MODULE 04

FOR B1 CERTIFICATION

ELECTRONIC FUNDAMENTALS

Aviation Maintenance Technician Certification Series

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REVISION LOG

VERSION	EFFECTIVE DATE	DESCRIPTION OF CHANGE
001	2016 01	Module Creation and Release
002	2016 05	Minor Corrections/Layout Adjustments
003	2018 07	Adjusted content for alignment to Part 66, Appendix 1. Added Static Electricity Protection to Sub-Module 02; Remove Logic Circuits from Sub-Module 1.2; other minor corrections.

ELECTRONIC FUNDAMENTALS

4.4 - RADIO COMMUNICATION - ELT AND ADS-B

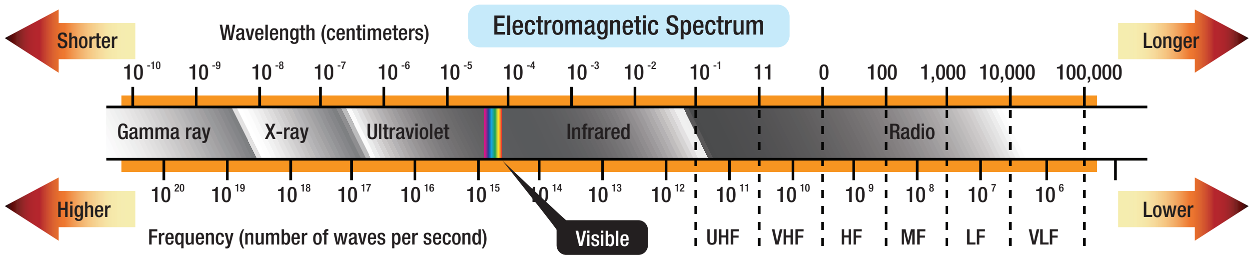

Figure 4-1. Radio waves are just some of the electromagnetic waves found in space.

Much of aviation communication and navigation is accomplished through the use of radio waves. Communication by radio was the first use of radio frequency transmissions in aviation.

RADIO WAVES

A radio wave is invisible to the human eye. It is electromagnetic in nature and part of the electronic spectrum of wave activity that includes gamma rays, x-rays, ultraviolet rays, infrared waves, and visible light rays, as well all radio waves. (***Figure 4-1***)

The atmosphere is filled with these waves. Each wave occurs at a specific frequency and has a corresponding wavelength. The relationship between frequency and wavelength is inversely proportional. A high frequency wave has a short wave length and a low frequency wave has a long wave length. In aviation, a variety of radio waves are used for communication. ***Figure 4-2*** illustrates the radio spectrum that includes the range of common aviation radio frequencies and their applications.

NOTE: A wide range of frequencies are used from low frequency (LF) at 100 kHz (100 000 cycles per second) to super high frequency (SHF) at nearly 10gHz (10 000 000 000 cycles per second). The Federal Communications Commission (FCC) controls the assignment of frequency usage. AC power of a particular frequency has a characteristic length of conductor that is resonant at that frequency. This length is the wavelength of the frequency that can be seen on an oscilloscope. Fractions of the wavelength also resonate, especially half of a wavelength, which is the same as half of the AC sign wave or cycle.

The frequency of an AC signal is the number of times the AC cycles every second. AC applied to the center of a radio antenna, a conductor half the wavelength of the AC frequency, travels the length of the antenna, collapses, and travels the length of the antenna in the opposite direction. The number of times it does this every second is known as the radio wave signal frequency or radio frequency as shown in ***Figure 4-2***.

As the current flows through the antenna, corresponding electromagnetic and electric fields build, collapse, build in the opposite direction, and collapse again. (***Figure 4-3***)

