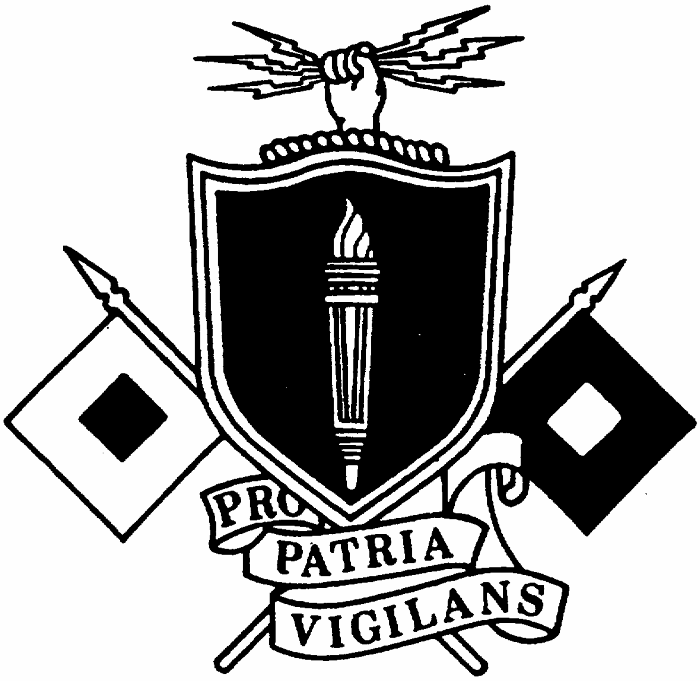
SUBCOURSE **EDITION**
SS0345 **6**

FUNDAMENTALS OF MICROWAVE COMMUNICATIONS



THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

A
I
P
D

READINESS / PROFESSIONALISM THRU GROWTH

U.S. ARMY SIGNAL SCHOOL
GENERAL PURPOSE USER (GPU) SKILL LEVELS 1, 2, 3, 4, AND 5 COURSES

FUNDAMENTALS OF MICROWAVE COMMUNICATIONS

SUBCOURSE NO. SS0345-6

U.S. Army Signal School
Fort Gordon, Georgia

2 CREDIT HOURS

GENERAL

The Fundamentals of Microwave Communications subcourse is designed to provide you with the knowledge necessary for performing tasks related to providing line-of-site radio transmission path, and profiling tropospheric scatter radio transmission path. The subcourse is presented in three lessons, each lesson corresponding to a terminal objective as indicated below:

Whenever pronouns or other references denoting gender appear in this document, they are written to refer to either male or female unless otherwise indicated.

Lesson 1: FUNDAMENTALS OF RADIO COMMUNICATIONS

TASK: The soldier will be able to identify the elements of fundamentals of transmission and reception, radio wave and methods of transmission.

CONDITIONS: Given information and diagrams about the elements of fundamentals of transmission, reception, radio wave and methods of transmission.

STANDARDS: Demonstrate competency of the objective by responding to 85 percent of the multiple-choice test covering the elements of fundamentals of transmission, reception, radio wave and methods of transmission for lesson 1.

(This objective supports Task 113-611-4004, Profile Tropospheric Scatter Transmission Path.)

Lesson 2: PROPAGATION OF RADIO WAVES

TASK: The soldier will identify the principles of propagation on radio waves, microwave multichannel systems and microwave multichannel radio antennas.

CONDITIONS: Given information and diagrams about the principles of propagation of radio waves, microwave multichannel systems, and microwave multichannel radio antennas.

STANDARDS: Demonstrate competency of the objective by responding to 85 percent of the multiple-choice test covering the principles of propagation of radio waves, microwave multichannel systems and microwave multichannel radio antennas in lesson 2.

(This objective supports SM Task 113-611-4004, Profile Tropospheric Scatter Transmission Path.)

Lesson 3: SYSTEM ALIGNMENT

TASK: The soldier will identify the principles of system alignment, noise, interference and fading.

CONDITIONS: Given information and diagrams about the principles of system alignment, noise and interference and fading.

STANDARDS: Demonstrate competency of the objective by responding to 85 percent of the multiple-choice test covering the principles of system alignment, noise interference and fading in lesson 3.

(This objective supports SM Task 113-611-4004, Profile Tropospheric Scatter Transmission Path.)

TABLE OF CONTENTS

Section Page

INTRODUCTION

Communications using microwave frequencies have been a fact for many years, and new developments in electronics have made it possible to expand the methods of communications in the microwave region. As a Signal Soldier, you must acquaint yourself with the characteristics and types of microwave communications.

After you complete this subcourse you will be aware of the need to understand the fundamentals of microwave communications.

This subcourse consists of three lessons and an examination.

* * * IMPORTANT NOTICE * * *

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%.

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

LESSON 1

FUNDAMENTAL OF RADIO COMMUNICATIONS

TASKS

The soldier will be able to identify the elements of fundamentals of transmission, reception, radio wave and methods of transmission.

CONDITIONS

Given information and diagrams about the elements of fundamentals of transmission and reception, radio wave and methods of transmission.

STANDARDS

Demonstrate competency of the objective by responding to 85 percent of the multiple-choice test covering the elements of fundamentals of transmission, reception, radio wave and methods of transmission for lesson 1.

REFERENCES

FM 11-65, FM 24-18, and FM 24-21.

Learning Event 1:
ELEMENTS OF TRANSMISSION AND RECEPTION

1. Radio equipment. A radio set consists essentially of a transmitter that generates radio frequency (RF) energy; a source of electrical power; a key, microphone, or teletypewriter, that controls these energy waves; a transmitting antenna that radiates RF waves; a receiving antenna that intercepts some of the radiated RF waves; a source of electrical power; a receiver that converts intercepted RF waves into usable energy (usually audio frequency (AF) energy); and a loudspeaker, headphones, or teletypewriter provided intelligibility. When the frequency coverage of two sets is similar, when they have the same modulation, and the distance between them does not exceed the range of the equipment, two-way communications using electromagnetic (radio) waves is possible. Figure 1 is a block diagram of a basic radio set.

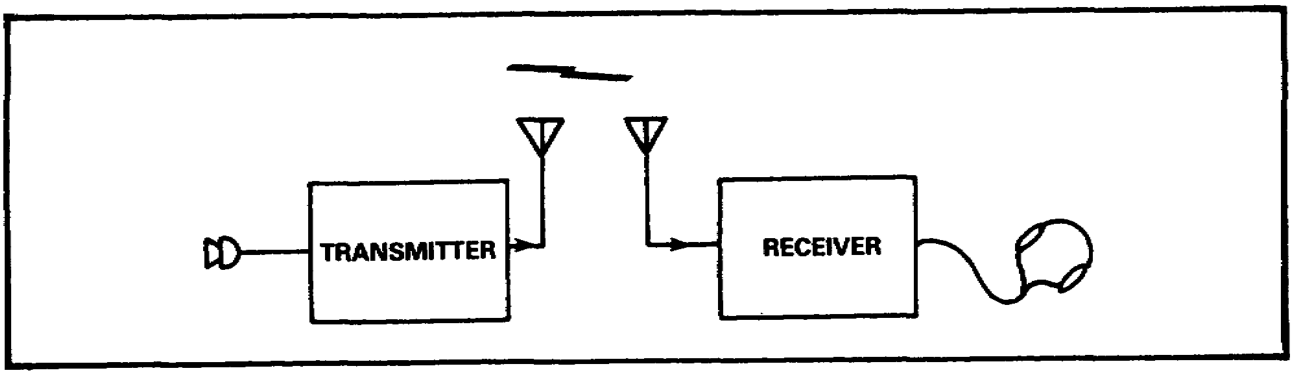


Figure 1. Block Diagram of Basic Radio Set.

2. Radio transmitter. The simplest radio transmitter (figure 2) consists of a power supply and an oscillator. The power supply can be batteries, a generator, an alternating-current (AC) power source, including a rectifier and filter or a direct-current (DC) rotating power source. The oscillator, which generates RF alternating current, must contain a tuned circuit to tune the transmitter to the desired operating frequency. The transmitter must also have some device for controlling the generated RF energy. The simplest device is a telegraph key, which is merely a type of switch for controlling the flow of electric current. When the key is operated, the oscillator is turned on and off for varying lengths of time to form dots and dashes of RF energy.

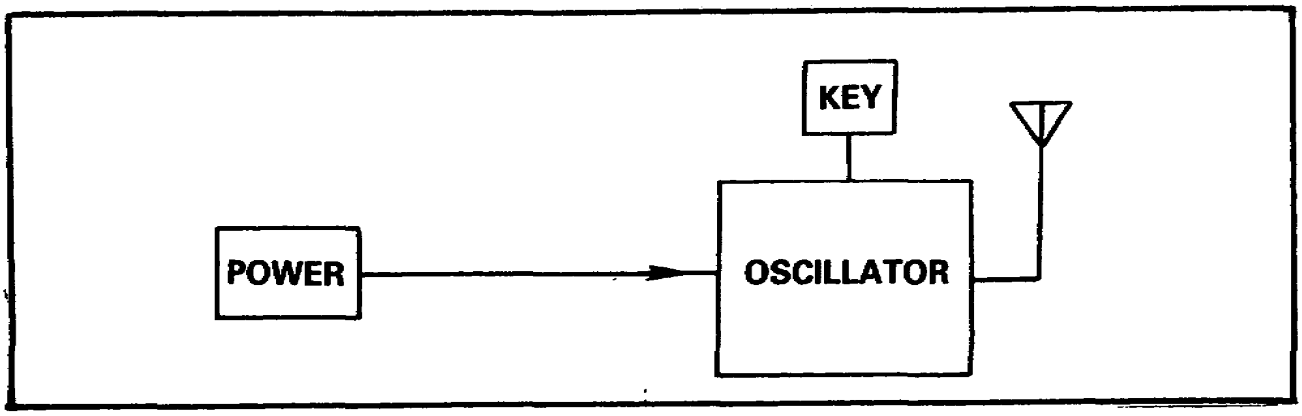


Figure 2. Block Diagram of a Simple Radio Transmitter

3. Antennas. After an RF signal has been generated and amplified in the transmitter, a means must be provided to radiate this RF energy into space. At the same time, a means must be provided at the receiver location to intercept (pick up) the signal. The device that fulfills these requirements is called an antenna. The transmitting antenna sends transmitter signal energy out into space. This energy, radiated in the form of electro-magnetic waves, is intercepted by a receiving antenna. If the receiver is tuned to the same frequency as the transmitter, the signal will be received and intelligible information made available.

4. Radio receiver.

a. Detector (demodulator). There are two general kinds of RF signals that can be received by a radio receiver: modulated RF signals that carry speech, music, or other audio energy, and continuous wave (CW) signals that are a burst of RF energy conveying intelligence by means of code (dot) signals. The process whereby the intelligence carried by an RF signal is extracted is called detection or demodulation. The circuit used to accomplish this is called a detector (figure 3), since it actually detects the incoming intelligence. The receiver must have some means of tuning in or selecting the frequency of the desired RF signal. This selective action is necessary to avoid the detection of many RF signals or different frequencies at the same time. That part of the detector which is used to tune in the desired signal is called a tuned circuit. In FM radio receivers, the detector is known as a discriminator.

