such as an antenna when the load and feed line impedance are identical or matched
  - If the feed line and load impedance do not match, some of the power is reflected by the load
  - The greater the difference between the feed line and load impedances, the more power is reflected by the load



Standing Wave Ratio (SWR)

- Reflected and forward power traveling in opposite directions creates a stationary wave-like interference pattern in the feed line called a *standing wave*
- SWR is determined by the amounts of forward and reflected power and changes with frequency
  - Thus, SWR is a measure of how well the antenna (or load) and feed line impedances are matched
  - A SWR of 1:1 means that there is no reflected power and thus no interference pattern, called a *perfect match* condition
  - A SWR of > 1:1 is an impedance mismatch and thus some power is reflected back to the transmitter through the feed line

Standing Wave Ratio (SWR)

- Low SWR = less power reflected by the antenna
- High SWR = Voltages increase can damage a transmitter (>2:1 may cause the transmitter’s protection circuits to reduce power automatically to avoid damage to the transmitter’s electronics)
  - High SWR often caused by antennas that are much too short or too long for the frequency being used

SWR	% Transmitted Power	SWR	% Transmitted Power
1:1	100	3:1	75
1.5:1	96	4:1	64
2:1	89	5:1	56
2.6:1	80	6:1	49

Radio Types

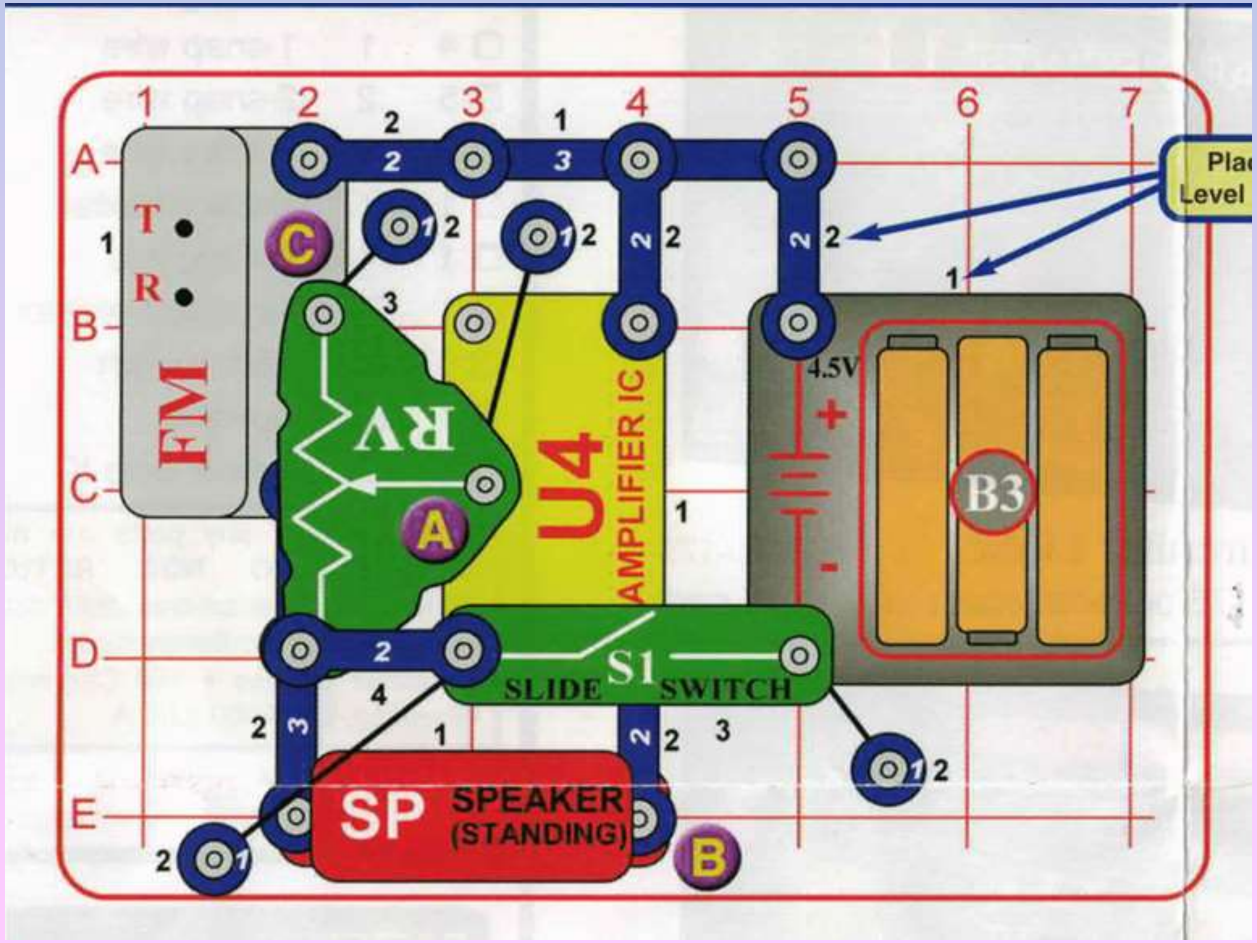
- All radio equipment is designed to generate or manipulate radio signals
- Two common types of radios
  - Those that only receive radio waves (receivers) and turn them it into a voice, digital data, or even Morse Code
  - Those that transmit and receive radio waves (transceivers)