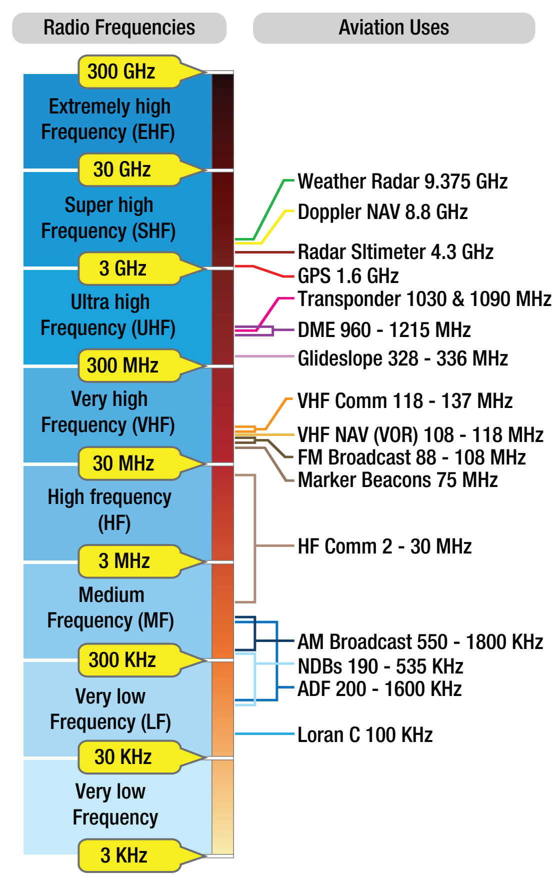

Figure 4-2. There is a wide range of radio frequencies. Aviation does not use very low frequencies or extremely high frequencies.