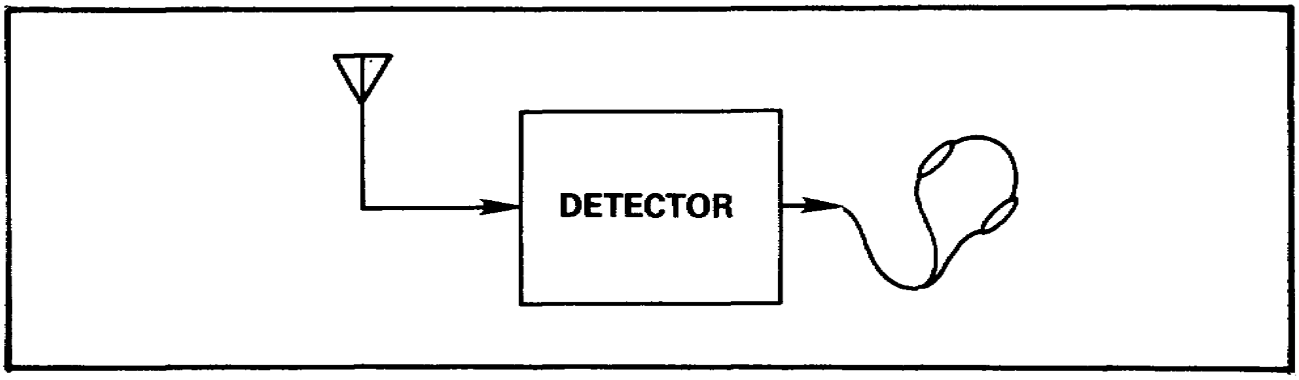


Figure 3. Block Diagram of Simple Radio Receiver.

b. RF amplifier. Because an RF signal diminishes in strength or amplitude at a very rapid rate after it leaves the transmitting antenna and because many RF signals of various frequencies are crowded into the radio frequency spectrum, a detector is not used alone. An RF amplifier (figure 4) is included in the receiver to increase the sensitivity (ability to receive weak signals) and the selectivity (ability to separate signals of different radio frequencies). The RF amplifier is provided with one or more tuned circuits so that the desired RF signal (the one to which it is tuned) is amplified more than RF signals of other frequencies.

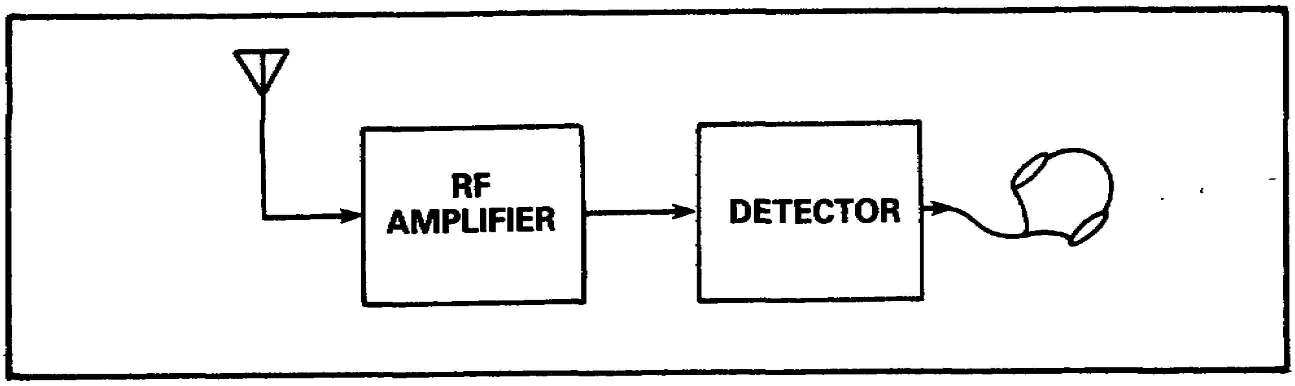


Figure 4. Block Diagram of Detector and RF Amplifier.

c. Audio frequency amplifier. The power output of a detector, with or without an RF amplifier, is generally too little to be useful. One or more audio frequency amplifiers (figure 5), therefore, are added to the receiver to increase the audio frequency power to a level that will operate headphones, a loudspeaker, or teletypewriter equipment.

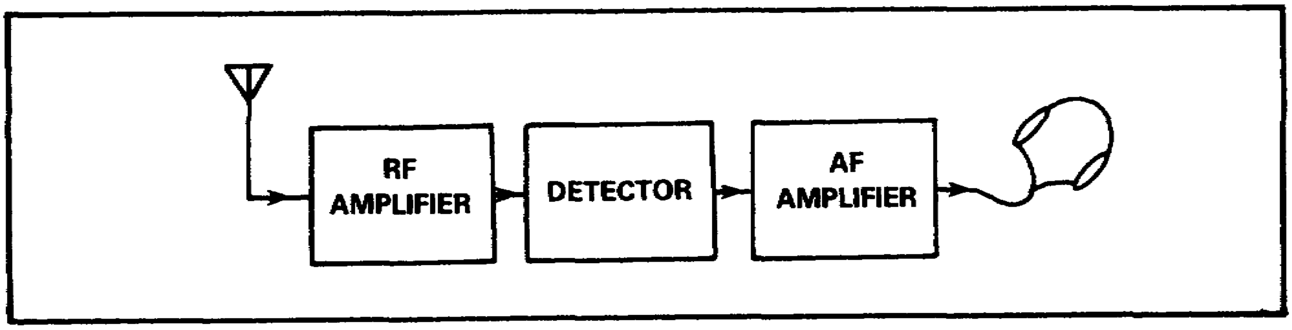


Figure 5. Block Diagram of Complete Radio Receiver.

Learning Event 2:
RADIO WAVES

1. General. Radio waves travel near the surface of the earth and also radiate skyward at various angles to the earth's surface (figure 6). These electromagnetic waves travel through space at the speed of light, approximately 186,000 miles (300,000 kilometers (km)) per second.

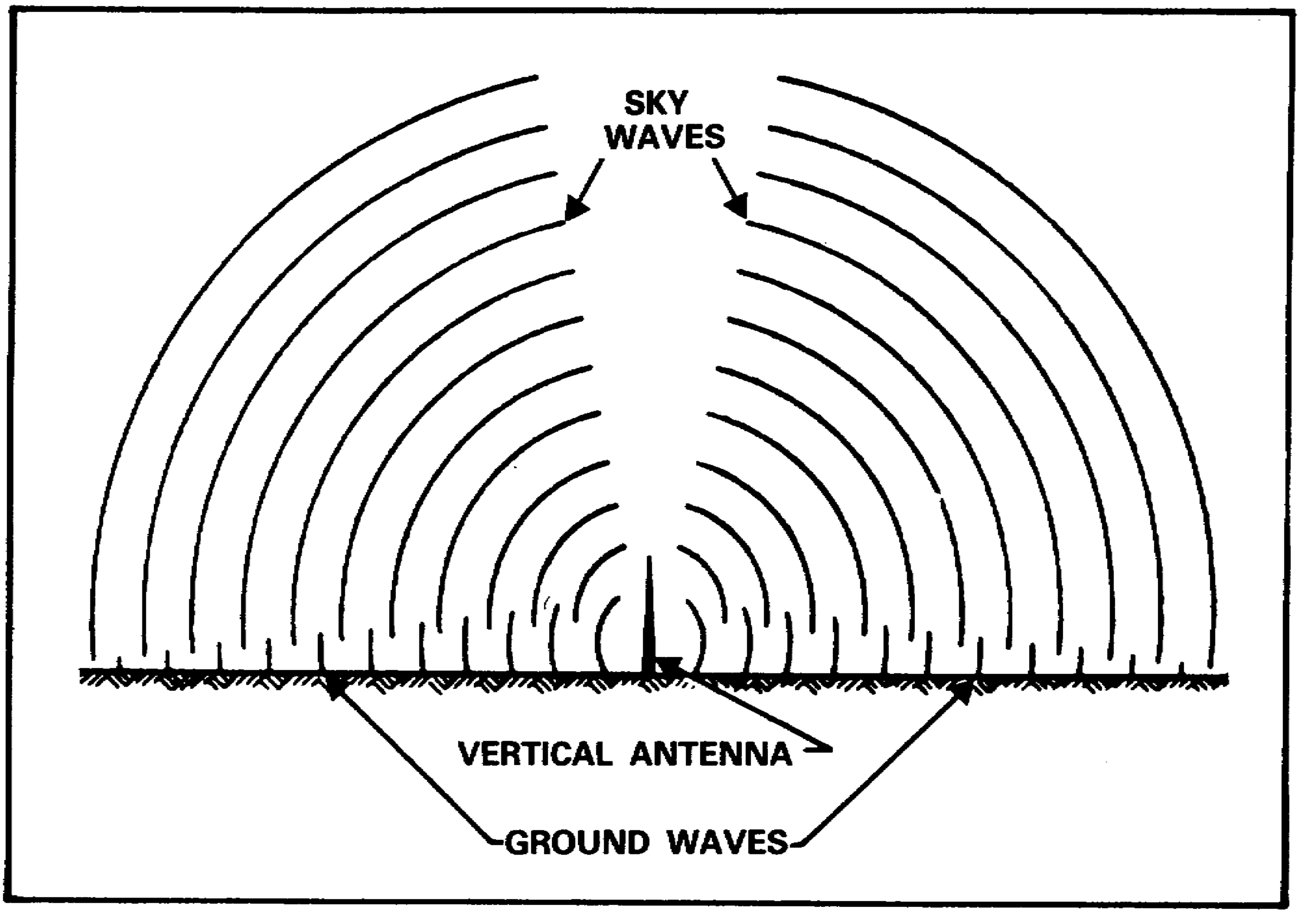


Figure 6. Radiation of Radio Waves From a Vertical Antenna.

a. Wavelength. The length of radio wave is the distance traveled by the wave in the period of time required to complete one cycle. Each complete cycle of two alternations of the wave (figure 7) is one wavelength and is expressed in meters. This wavelength may be measured from the start of one wave to the start of the next wave, or from the crest of one wave to the crest of the next wave. In either case, the distance is the same.

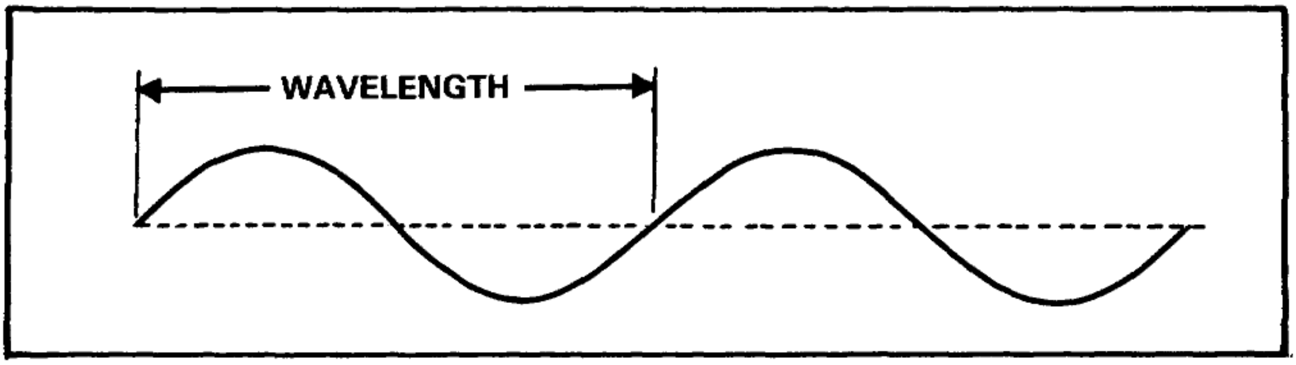


Figure 7. Wavelength of a Radio Wave.

b. Frequency.

(1) The frequency of a radio wave is the number of complete cycles that occur in one second. The longer the time of one cycle, the longer the wavelength and the lower the frequency. The shorter the time of one cycle, the shorter the wavelength and the higher the frequency. Figure 8 compares the wavelength of a 2 mc wave with that of a 10 mc wave.