Activity – Youngest Cabin

- Activity #1 = Build and use a FM portable radio (Elenco Snap Circuits FM Radio Discover Kit, ASIN B01GHN65CU, Amazon Web Page = https://www.amazon.com/gp/product/B01GHN65CU/ref=ppx_yo_dt_b_asin_image_o02_s00?ie=UTF8&psc=1)

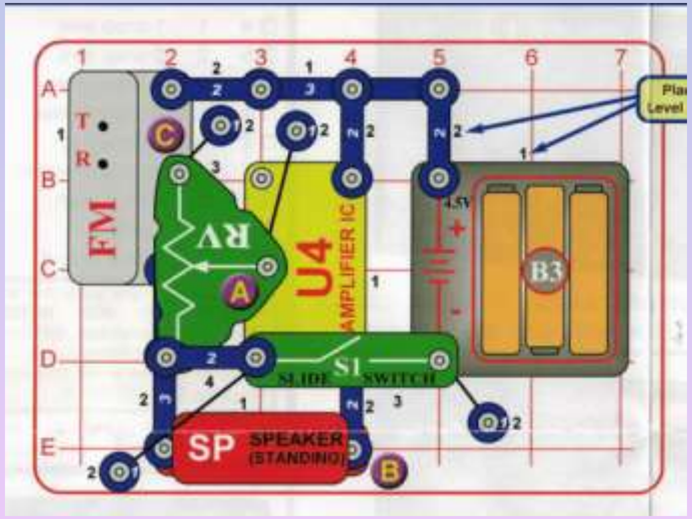
FM Radio Components

- B3 = Battery holder
- FM = FM module
- RF = Adjustable resistor
- S1 = Slide switch
- SP = Speaker
- U4 = Power amplifier