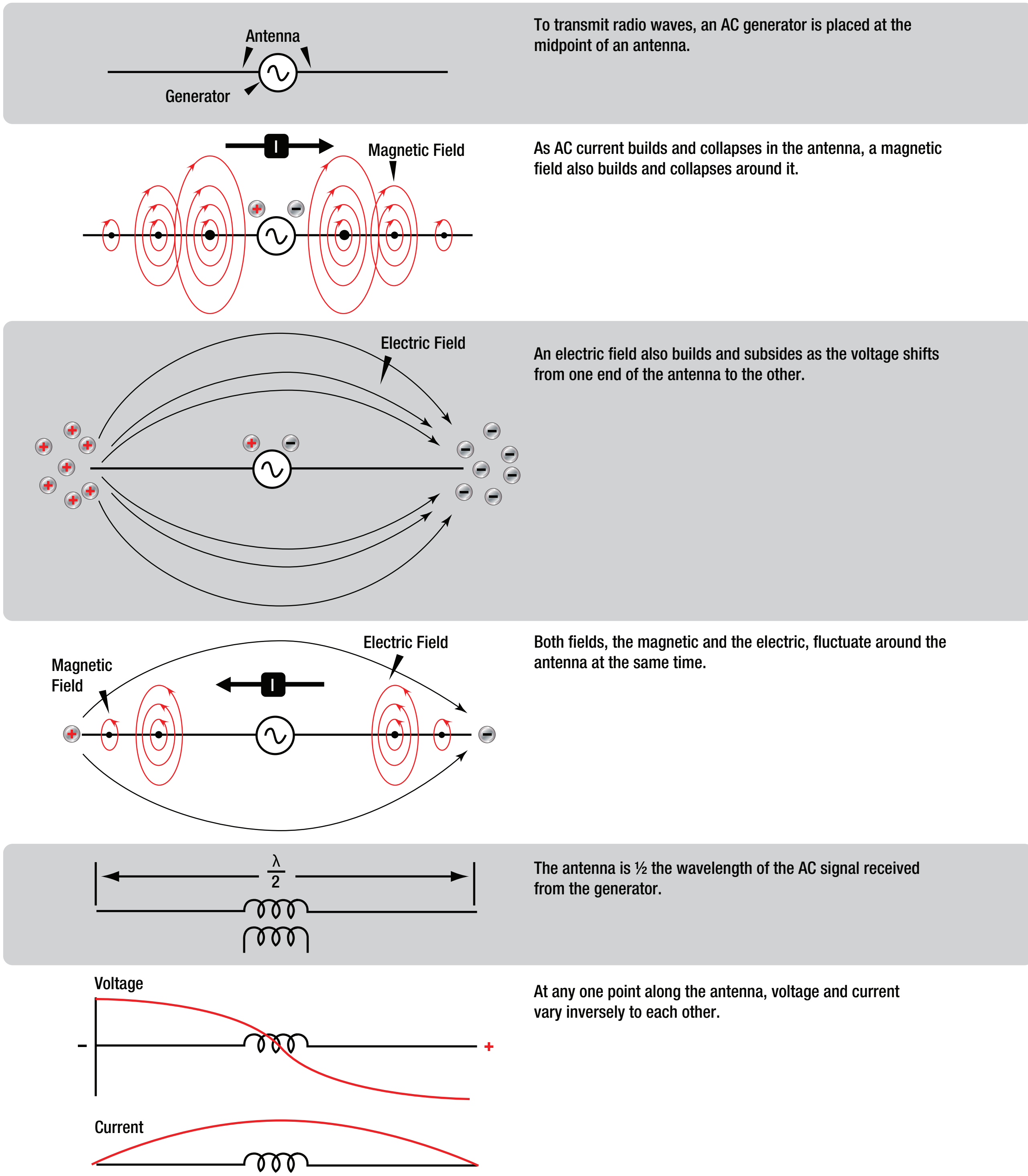

Figure 4-3. Radio waves are produced by applying an AC signal to an antenna. This creates a magnetic and electric field around the antenna. They build and collapse as the AC cycles. The speed at which the AC cycles does not allow the fields to completely collapse before the next fields build, collapsing fields are then forced out into space as radio waves.

To transmit radio waves, an AC generator is placed at the midpoint of an antenna. As AC current builds and collapses in the antenna, a magnetic field also builds and collapses around it. An electric field also builds and subsides as the voltage shifts from one end of the antenna to the other. Both fields, the magnetic and the electric, fluctuate around the antenna at the same time. The antenna is half the wavelength of the AC signal received from the generator. At any one point along the antenna, voltage and current vary inversely to each other.

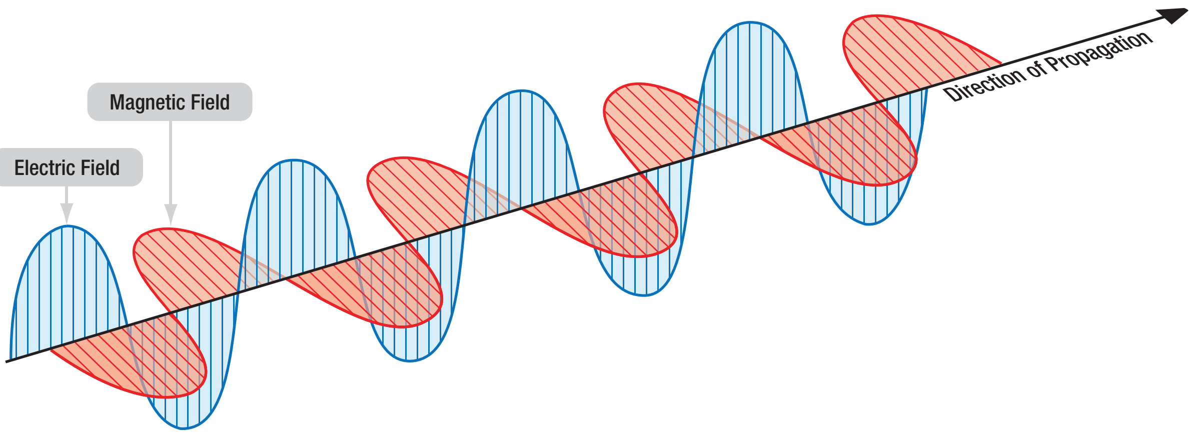

Figure 4-4. The electric field and the magnetic field of a radio wave are perpendicular to each other and to the direction of propagation of the wave.

Because of the speed of the AC, the electromagnetic fields and electric fields created around the antenna do not have time to completely collapse as the AC cycles. Each new current flow creates new fields around the antenna that force the not totally collapsed fields from the previous AC cycle out into space. These are the radio waves. The process is continuous as long as AC is applied to the antenna. Thus, steady radio waves of a frequency determined by the input AC frequency propagate out into space.