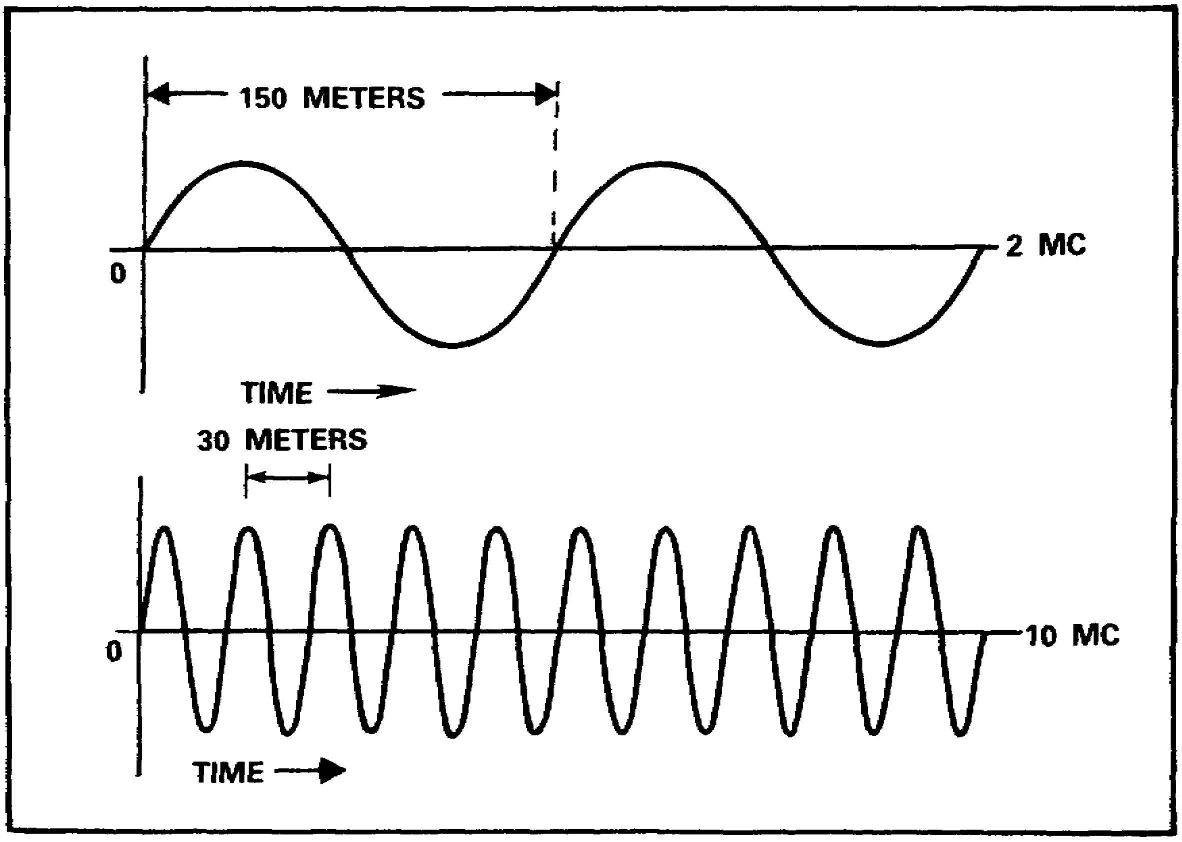


Figure 8. Comparison of Two Waves of Different Frequency.

(2) Since the frequency of a radio wave is very great, it is expressed in kilocycles per second (kc) or megacycles per second (mc). One kc is equal to 1,000 cycles per second, and 1 mc is equal to 1,000,000 cycles per second.

(3) For practical purposes, the velocity of a radio wave is considered to be constant, regardless of the frequency or the amplitude of the transmitted wave; therefore, to find the wavelength when the frequency is known, divide the velocity of the frequency.

$$\begin{aligned}\underset{\text{(free space)}}{\text{Wavelength (in meters)}} &= \frac{300{,}000{,}000 \text{ (meters per second)}}{\text{frequency (cycles per second)}}\\ &= \frac{300{,}000}{\text{frequency (kc)}}\\ &= \frac{300}{\text{frequency (mc)}}\end{aligned}$$

(4) To find the frequency when the wavelength is known, divide the velocity by the wavelength.

$$\begin{aligned}\underset{\text{(cycles per second)}}{\text{frequency}} &= \frac{300{,}000{,}000}{\text{wavelength (meters)}}\\ \text{frequency (kc)} &= \frac{300{,}000}{\text{wavelength (meters)}}\\ \text{frequency (mc)} &= \frac{300}{\text{wavelength (meters)}}\end{aligned}$$

c. Frequency bands. Most tactical radio sets operate within the 1.5 mc to 400 mc portion of the frequency spectrum. Radio frequencies are divided into groups or bands of frequencies for convenience of study and reference. The frequency bands of the radio spectrum are shown in the following chart.

Band	Frequency (mc)
Very low frequencies (VLF)	Below .03
Low frequency (LF)	.03 to .3
Medium frequency (MF)	.3 to 3.0
High frequency (HF)	3.0 to 30
Very high frequency (VHF)	30 to 300
Ultrahigh frequency (UHF)	300 to 3,000
Superhigh frequency (SHF)	3,000 to 30,000
Extremely high frequency (EHF)	30,000 to 300,000

d. Characteristics of frequency bands. The data in the chart below, which are approximate under normal operating conditions, indicate that each frequency band has certain transmission characteristics. The exact characteristic depends upon the condition of the propagation medium, the transmitter power output, and many other factors.

Band	Range				Power required (kW)
	Ground Waves		Sky Waves		
	Miles	km	Miles	km	
LF	0 to 1000	0 to 1609	500 to 8000	835 to 12,872	above 50
MF	0 to 100	0 to 161	100 to 1500	161 to 2415	**.5 to 50
HF	0 to 50	0 to 83	100 to 8000	161 to 12,872	.5 to 5
VHF	0 to 30	0 to 48	*50 to 150	*83.5 to 241	.5 or less
UHF	0 to 50	0 to 83	----------	------------	.5 or less

* Troposcatter or ionospheric scatter provides this range.

** Troposcatter or ionospheric scatter requires this power range.

Learning Event 3:
METHODS OF TRANSMISSION

General. The radio communications equipment in lower echelon units is used primarily to transmit intelligence in the form of speech or telegraphic code. When audio-frequency vibrations (speech or telegraphic code) activate the ear drum, the effect on the human nervous system is called sound. This form of acoustical energy travels through the air at a velocity of approximately 1,100 feet per second. Although sound can be converted to audio-frequency electrical energy, it is not practical to transmit it in this energy form through the earth's atmosphere by electromagnetic radiation. For example, efficient transmission of a 20-cycle audio signal would require an antenna almost 5,000 miles long. None of the above limitations apply when radio-frequency electrical energy is used to carry the intelligence. Tremendous distances can be covered; efficient antennas for radio frequencies are of practical lengths; antenna power losses are at reasonable levels; many channels, each carrying information, can be used; and selectivity or information is possible.

a. Modulation.

(1) Since the carrier wave (figure 9) itself does not convey intelligence, information in the form of a signal wave is super-imposed upon the carrier. This process, which is called modulation, varies or modifies either the frequency or the amplitude of the carrier waveform. Both amplitude modulation and frequency modulation methods are used in military radio communications systems.

(2) When antenna frequency signals are superimposed on the RF carrier, additional RF signals are generated. The additional frequencies are equal to the sum and difference of the audio frequencies and the radio frequency involved. For example, assume that a 1000 kc carrier is modulated by a 1 kc audio tone. Two new radio frequencies are developed, one at 1001 kc (the sum of 1000 and 1 kc) and the other at 999 kc (the difference between 1000 and 1 kc). If a complex audio signal is used instead of a single tone, two new frequencies will be set up for each of the audio frequencies involved. The new frequencies are called sidebands.

b. Amplitude modulation (AM). Amplitude modulation is defined as the variation of the RF power of a transmitter at an audio rate. In other words, the RF energy increases and decreases in power according to the audio (sound) frequencies. In very simple terms, amplitude modulation is the process of varying the power output of a transmitter (figure 9).

(1) When an RF carrier is modulated by a single audio tone, two additional frequencies are produced. One is the upper frequency, which equals the sum of the frequency of the RF carrier and the frequency of the audio note. The other is the lower frequency, which equals the difference between the frequency of the RF carrier and the frequency of the audio note. The one higher than the carrier frequency is the upper side frequency; the one lower than the carrier frequency is the lower side frequency.

(2) When the modulating signal is made up of complex tones, as in speech, each individual frequency component of the modulating signal produces its own upper and lower side frequencies. These side frequencies occupy a band of frequencies called sidebands. The sideband that contains the sum of the carrier and modulating frequencies is called the upper sideband; the sideband that contains the difference of the carrier and the modulating frequencies is called the lower sideband.

(3) The space that a carrier and its associated sidebands occupy in a frequency spectrum is called a channel. In amplitude modulation, the width of the channel (bandwidth) is equal to twice the highest modulating frequency. Consequently, if a 5,000 kc carrier is modulated by a band of frequencies ranging from 200 to 5,000 cycles (.2 to 5 kc), the upper sideband extends from 5,000.2

to 5,005 kc, and the lower sideband extends from 4,999.8 to 4,995 kc. The bandwidth is then 10 kc, which is twice the highest modulating frequency (5 kc).

(4) The intelligence of an amplitude-modulated signal exists solely in the sidebands, the amplitude of which vary according to the strength of the modulating signal.

(5) Amplitude modulation generally is used by radiotelephone transmitters operating in the medium and high frequency portions of the spectrum.

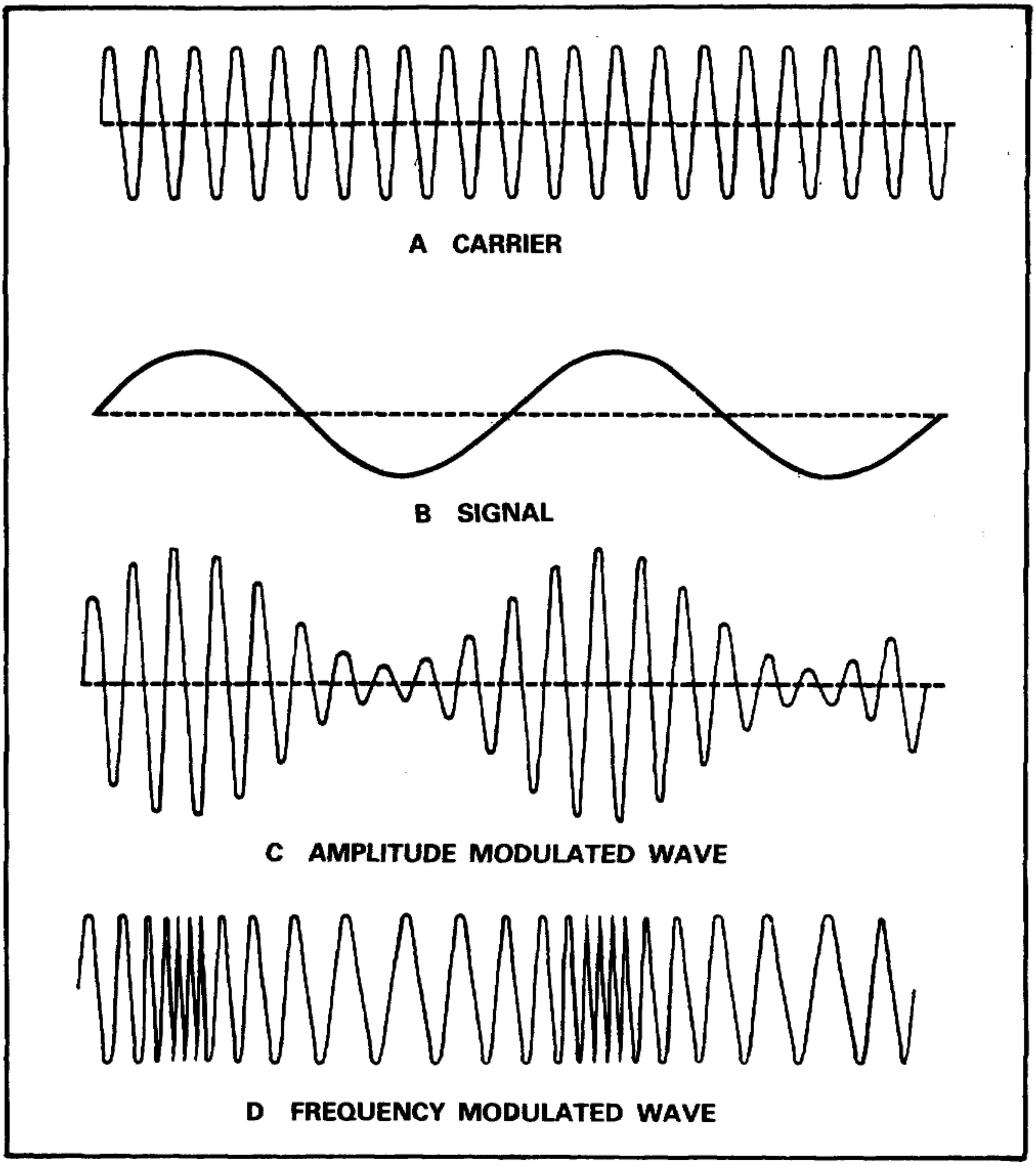


Figure 9. Waveshape.

c. Frequency modulation (FM). Frequency modulation is the process of varying the frequency (figure 9) of the carrier wave.