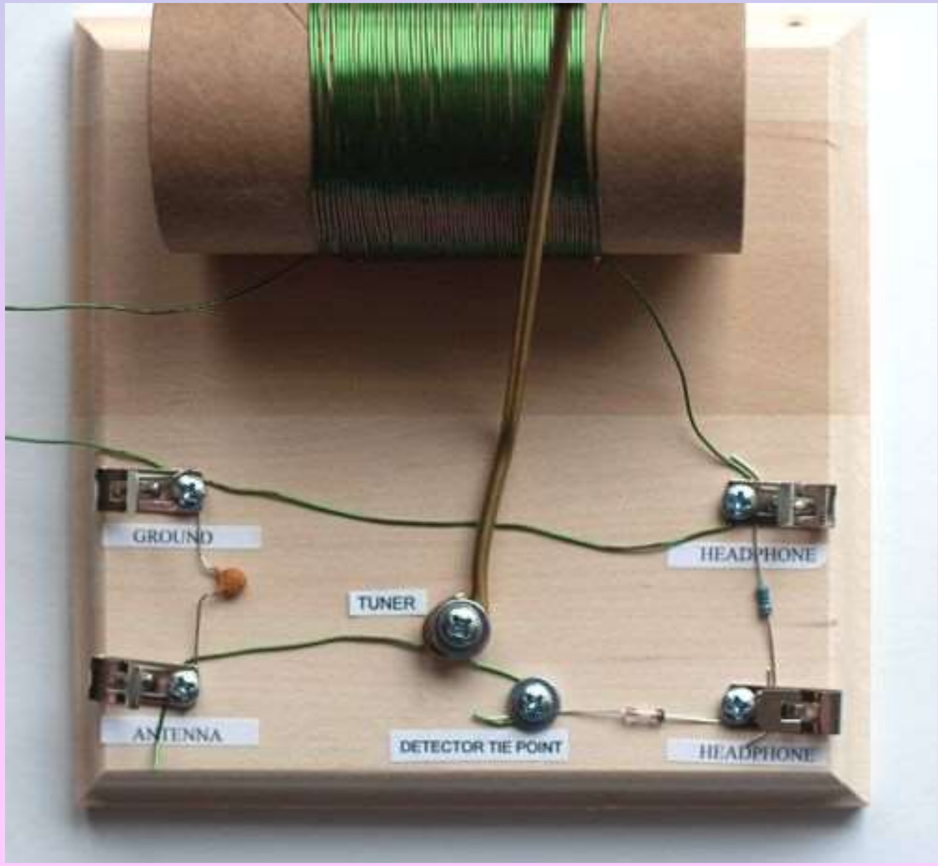
FM Radio – How it Works

- Pressing the T button on the FM module causes the frequency of a local oscillator (F_o) inside the module to increase
  - F_o is compared to incoming FM radio station frequencies
  - The FM radio station frequency that is a specific value below F_o is allowed to pass through the rest of the FM radio circuit components
  - Pressing the T button again starts the cycle again, increasing F_o
  - Pressing the R button resets everything at the bottom of the FM frequency band

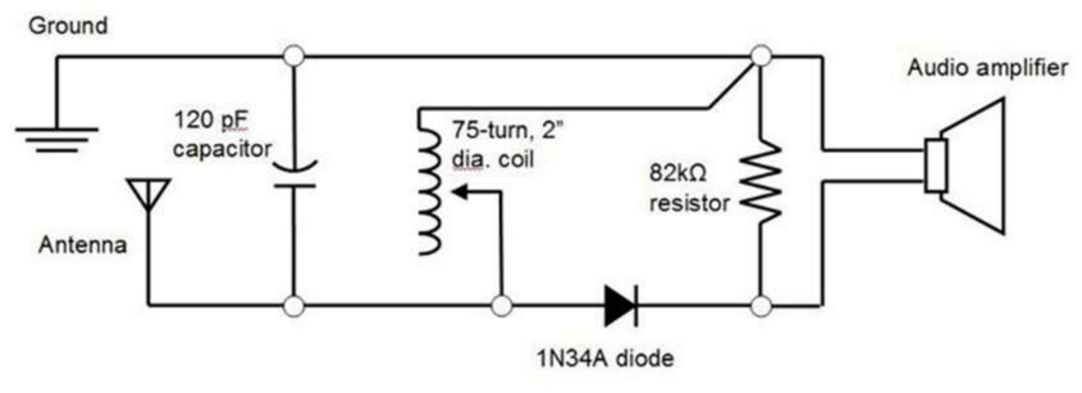


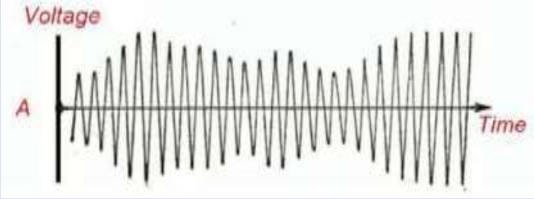
Activity – Middle Age Cabins

- Activity #1 = Build and use an AM crystal radio

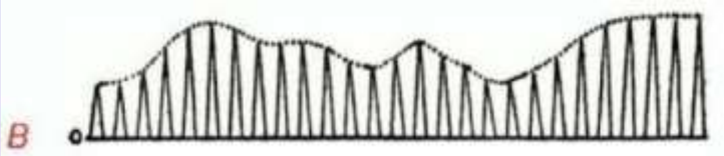


AM Crystal Radio Circuit Diagram





AC from antenna



Rectification of AC by diode into DC

The **antenna** picks up AM waves, which creates and **alternating current (AC)** in the antenna wire

A **diode** is a circuit component that allows current to flow in one direction (+ or -). This process is called rectification, and it results in alternating current being changed to **direct current (DC).** When crystal radios were first made, the diode was composed of a thin wire that scratched against the surface of a crystal of semi conductive material, thus imparting the name "crystal" radio.

The **earphones** convert the direct current to sound. The electrical current is converted into vibration, and that vibration generates sound waves.