Radio waves are directional and propagate out into space at 186 000 miles per second. The distance they travel depends on the frequency and the amplification of the signal AC sent to the antenna. The electric field component and the electromagnetic field component are oriented at 90˚to each other, and at 90˚to the direction that the wave is traveling. (***Figure 4-4***)

TYPES OF RADIO WAVES

Radio waves of different frequencies have unique characteristics as they propagate through the atmosphere. Very low frequency (VLF), LF, and medium frequency (MF) waves have relatively long wavelengths and utilize correspondingly long antennas. Radio waves produced at these frequencies ranging from 3kHz to 3mHz are known as ground waves or surface waves. This is because they follow the curvature of the earth as they travel from the broadcast antenna to the receiving antenna. Ground waves are particularly useful for long distance transmissions. Automatic direction finders (ADF) and LORAN navigational aids use these frequencies. (***Figure 4-5***)

High frequency (HF) radio waves travel in a straight line and do not curve to follow the earth's surface. This would limit transmissions from the broadcast antenna to receiving antennas only in the line-of-sight of the broadcast antenna except for a unique characteristic. HF radio waves bounce off of the ionosphere layer of the atmosphere. This refraction extends the range of HF signals beyond line-of-sight. As a result, transoceanic aircraft often use HF radios for voice communication. The frequency range is between 2 to 25 MHz. These kinds of radio waves are known as sky waves. (***Figure 4-5***)

Above HF transmissions, radio waves are known as space waves. They are only capable of line-of-sight transmission and do not refract off of the ionosphere. (***Figure 4-5***) Most aviation communication and navigational aids operate with space waves. This includes VHF (30-300MHz), UHF (300MHz-3GHz), and super high frequency (SHF) (3GHz- 30GHz) radio waves.

VHF communication radios are the primary communication radios used in aviation. They operate in the frequency range from 118.0 MHz to 136.975MHz. Seven hundred and twenty separate and distinct channels have been designated in this range with 25 kilohertz spacing between each channel. Further division of the bandwidth is possible, such as in Europe where 8.33 kilohertz separate each VHF communication channel. VHF radios are used for communications between aircraft and air traffic control (ATC), as well as air-to-air communication between aircraft. When using VHF, each party transmits and receives on the same channel. Only one party can transmit at any one time.