(1) In a frequency-modulated wave, the frequency varies instantaneously about the unmodulated carrier frequency in proportion to the amplitude of the modulating signal. When the modulating signal increases in amplitude, the instantaneous frequency increases; when the modulating signal decreases, the frequency decreases.

(2) In an FM wave, the amplitude of the modulating signal determines the extent of departure of the instantaneous frequency from the center, or rest, frequency. Thus, the instantaneous frequency can be made to deviate as much as desired from the carrier frequency by changing the amplitude of the modulating signal. This deviation frequency may be as high as several hundred kilocycles, even though the modulation frequency is only a few kilocycles. The sideband pairs generated by frequency modulation are not restricted, as in amplitude modulation, to the sum and difference between the highest modulating frequency and the carrier.

(3) The first pair of sideband pairs in an FM signal are those of the carrier frequency plus and minus the modulating frequency. Additional sideband pairs will appear at each multiple of the modulating frequency. For example, if a carrier of 1 mc is frequency modulated by an audio signal of 10 kc, there will be several sideband pairs spaced equally on either side of the carrier frequency at 990 kc and 1,010 kc, at 980 kc and 1,020 kc, at 970 kc and 1,030 kc, and so on. As a result, a frequency-modulated signal occupies a greater bandwidth than does an amplitude-modulated signal.

(4) As indicated above the FM wave consists of a center or carrier frequency and a number of sideband pairs. When modulation is applied and the amplitude of the modulating signal is increased, power is taken from the center-frequency component and forced into the sideband pairs.

(5) The FM signal leaving the transmitting antenna is constant in amplitude, but varying in frequency according to the audio-modulating signal. As the signal travels between the transmitting and receiving antennas, however, it is combined with natural and manmade noises that cause amplitude variations in the signal. All of these undesirable amplitude variations are amplified as the signal passes through successive stages of the receiver until the signal reaches the limiter stage.

(6) The limiter eliminates amplitude variations and passes the FM signal on to the discriminator, which is sensitive to variations in the frequency of an RF wave. The resultant constant-amplitude, frequency-modulated signal is then processed by the discriminator circuit, which transforms the frequency variations of the signal into corresponding voltage amplitude variations. These voltage variations reproduce the original modulating signal in a reproducing device, such as a headset, loudspeaker, or teletypewriter.

(7) Frequency modulation generally is used by radiotelephone transmitters operating in the VHF and higher frequency bands.

d. Radiotelephone.

(1) A microphone of a radiotelephone set converts voice or soundwaves (figure 10) to weak electrical impulses. These impulses are strengthened by passing them through a series of audio amplifiers and then through a modulator. The modulator provides the audio power necessary to modulate the RF amplifier. At the receiver, the modulated RF is demodulated, allowing only the audio component of the incoming signal to be reproduced by a loudspeaker or headset.

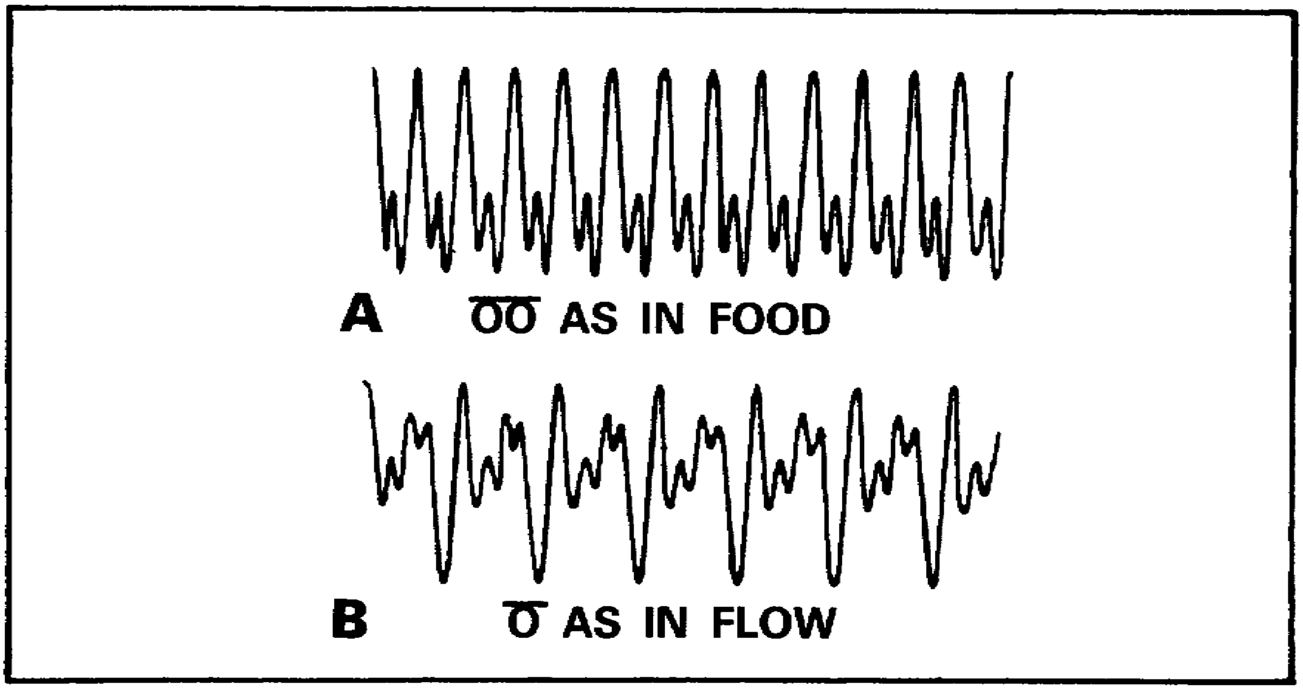


Figure 10. Examples of Voice-Sound Wave.

(2) Radiotelephone transmission is used extensively for communications with highly mobile combat units, where speed of transmission is essential. It is used for person-to-person contact, where security is not a limiting factor.

LESSON 1

PRACTICE EXERCISE
(PERFORMANCE-ORIENTED)

1. Which of the following is the simplest radio transmitter?

   a. Power supply and antenna.
   b. Power supply and transmitter.
   c. Power supply and receiver.
   d. Power supply and oscillator.

2. Which of the following can be a radio transmitter power supply?

   a. Generator.
   b. Switch.
   c. Rectifier.
   d. Antenna.

3. What type of circuit does the oscillator contain?

   a. Power circuit.
   b. Tune circuit.
   c. Close circuit.
   d. None of the above.

4. What is the purpose of the detector?

   a. Extracts intelligence from the RF signal.
   b. Induces intelligence into the RF signal.
   c. Modulates the RF signal.
   d. Stops the RF signal.

5. What is the use of the RF amplifier?

   a. Increases the audio frequency.
   b. Increases the power frequency.
   c. Increases the radio frequency.
   d. Increases the ground frequency.

6. What is the approximate speed of the radiowave?

   a. 186,000 kilometers per second.
   b. 300,000 kilometers per second.
   c. 18,600 kilometers per second.
   d. 30,000 kilometers per second.

7. What type of frequency will you have when the wavelength is long?

   a. Higher.
   b. Shorter.
   c. Lower.
   d. Longer.

8. What is the approximate distance that the VHF band of frequencies can travel?

   a. 500 to 800 miles.
   b. 100 to 1500 miles.
   c. 100 to 150 miles.
   d. 50 to 150 miles.

9. Where does intelligence of an amplitude modulated signal exist?

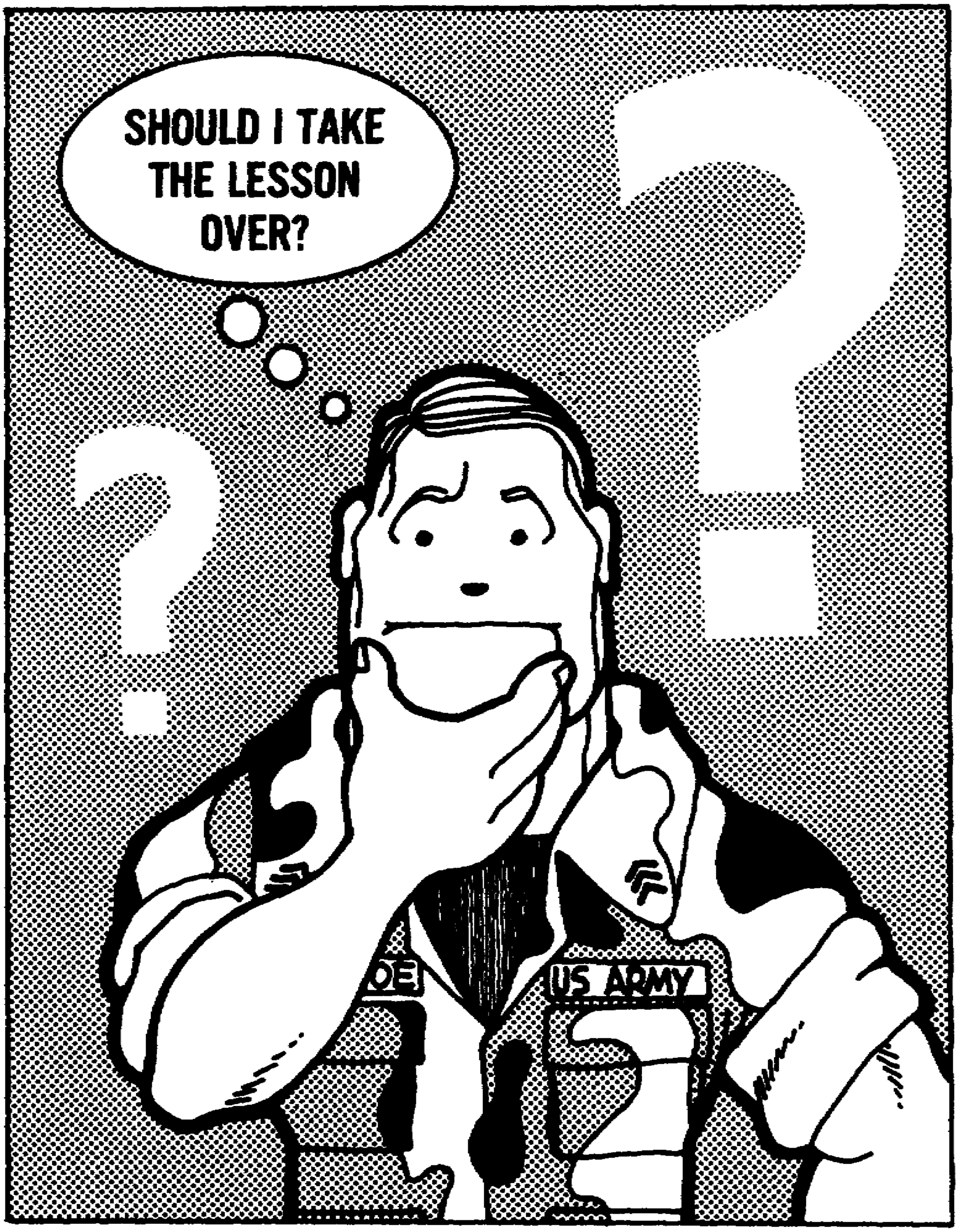
   a. RF carrier.
   b. Sidebands.
   c. FM carrier.
   d. None of the above.

10. What is the state of the frequency modulated signal as it leaves the transmitting antenna?

  a. Constant amplitude.
  b. Varying amplitude.
  c. No amplitude.
  d. All of the above.

LESSON 1

FUNDAMENTALS OF RADIO COMMUNICATIONS



LESSON 2

PROPAGATION OF RADIO WAVES

TASK

The soldier will identify the principles of propagation of radio waves, microwave multichannel systems and microwave multichannel radio antennas.

CONDITIONS

Given information and diagrams about the principles of propagation of radio waves, microwave multichannel systems, and microwave multichannel radio antennas.

STANDARDS

Demonstrate competency of the objective by responding to 85 percent of the multiple-choice test covering the principles of propagation of radio waves, microwave multichannel systems and microwave multichannel radio antennas in lesson two.