The **tuner** allows you to select the AM frequency for the crystal radio to zone in on. The tuner has many coils of wire. By changing how much coil is used, you change the tuner's **resonant frequency and thus the inductance of the coil**. This allows you to "tune" in to a specific station by matching the tuner's resonant frequency to the station's broadcast frequency. The tuner coil in the circuit is also called an **inductor**.

The **electrical ground** allows current to flow through the circuit. All circuits need a ground to work properly.

The **capacitor** is a circuit component that can store and electrical charge and also allows for better tuning.

Activity – Oldest Campers Group 1

- Activity #1 = Build and tune a 15 meters λ band dipole antenna
  - λ in meters = $\frac{300}{f\ in\ MHz}$ and total length of antenna in feet = ½ λ = $\frac{468}{f\ in\ MHz}$
    - ❖ Therefore, f in MHz = $\frac{300}{\lambda\ in\ meters}$ = $\frac{300}{15}$ = 20 MHz. Since the 15 meter band covers 21 Mhz to 21.2 Mhz, build antenna for middle of range and thus 21.1 MHz
  - Thus, total length of antenna in feet = ½ λ = $\frac{468}{21.1}$ = 22.2 feet
    - ❖ Each leg of the antenna = ¼ λ = $\frac{22.2\ feet}{2}$ = 11.1 feet long
    - ❖ Add additional length to be able to tune antenna. Commonly, the formula $\frac{490}{f\ in\ MHz}$ is used, so make total length of antenna = $\frac{490}{21.1}$ = 23.2 feet long and thus each leg $\frac{23.2}{2}$ = 11.6 feet = 11 feet, 7 ¼ inches long at first
  - Feeder line will be a RG-58 coax cable (thus, cable impedance = 50 Ω)

Activity – Oldest Campers Group 1

- Activity #1 = Build and tune a 15 meters λ band dipole antenna
  - Use a 1:1 current Balun as the center insulator
  - Use a SWR antenna analyzer to tune the antenna, making physical adjustments as necessary to achieve minimize SWR
- Activity #2 =
  - Use hand held ham radio capable of 70 cm and 2 meter bands to talk to people. Illustrate the use of repeater towers.
  - Set up a vertical antenna and ham base station ham radio capable of 6 meter, 10 meter, 12 meter, 15 meter, 17 meter, 20 meter, 30 meter, and 40 meter bands and talk to people around the world
  - Hook up the 15 meter dipole made previously to the ham base station and talk to people

Activity – Oldest Campers Group 2

- Activity #1 = Build and tune a 6 meters λ band dipole antenna.
  - λ in meters = $\frac{300}{f\ in\ MHz}$ and total length of antenna in feet = ½ λ = $\frac{468}{f\ in\ MHz}$
    - ❖ Therefore, f in MHz = $\frac{300}{\lambda\ in\ meters}$ = $\frac{300}{6}$ = 50 MHz. Since the 6 meter band covers 50 Mhz to 54 Mhz, build antenna for middle of range and thus 52 MHz
  - Thus, total length of antenna in feet = ½ λ = $\frac{468}{52}$ = 9 feet
    - ❖Each leg of the antenna = ¼ λ = $\frac{9\ feet}{2}$ = 4.5 feet long
    - ❖Add additional length to be able to tune antenna. Commonly, the formula $\frac{490}{f\ in\ MHz}$ is used, so make total length of antenna = $\frac{490}{52}$ = 9.4 feet long and thus each leg $\frac{9.4}{2}$ = 4.7 feet = 4 feet, 8 3/8 inches long at first
  - Feeder line will be a RG-58 coax cable (thus, cable impedance = 50 Ω)

Activity – Oldest Campers Group 2

- Activity #1 = Build and tune a 6 meters λ band dipole antenna
  - Use a 1:1 current Balun as the center insulator
  - Use a SWR antenna analyzer to tune the antenna, making physical adjustments as necessary to achieve minimize SWR
- Activity #2 =
  - Use hand held ham radio capable of 70 cm and 2 meter bands to talk to people. Illustrate the use of repeater towers.
  - Set up a vertical antenna and ham base station ham radio capable of 6 meter, 10 meter, 12 meter, 15 meter, 17 meter, 20 meter, 30 meter, and 40 meter bands and talk to people around the world
  - Hook up the 15 meter dipole made previously to the ham base station and talk to people