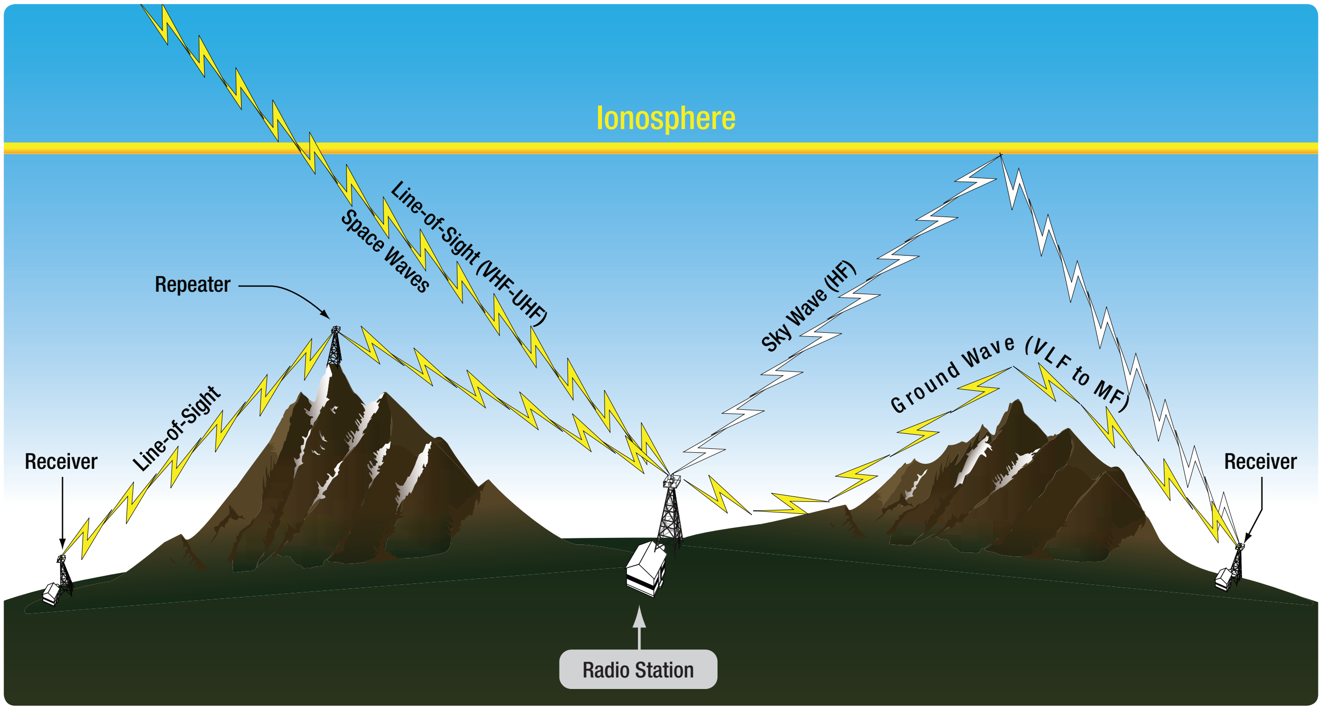

Figure 4-5. Radio waves behave differently in the atmosphere depending in their frequency.

LOADING INFORMATION ONTO A RADIO WAVE

The production and broadcast of radio waves does not convey any significant information. The basic radio wave discussed above is known as a carrier wave. To transmit and receive useful information, this wave is altered or modulated by an information signal. The information signal contains the unique voice or data information desired to be conveyed. The modulated carrier wave then carries the information from the transmitting radio to the receiving radio via their respective antennas. Two common methods of modulating carrier waves are amplitude modulation and frequency modulation.

AMPLITUDE MODULATION (AM)

A radio wave can be altered to carry useful information by modulating the amplitude of the wave. A DC signal, for example from a microphone, is amplified and then superimposed over the AC carrier wave signal. As the varying DC information signal is amplified, the amplifier output current varies proportionally. The oscillator that creates the carrier wave does so with this varying current. The oscillator frequency output is consistent because it is built into the oscillator circuit. But the amplitude of the oscillator output varies in relation to the fluctuating current input. (***Figure 4-6***)

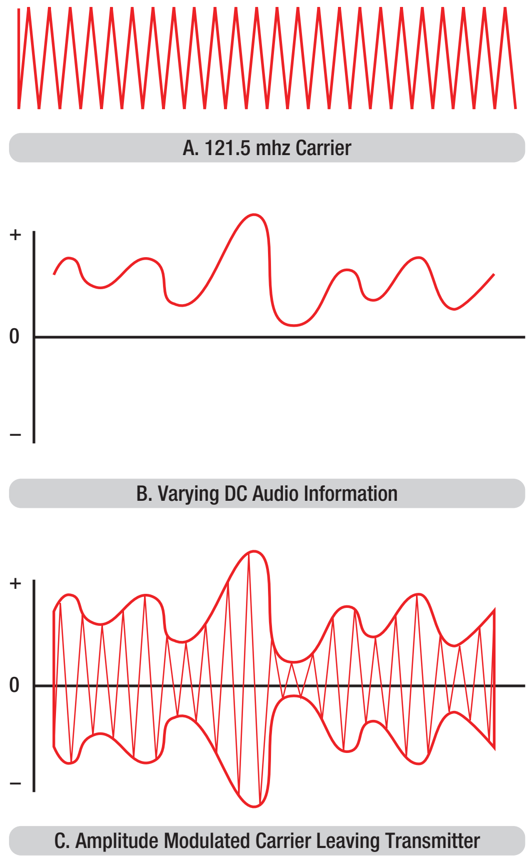

Figure 4-6. A DC audio signal modifies the 121.5 MHz carrier wave as shown in C. The amplitude of the carrier wave (A) is changed in relation to modifier (B). This is known as amplitude modulation (AM).

When the modulated carrier wave strikes the receiving antenna, voltage is generated that is the same as that which was applied to the transmitter antenna. However, the signal is weaker. It is amplified so that it can be demodulated.