REFERENCES

FM 11-65 and FM 24-21.

Learning Event 1:
PROPAGATION OF RADIO WAVES.

1. The atmosphere. Wave propagation deals with the properties and the nature of the atmosphere through which radio waves must travel from the transmitting antenna to the receiving antenna. The atmosphere is not uniform, but varies with the altitude, geographic location, time of day or night, season, and year. A knowledge of the composition and properties of the atmosphere aids in the solution of problems that arise in planning radio communications paths and in predicting the reliability of communications.

a. Troposphere. The troposphere is that portion of the earth's atmosphere extending from the surface of the earth to heights of approximately 6 1/2 miles (10 km). Within the troposphere, the bending of radio waves by refraction causes the radio horizon to exceed the optical horizon. Tropospheric refraction (reflection caused by sudden changes in the characteristics of air in a lower atmosphere) affect the received signal at distances beyond the radio horizon.

b. Stratosphere. The stratosphere is that portion of the earth's atmosphere lying between the troposphere and ionosphere about 6 1/2 miles to 30 miles (10 to 48 km) above the earth. The temperature in this region is nearly constant.

c. Ionosphere. The ionosphere is that portion of the earth's atmosphere above the lowest level at which ionization (splitting of molecules into positive and negative charges, or ions) of low pressure gasses will affect the transmission of radio waves. It extends from about 30 to 250 miles (48 to 402 km) above the earth. The ionosphere is composed of several distinct layers in which ionization occurs at different levels and intensities.

d. In the ultra-high-frequency band (300 to 3000 mc), the direct wave must be used for all radio transmissions. Communications is limited to a short distance beyond the horizon. Lack of static and fading in these bands makes line-of-sight reception very satisfactory. Highly directive antennas can be built into small spaces to concentrate RF energy into a narrow beam, thus increasing the signal intensity.

2. Radiation.

a. When power is delivered to an antenna, two fields are set up by the fluctuating energy: One is the induction field, which is associated with the stored energy; the other is the radiation field, which moves out into space at nearly the speed of light. At the antenna, the intensities of these fields are high and are proportional to the amount of power delivered to the antenna. At a short distance from the antenna, and beyond, only the radiation field remains. This radiation field is composed of an electric component and a magnetic component.

b. The electric and magnetic fields (components) radiated from an antenna form the electromagnetic field. This field is responsible for the transmission and reception of electromagnetic energy through free space. Thus, the radio wave may be described as a moving electromagnetic field, having velocity in the direction of travel, and with components of electric intensity and magnetic intensity arranged at right angles to each other (figure 11).

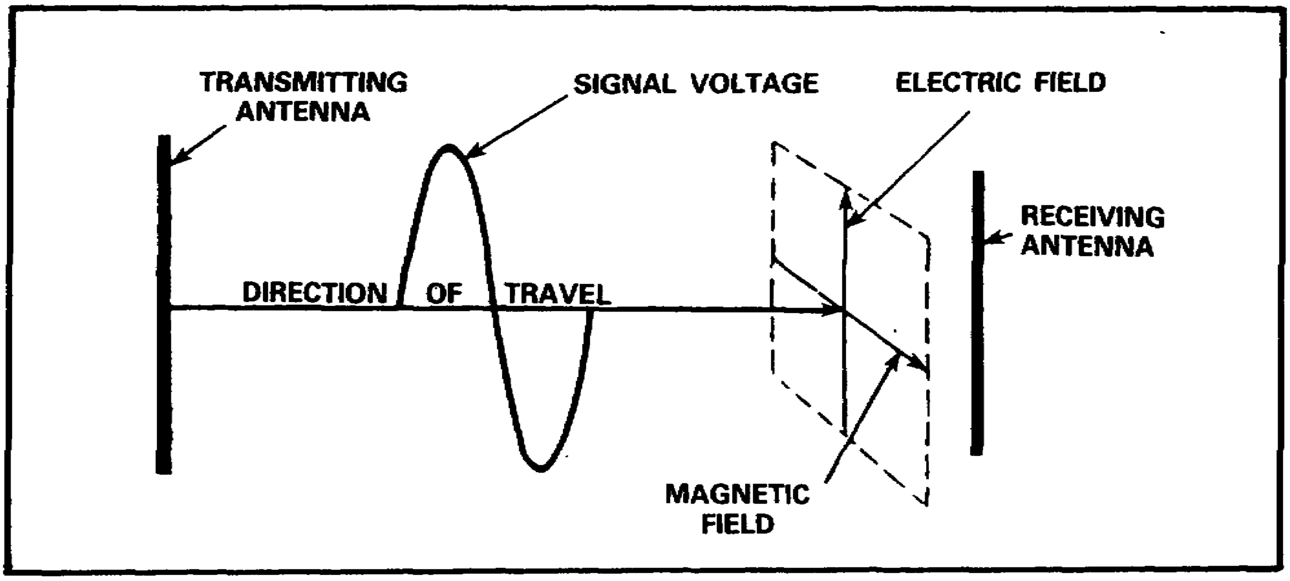


Figure 11. Components of Electromagnetic Wave.

3. Directivity. Communications over a radio circuit is satisfactory when the received signal is strong enough to override undesired signals and noise. In other words, the receiver must be within range of the transmitter. Communications effectiveness can be increased between two radio stations by increasing the transmitting power, changing the type of emission (for example, changing from a radiotelephone to CW), changing to a frequency that is not readily absorbed, or using more directional antenna. In point-to-point communications, it is usually more economical to increase the directivity of the antenna system. Directional transmitting antennas concentrate radiation in a given direction and minimize radiation in other directions. A directional antenna may also be used to lessen interception by the enemy and interference with friendly stations.

Learning Event 2:
MICROWAVE MULTICHANNEL RADIO SYSTEMS.

1. General. The radios used in microwave multichannel systems are designed specifically for such use and are not generally used without multiplex equipment. The radios (figure 12) are used in pairs; one at each end of the line-of-sight or troposcatter path. These radios operate on frequencies above 30 megahertz (MHz). The frequency range and associated multiplex equipment determine whether the sets are compatible with each other. Since radio is the least secure means of communications, transmission security is a constant concern in multichannel operation. The enemy obtains information through merely knowing that such radio sets are operating. His analysis of the number and location of radios in operation and their volume of traffic, may produce even more

valuable data. Transmission security is part of communications security (COMSEC). COMSEC, along with electronic security (ELSEC), are embodied in signal security (SIGSEC).

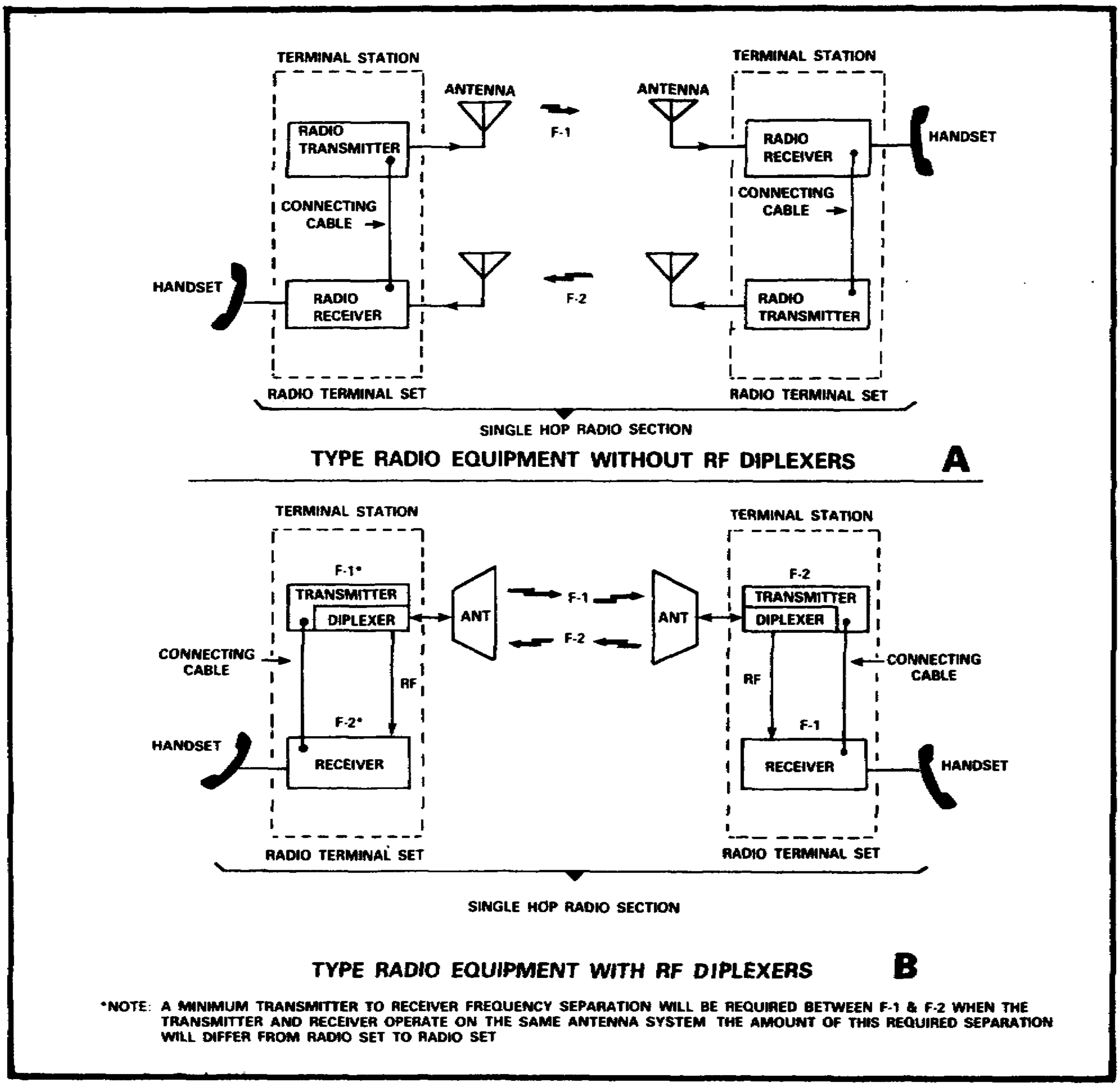


Figure 12. Typical Radio System.

a. Radio frequency spectrum use by microwave multichannel radio.

(1) Spectrum. The radio frequency spectrum is very broad. It is used by many radio frequency (RF) emitting devices other than those radios used in multichannel communications. The radios used in multichannel communications systems use only a selected portion of the overall RF spectrum; that ranging from very high frequency (VHF) through ultra high frequency (UHF) up to super high frequency (SHF).

(2) Frequency range. Each radio operates on a range of frequencies that may overlap or parallel the frequencies used by another radio. Yet, the radios may not be technically compatible or may use entirely different modes of propagation. For this reason, it is difficult to confine a particular type of radio to a distinct RF operating class or to define a radio by its operating frequency. Figure 13 illustrates the use of the RF spectrum by various radios used in multichannel systems.