Demodulation is the process of removing the original information signal from the carrier wave. Electronic circuits containing capacitors, inductors, diodes, filters, etc., remove all but the desired information signal identical to the original input signal. Then, the information signal is typically amplified again to drive speakers or other output devices. (***Figure 4-7***)

AM has limited fidelity. Atmospheric noises or static alter the amplitude of a carrier wave making it difficult to separate the intended amplitude modulation caused by the information signal and that which is caused by static. It is used in aircraft VHF communication radios.

FREQUENCY MODULATION (FM)

Frequency modulation (FM) is widely considered superior to AM for carrying and deciphering information on radio waves. A carrier wave modulated by FM retains its constant amplitude. However, the information signal alters the frequency of the carrier wave in proportion to the strength of the signal. Thus, the signal is represented as slight variations to the normally consistent timing of the oscillations of the carrier wave. (***Figure 4-8***)

Since the transmitter oscillator output fluctuates during modulation to represent the information signal, FM bandwidth is greater than AM bandwidth. This is overshadowed by the ease with which noise and static can be removed from the FM signal. FM has a steady current flow and requires less power to produce since modulating an oscillator producing a carrier wave takes less power than modulating the amplitude of a signal using an amplifier.

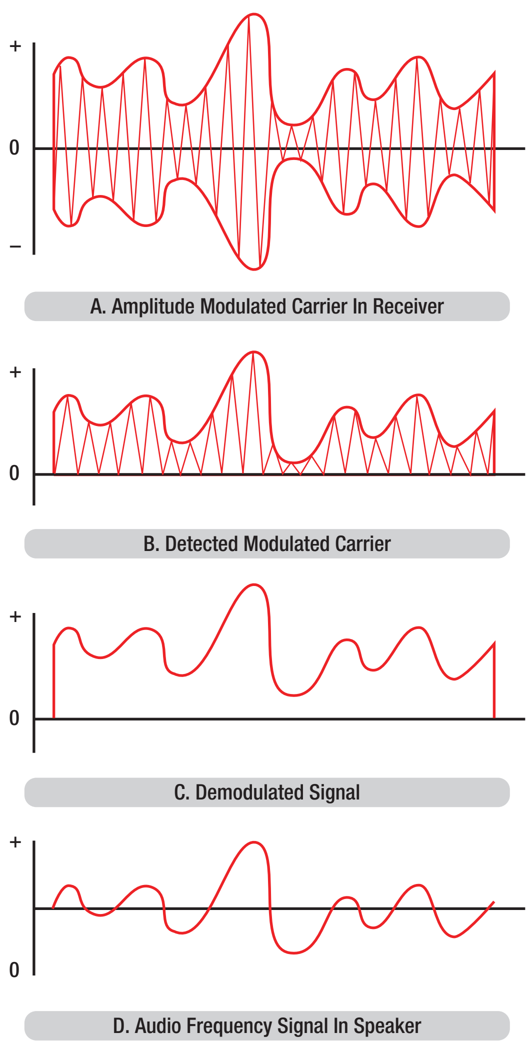

Figure 4-7. Demodulation of a received radio signal involves separating the carrier wave from the information signal.

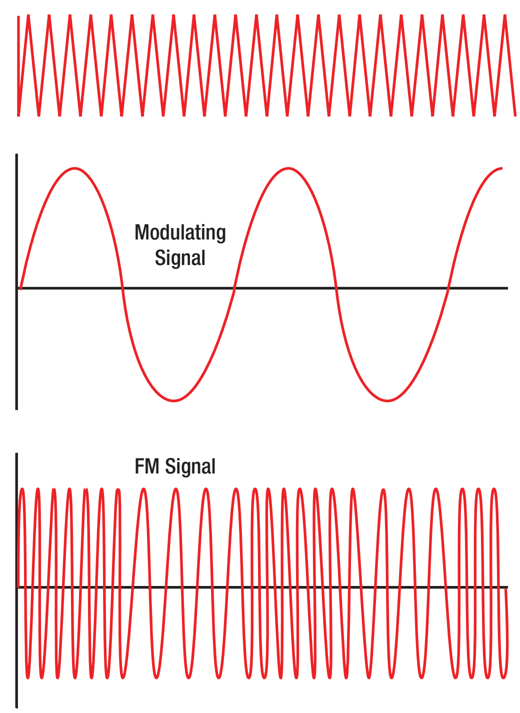

Figure 4-8. A frequency modulated (FM) carrier wave retains the consistent amplitude of the AC sign wave. It encodes the unique information signal with slight variations to the frequency of the carrier wave. These variations are shown as space variations between the peaks and valleys of the wave on an oscilloscope.