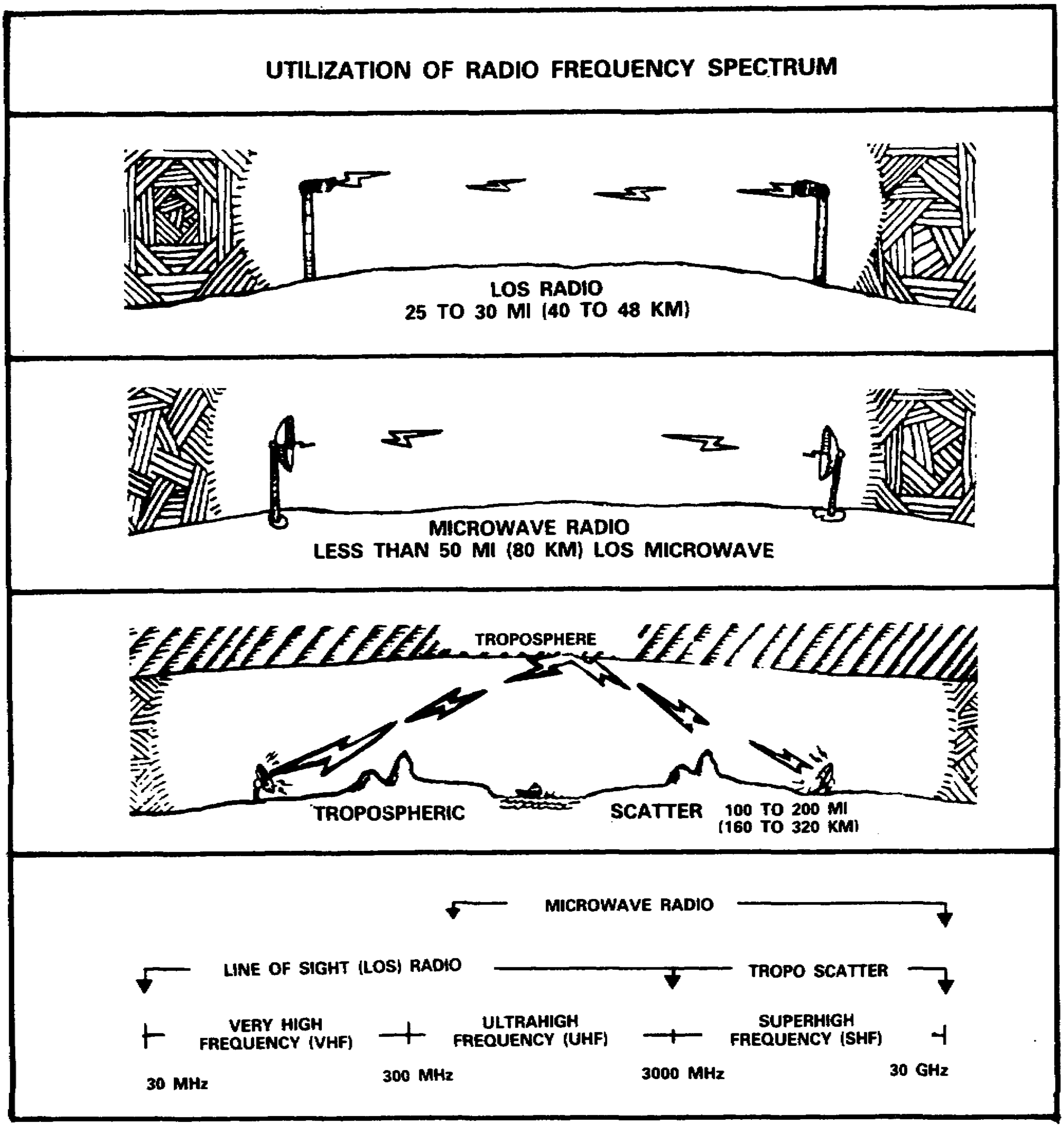


Figure 13. RF Spectrum Use by Microwave Multichannel Radio.

(3) VHF and UHF bands. The VHF and UHF bands cover frequencies from 30 to 300 MHz and from 300 to 3000 MHz respectively. Radio waves in these bands travel in nearly straight lines, and normally require a line-of-sight path between the transmitting and receiving antennas. Useful transmissions in these bands are generally limited by the curvature of the earth to 25 to 30 miles (40 to 48 km). However, longer transmissions may be possible under abnormal conditions.

(4) Microwave. Microwave radios operate in the UHF and SHF bands. Microwave frequencies start at approximately 1000 MHz in the UHF band and range upward into a portion of the SHF band. The SHF band extends from 3 gigahertz (GHz) to 30 GHz. Radio waves in the SHF band also travel in nearly straight lines. This generally limits transmissions to line-of-sight paths and distances under 50 miles (80 km). The exception is when a portion of the SBF band is used for tropospheric scatter transmissions.

(5) Tropospheric scatter. Tropospheric scatter radio sets operate in the SHF band. Stable and reliable radio propagation is possible over great distances by forward scatter of SHF waves (figure 13). Tropospheric scatter is one of two types of scattered transmission. Ionospheric scatter is the other, but it is useful only at frequencies below 60 MHz. In tropospheric scatter, radio waves are reflected off areas of turbulence in the troposphere 6-10 miles (10-16 km above the earth). The reflected energy is scattered back to earth beyond the horizon, permitting reliable communications at distances of 100 to 200 miles (160 to 320 km). The results of scatter propagation are generally predictable and useful.

Learning Event 3:
MICROWAVE MULTICHANNEL RADIO ANTENNAS.

1. General. In microwave multichannel systems, radio-frequency energy is generated by the transmitter and fed to a transmitting antenna through a transmission line. The antenna radiates this energy into space at approximately the speed of light. A receiving antenna absorbs part of this energy and sends it to the receiving equipment through another transmission line.

a. Functions of antennas. The transmitting antenna converts the output power generated by the radio into an electromagnetic field that is radiated through space. Thus, the transmitting antenna converts energy from one form to another. The receiving antenna has the opposite function. It converts the electromagnetic field that sweeps by it into energy that the radio receiver can use. In transmission, the antenna operates as the load for the transmitter. In reception, it operates as the signal source for the receiver.

b. Antenna gain. The gain of an antenna depends primarily on its design. Transmitting antennas are designed for high efficiency in radiating electromagnetic energy, while receiving antennas are designed for the efficient pickup of electromagnetic energy. In radio links of multichannel systems, transmission is needed between the transmitter and only one receiver. This situation makes it desirable to radiate as much energy as possible in only one direction. The directional characteristics of antennas increase the energy transfer in the favored direction and, at the same time, reduce the reception of unwanted noise and signals from other directions. Antennas are designed to minimize energy losses and maximize efficiency as radiators and receptors.

c. Radiation.

(1) When power is delivered to an antenna, two fields are set up. One is the induction field, which is associated with the stored energy; the other is the radiation field, which moves out into space. At the antenna, the intensities of both these fields are high. At a short distance from the antenna, and beyond, only the radiation field remains.

(2) The electromagnetic field is responsible for the transmission and reception of electromagnetic signals through free space. Radio waves consist of components of electric intensity and components of magnetic intensity. Thus, radio waves are moving electromagnetic fields (figure 14).

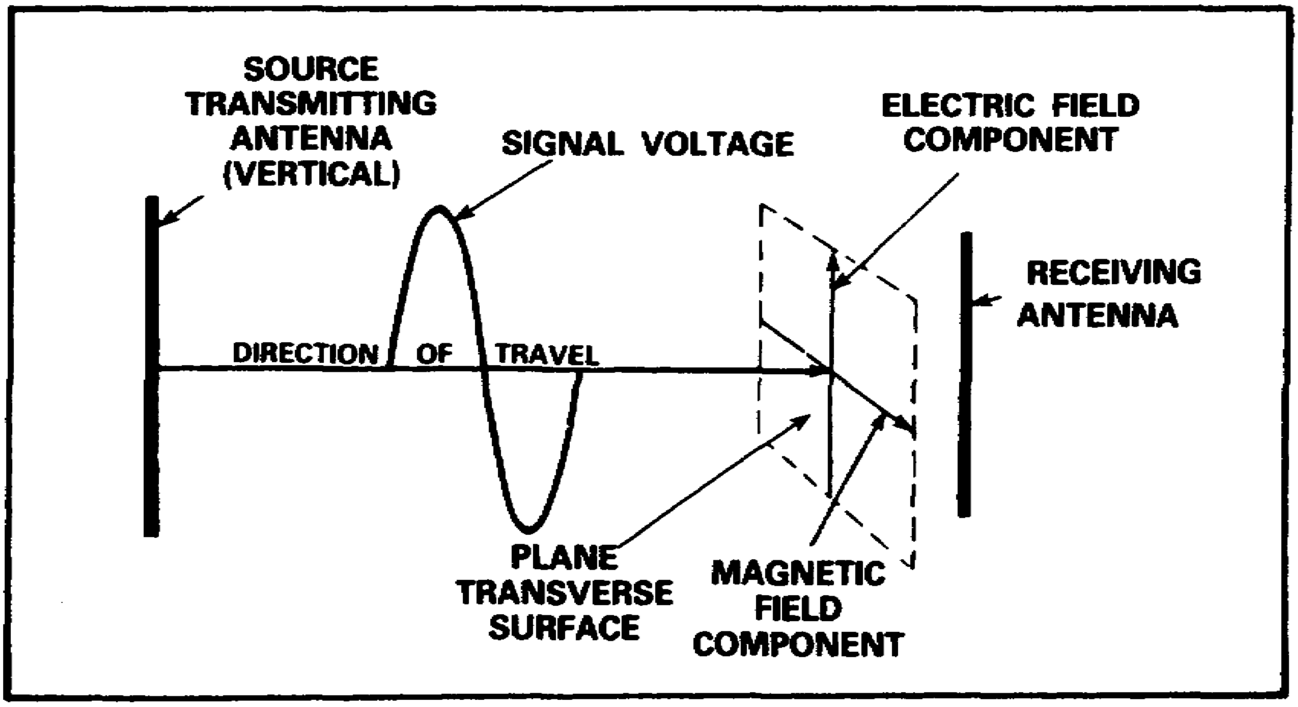


Figure 14. Electromagnetic Wave Component.

d. Antenna radiation patterns.

(1) The energy radiated by an antenna forms an electromagnetic field having a definite pattern, depending on the type of antenna used. This pattern is used to show both range and directional characteristics of an antenna. A vertical antenna theoretically radiates energy equally in all directions. In practice, however, the pattern is usually distorted by nearby obstructions or terrain features.

(2) The full radiation pattern is a three-dimensional field. It looks somewhat like a doughnut with the transmitting antenna in the center (figure 15). Radiation patterns will change with the design of the antenna. The virtually round doughnut shape is radiated by omni-directional antennas. Elongated ellipses are formed by the directional VHF and UHF antennas. Narrow, highly concentrated beams are associated with microwave and tropospheric signals in the UHF and SHF range. The elliptical and narrow beam patterns permit the major portion of the energy to be concentrated in the direction of transmission. This directional pattern is known as the lobe (figure 16).

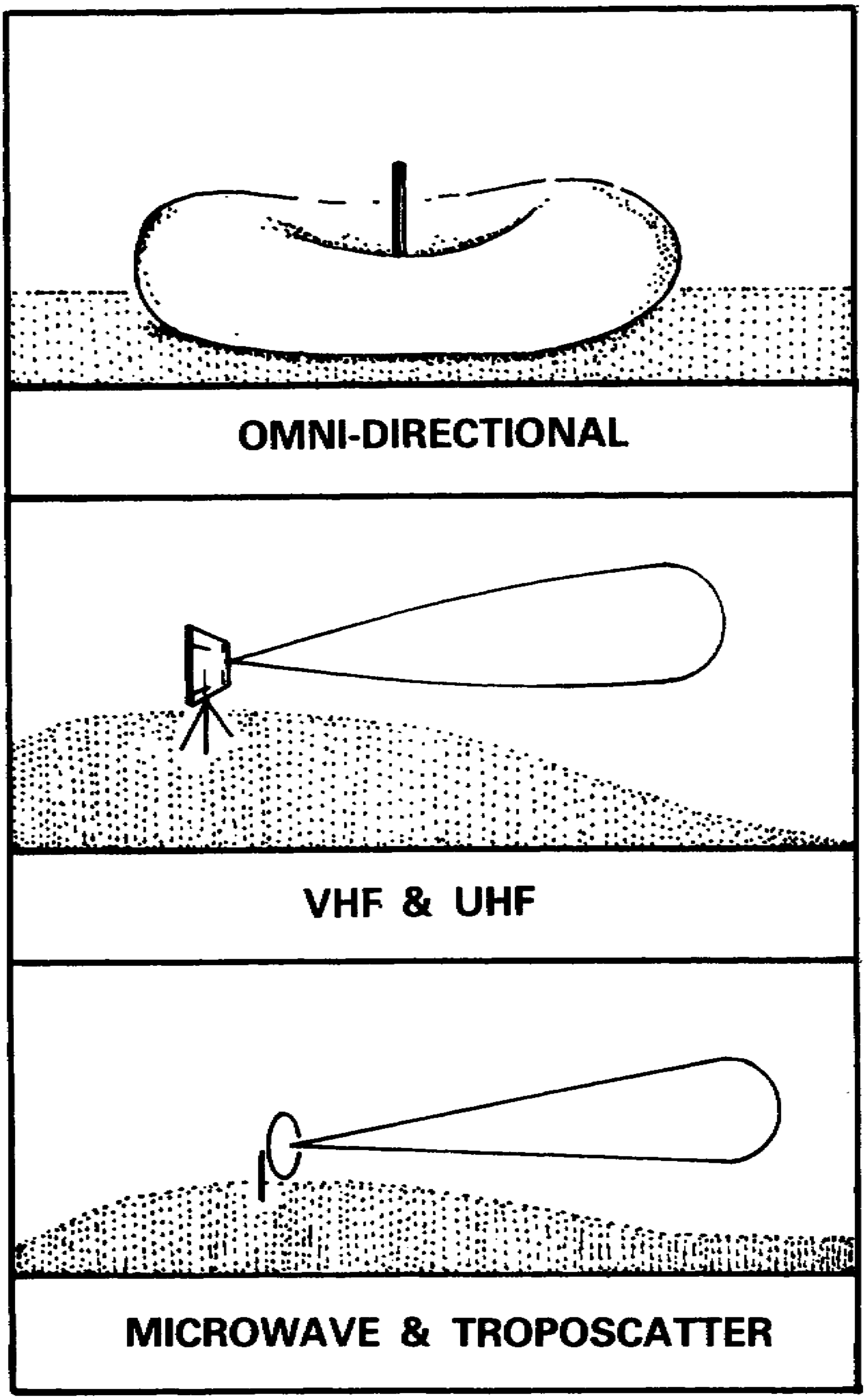


Figure 15. Antenna Radiation Patterns.