Demodulation of an FM signal is similar to that of an AM receiver. The signal captured by the receiving antenna is usually amplified immediately since signal strength is lost as the wave travels through the atmosphere. Numerous circuits are used to isolate, stabilize, and remove the information from the carrier wave. The result is then amplified to drive the output device.

SINGLE SIDE BAND (SSB)

When two AC signals are mixed together, such as when a carrier wave is modulated by an information signal, three main frequencies result:

1. Original carrier wave frequency;
2. Carrier wave frequency plus the modulating frequency; and
3. Carrier wave frequency minus the modulating frequency.

Due to the fluctuating nature of the information signal, the modulating frequency varies from the carrier wave up or down to the maximum amplitude of the modulating frequency during AM. These additional frequencies on either side of the carrier wave frequency are known as side bands. Each side band contains the unique information signal desired to be conveyed. The entire range of the lower and upper sidebands including the center carrier wave frequency is known as bandwidth. (***Figure 4-9***)

There are a limited number of frequencies within the usable frequency ranges (i.e., LF, HF, and VHF). If different broadcasts are made on frequencies that are too close together, some of the broadcast from one frequency interfere with the adjacent broadcast due to overlapping side bands. The FCC divides the various frequency bands and issues rules for their use. Much of this allocation is to prevent interference. The spacing between broadcast frequencies is established so that a carrier wave can expand to include the upper and lower side bands and still not interfere with a signal on an adjacent frequency.

As use of the radio frequencies increases, more efficient allocation of bandwidth is imperative. Sending information via radio waves using the narrowest bandwidth possible is the focus of engineering moving forward. At the same time, fully representing all of the desired information or increasing the amount of information conveyed is also desired. Various methods are employed to keep bandwidth to a minimum, many of which restrict the quality or quantity of information able to be transmitted. In lower frequency ranges, such as those used for ground wave and some sky wave broadcasts, SSB transmissions are a narrow bandwidth solution.

Each side band represents the initial information signal in its entirety. Therefore in an SSB broadcast, the carrier wave and either the upper or lower sidebands are filtered out. Only one sideband with its frequencies is broadcast since it contains all of the needed information. This cuts the bandwidth required in half and allows more efficient use of the radio spectrum. SSB transmissions also use less power to transmit the same amount of information over an equal distance. Many HF long distance aviation communications are SSB. (***Figure 4-10***)

RADIO TRANSMITTERS AND RECEIVERS

Radio transmitters and receivers are electronic devices that manipulate electricity resulting in the transmission of useful information through the atmosphere or space.

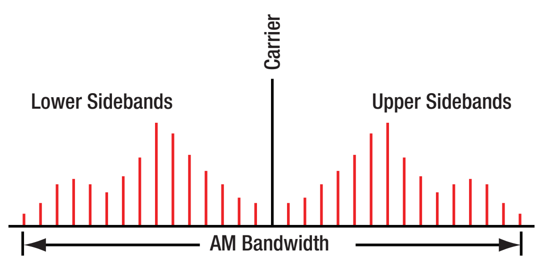

Figure 4-9. The bandwidth of an AM signal contains the carrier wave, the carrier wave plus the information signal frequencies, and the carrier wave minus the information signal frequencies.

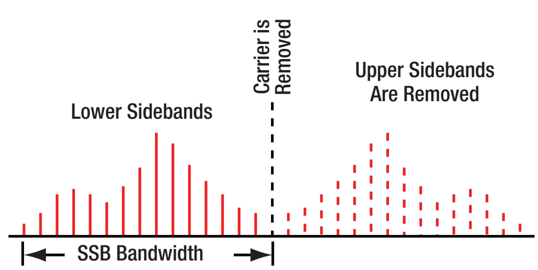

Figure 4-10. The additional frequencies above and below the carrier wave produced during modulation with the information signal are known as sidebands. Each sideband contains the unique information of the information signal and can be transmitted independent of the carrier wave and the other sideband.