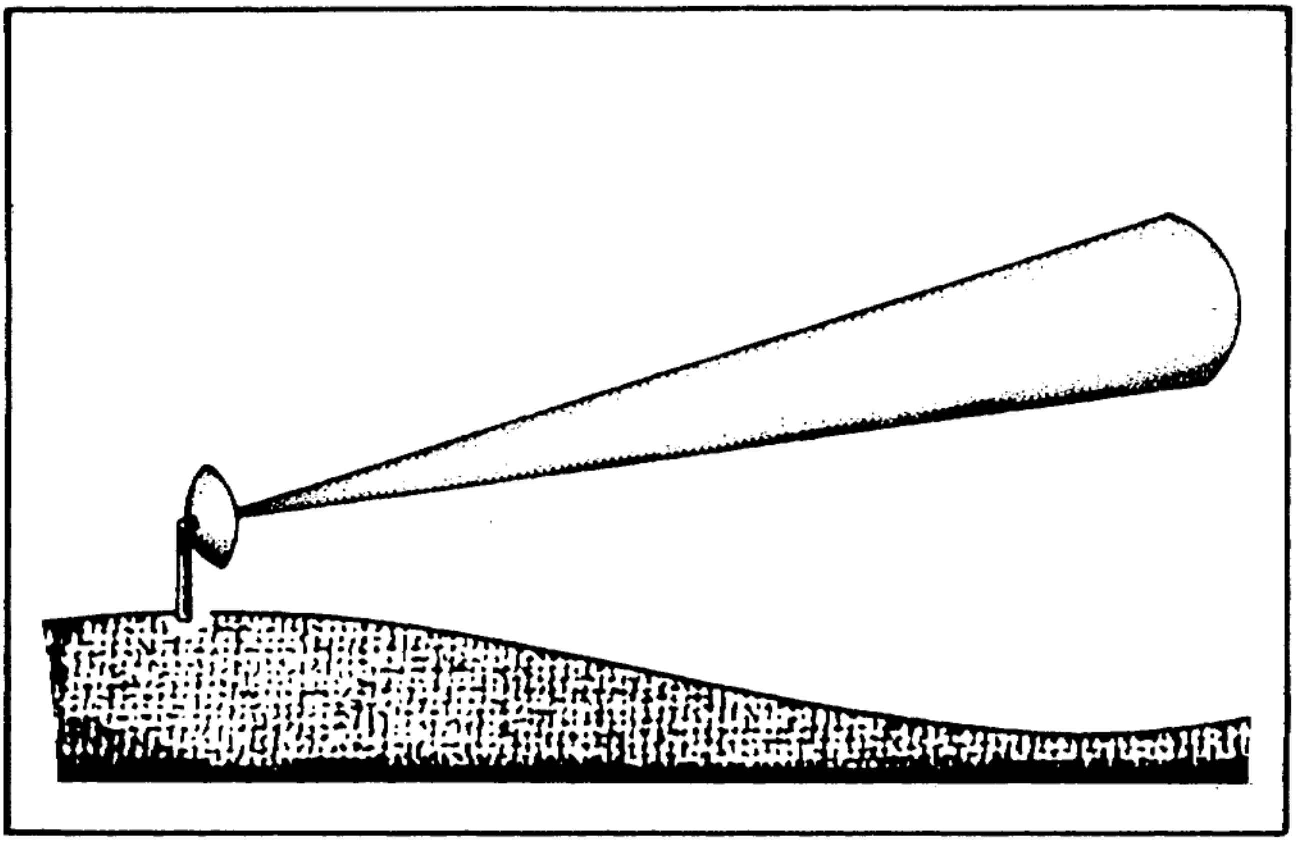


Figure 16. Example of a Direction Lobe.

e. Polarization.

(1) Polarization of a radiated wave is determined by the direction of the lines of force making up the magnetic field. If the lines of electric force are at the right angles to the surface of the earth, the wave is said to be vertically polarized. If the lines of electric force are parallel to the surface of the earth, the wave is said to be horizontally polarized.

(2) Maximum energy transfer results when a receiving antenna is so oriented that its polarity lies in the same plane as the electric field component of the transmitting antenna. Thus, a vertical antenna is used for efficient reception of vertically polarized waves, and a horizontal antenna is used for the reception of horizontally polarized waves. In some cases, the field rotates as the waves travel through space. Under these conditions, both horizontal and vertical components of the field exist and the wave is said to have elliptical polarization.

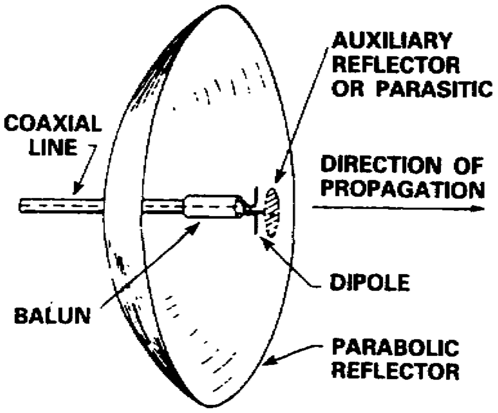
f. Directivity. Antennas used in multichannel systems possess high directivity. They concentrate radiation in a given direction and minimize radiation in other directions. Because wave lengths in the VHF and UHF ranges are short, it is practical to use antennas of such directivity and gain that moderately low power can provide reliable communications. The high directivity also aids in obtaining a slight degree of security, makes enemy direction finding more difficult, and reduces noise, interference, and fading.

g. Antennas used in the VHF and UHF ranges.

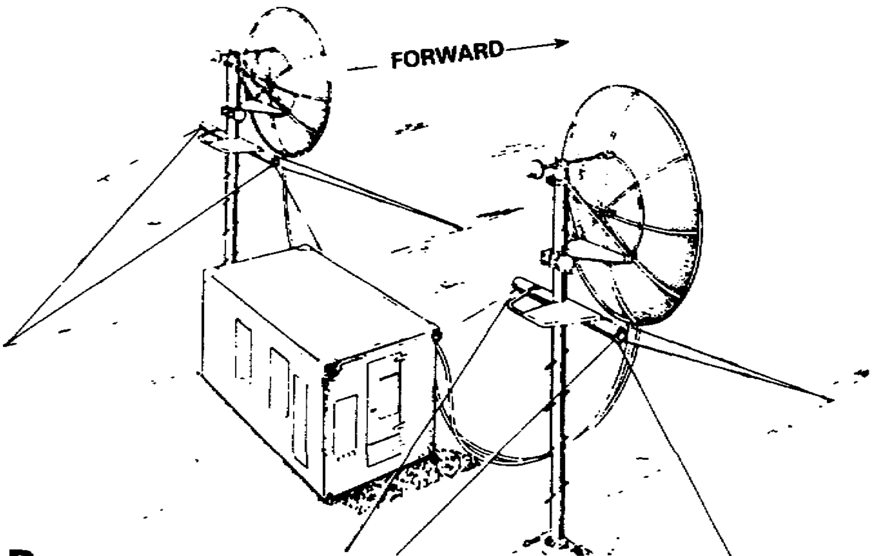
(1) The VHF frequency range begins at 30 MHz and the UHF frequency range ends at 3000 MHz. The antennas used in multi-channel systems are designed to match those frequencies. The wire rhombic and log periodic antennas used in the high frequency (HF) (3-30 MHz) range are not effective when used in the VHF and UHF ranges. Therefore, rhombics and log periodic antennas are seldom used at frequencies above 30 MHz. Reflective antennas, such as corner reflectors and parabolic reflectors, are preferred.

(2) At frequencies above 100 MHz, corner reflectors may be used. Above 400 MHz, the wave length is such that even a parabolic reflector, excited by a dipole at the focal point, is practical.

h. Parabolic reflector antenna. A parabolic reflector antenna (figure 17) consists of a saucer-like reflecting surface (parabola) with a small waveguide opening or a dipole (feed device) placed at its focal point. The wave from the primary source is reflected forward by the parabolic reflector as a plane wave. The larger the surface, the greater the antenna gain and the narrower the beam width. When a dipole source is used, a parasitic element or a small auxiliary reflector is often placed in front of the dipole so that more of the energy is directed toward the large parabolic surface. The presence of the dipole and auxiliary element has some blocking effect on the forward pattern, but the loss is small in large reflector antennas. The polarization of the field in the horizontal and vertical planes is the same as that of the primary source. In other directions, a cross polarized wave is developed that has both horizontal and vertical components. The reflector surface may be solid or perforated. To reduce wind resistance, some of the larger reflectors often have perforated surfaces or grid wires in which the spacings are a precalculated fraction of a wave length. Perforated and grid reflectors serve as well as solid reflectors. Parabolic reflector antennas are not restricted to the VHF portion of the spectrum. They are equally effective in line-of-sight microwave (frequencies at 1000 MHz or above) paths and tropospheric scatter paths. In microwave multichannel systems, parabolic reflector antennas are used with microwave radios using frequencies from 1500 MHz upwards, and with microwave and tropospheric scatter radios using frequencies up to and above 5000 MHz. Tropospheric scatter antennas must be sited to obtain the lowest possible line-of-fire angels while microwave antennas must be sited to obtain the best possible line-of-sight paths between stations.



A TYPE PARABOLIC REFLECTOR WITH DIPOLE EXCITATION



B TYPE TROPOSPHERIC SCATTER SYSTEM EMPLOYING TWO PARABOLIC REFLECTORS

Figure 17. Parabolic Reflector Antennas.

i. Polarization of antennas.

(1) General. Radio waves transmitted from a vertical antenna are vertically polarized and those transmitted from a horizontal antenna are horizontally polarized. Either type of polarization may be used, but the performance will vary under certain conditions. In all cases, the polarization of the receiving antenna must be the same as the transmitting antenna, otherwise, the loss of signal strength may be great enough to prevent communications.

(2) Advantages of vertical polarization.

(a) Vertically polarized waves are less affected by aircraft flying over the transmission path than are horizontally polarized waves.

(b) Vertically polarized antennas are more efficient for transmission over sea water at frequencies lower than 100 MHz. Ordinary line-of-sight antennas, less than 45 to 50 feet (15 meters) high, work best when vertically polarized. At higher frequencies, there is little difference in performance.

(3) Advantages of horizontal polarization.

(a) Horizontal antennas are less likely to pick up manmade electrical interference such as that which comes from power lines and transformers. Such interference is usually vertically polarized.

(b) In fairly dense forests, horizontally polarized waves suffer less loss than vertically polarized waves. Also, standing wave effects are not as pronounced with horizontal polarization. Standing wave effects can cause great variation in the field strength of vertically polarized waves when antennas are moved among trees or buildings.

(c) In very dense jungles, there is no advantage in either type of polarization. Performance is poor in this environment for all types of polarization.

(4) Cross polarization. In this configuration, the transmit and receive antennas at a multichannel station are oppositely polarized. Depending on equipment capabilities, the transmit and receive antennas may be mounted on a common mast or on separate masts. Cross polarization is normally used to reduce the required transmitter-to-receiver frequency separation.

(5) Polarization effects over tropospheric scatter paths. The transmitted polarization is generally preserved in tropospheric scatter operation paths. Experiments show that 90 percent of the received signal has the same polarization as the transmitted signal. Tests also indicate there are no appreciable differences in signal strength for horizontal, vertical, or circular polarization. Therefore, polarization has no significant effect on signal strength provided the receiving antenna is oriented in the same plane as launched by the transmitting antenna.

LESSON 2

PRACTICE EXERCISE
(PERFORMANCE-ORIENTED)

1. The troposphere is approximately how many miles above the earth's surface?

   a. 6 1/2 miles.

   b. 3 1/2 miles.

   c. 4 1/2 miles.

   d. 2 1/2 miles.

2. Where is the location of the stratosphere?

   a. Between the earth and ionosphere.

   b. Above the ionosphere.

   c. Between the troposphere and ionosphere.

   d. Below the troposphere.

3. What are the two fields set up in the antenna by the fluctuating energy?

   a. Induction and radiation fields.

   b. Left and right fields.

   c. Modulation and carrier fields.

   d. Passive and active fields.

4. What is the advantage of using a directional transmitting antenna?

   a. You can see the direction of travel.

   b. You can concentrate the radiation.

   c. You can interface with friendly stations.

   d. None of the above.

5. In what direction does the band of frequencies in the VHF and UHF travel?

   a. Straight.
   b. Parabolic.
   c. Hyperbala.
   d. Curve.

6. What are the frequencies used in microwave systems?

   a. 1000 MHz and above.
   b. 200 MHz and above.
   c. 300 MHz and above.
   d. 50 MHz and above.

7. Which agency handles part of the transmission security?

   a. MOMSEC.
   b. COMSEC.
   c. EOMSEC.
   d. BEMSEC.

8. What kind of polarity will there be when the lines of electric force are at the right angles to the surface of the earth?

   a. Horizontally polarized.
   b. Vertically polarized.
   c. Cross polarized.
   d. All of the above.

9. What polarity does the receiving antenna have to be to receive maximum power transfer from the transmitting antenna?

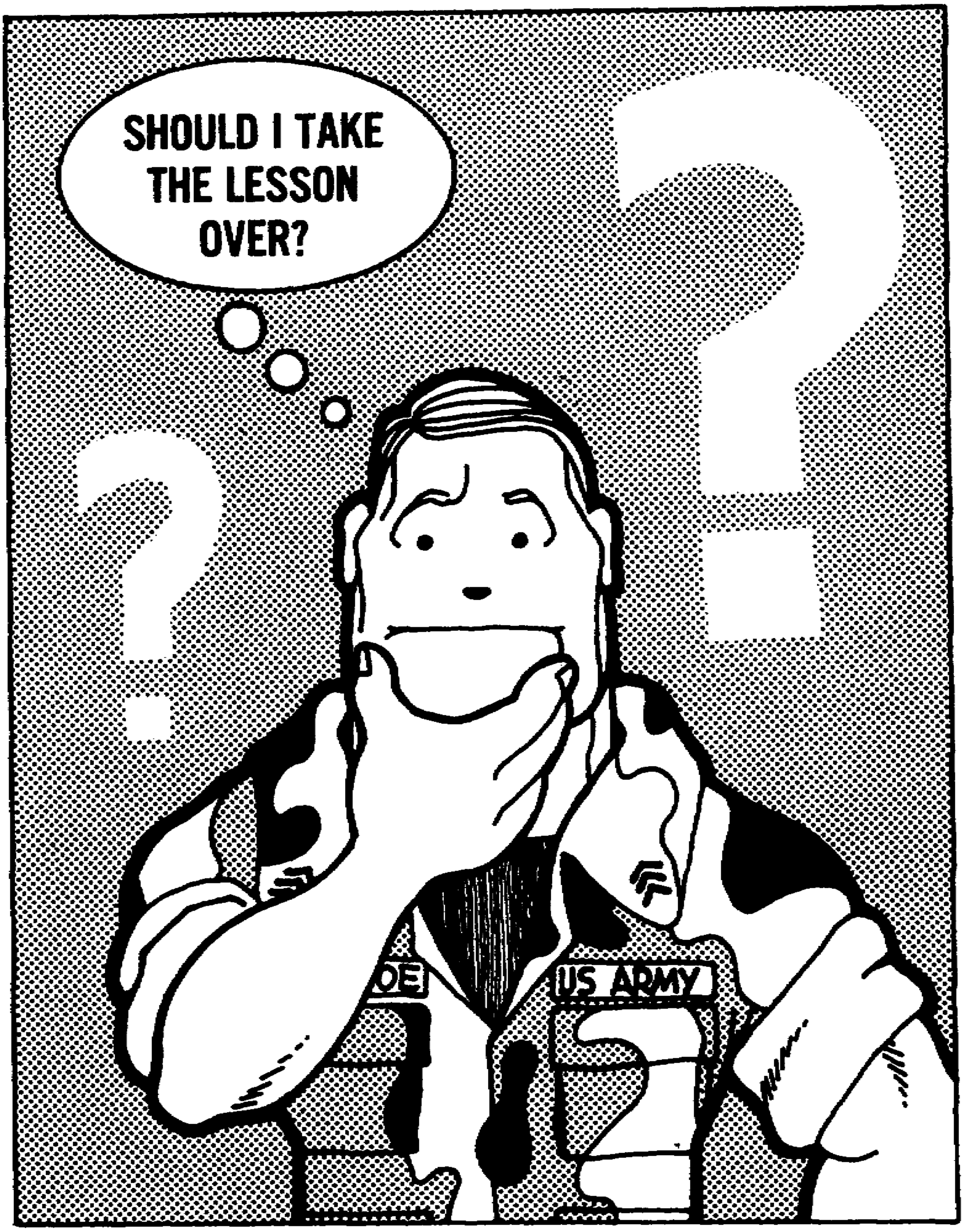
   a. Receiving is vertical, transmitting horizontal.
   b. Receiving is vertical, transmitting vertical.
   c. Receiving is horizontal, transmitting vertical.
   d. None of the above.

10. What purpose does the paratolic reflector serve?

   a. Increases antenna gain.
   b. Decreases antenna gain.
   c. Stops antenna gain.
   d. All of the above.

LESSON 2

PROPAGATION OF RADIO WAVES



LESSON 3

SYSTEM ALIGNMENT

TASK

The soldier will define the principles of system alignment, noise, interference and fading.

CONDITIONS

Given information and diagrams about the principles of system alignment, noise, interference and fading.

STANDARDS

Demonstrate competency of the objective by responding to 85 percent of the multiple-choice test covering the principles of system alignment, noise, interference and fading in lesson 3.

REFERENCE

FM 24-21

Learning Event 1:
CONTROL OF ALIGNMENT

1. General.

The overall microwave multichannel system must be aligned in accordance with instructions contained in the appropriate equipment technical manuals (TM). Both the radio system and the multiplexer system are included in the overall system alignment.

2. Control of alignment.

a. All alignments are supervised by the controlling terminal, designated terminal A. The remaining terminal in the system is designated terminal B. The multichannel equipment operators at terminal A will supervise the overall system alignment.

b. During system alignment, intermediate or repeater stations report all readings to the controlling terminals.

c. Permission to make alignment adjustments must be obtained from the control terminal. If equipment is being used that requires critical signal levels to be transmitted over the system, the control terminal must ensure that no more than a 2 dB change will result in the system as a result of any one alignment.

3. Radio-system alignment.

a. The radio system alignment is performed after the starting procedures for each radio set of the system have been made. If connections to the multiplexing system have been made, the control multiplexing terminal must be informed when the radio-system line-up is completed. Then the overall system alignment may be accomplished.

b. The radio alignment procedure is accomplished first in the A-B direction, and then in the B-A direction. When performing the alignment, the controls of the transmitter at radio terminal A are adjusted first. When this has been accomplished, the control radio terminal attendant directs the attendant at the next receiver in the A-B direction to adjust his receiver control to obtain appropriate signal level. When this has been accomplished, radio terminal A then directs that the next transmitter in the A-B direction be adjusted. Each successive receiver and transmitter in the A-B direction is aligned in sequence until the receiver at terminal B is aligned. At this point, radio terminal B assumes temporary control, and directs the alignment in the B-A direction.

4. Overall system alignment.

The overall system alignment is performed for both the multiplexing system and the radio system. The alignment is performed at the direction of the controlling multiplexing terminal. As in the case of the radio system alignment, the multiplexing system alignment is accomplished first in the A-B direction and then in the B-A direction. The procedure followed is the same at both terminal and repeater stations as in radio alignment.

Learning Event 2:
NOISE AND INTERFERENCE.

1. General. The amount of noise or interference at the receiver location limits the length of hops between multichannel equipment. The more noise or interference that is present, the shorter the distance that can be covered. A high noise level will reduce quality in telephone circuits and cause errors in teletypewriter circuits. In the automatic switching system, an excessive noise level can cause trunk call blockage.

a. Noise in line-of-sight and tropospheric scatter systems. The two basic types of noise existing within line-of-sight or tropospheric scatter relay systems are:

(1) Idle noise. This noise is always present in a system, with or without modulation. Idle noise includes thermal noise generated within the equipments by mixer diodes, low level amplifiers. It includes shot noise from klystrons. It also includes noise generated by semi-conductors, multiplier chains, and crossover electro-magnetic effects.

(2) Intermodulation noise. This noise is introduced into the system as a result of heavy signal load or increased operating level. The greater the traffic load or the higher the operating level, the more intermodulation noise introduced. Usually intermodulation noise increases slowly until a "break point" is reached, after which, it increases rapidly. Generally, it is desirable to operate the systems at as high a signal level as possible (short of the breakpoint) in order to improve the signal/noise (S/N) ratio. For some equipment, however, specific signal levels must be maintained to ensure proper operation.

b. Interference in line-of-sight and tropospheric scatter systems. Most interference in line-of-sight or tropospheric scatter systems is generally of three types; interference from natural sources, man-made interference, and mutual interference. The prime requirement for good communications is a high S/N ratio. Radio interference is discussed in more detail in the next three paragraphs.

c. Interference from natural sources.

(1) Radio interference from natural sources may be divided into four classifications:

(a) Atmospheric interference; electrical storms.

(b) Solar and cosmic interference; eruptions on the sun and other stars.

(c) Precipitation static from charged particles in the atmosphere. Particles may be rain, sleet, snow, sand, and smoke or dust. Dry particles produce greater charges than wet ones.

(d) Fading from disturbances in the medium through which radio waves are propagated.

(2) The interferences listed above appear in electronic equipment as audible noise or errors in the output of some terminal equipments. There is some interference at most frequencies, but the higher the frequency, the less noise.

d. Mutual interference.

(1) When one communications system interferes with another or when one unit in a system interferes with other units in the same system, there is a condition of mutual interference.

(2) Mutual interference may appear in several forms, such as noise, crosstalk, and harmonic interactions. Some of the common conditions that cause mutual interference are as follows:

(a) Transmitter fundamental radiation to receiver fundamental response.

(b) Transmitter spurious radiation to receiver fundamental response.

(c) Transmitter fundamental radiation to receiver spurious response.

(d) Transmitter spurious radiation to receiver spurious response.

(e) Receiver radiation to receiver fundamental response.

(f) RF arcing in transmitters.

(g) Impedance mismatch in the antenna system.

(h) High voltage pulse interference.

(i) Improper frequency assignments.

(3) Spurious radiation refers to signals radiated from the transmitter on many frequencies other than the fundamental or carrier frequency. While these spurious radiations are weaker than the fundamental or carrier frequency, they may be strong enough to cause interference (noise) in nearby receivers. This is true especially when a receiver is tuned to a frequency corresponding to one of the spurious transmitter radiations.

(4) If these interference signals are strong enough, they may be amplified to the point where they will render the desired signal unintelligible. It is possible for the local oscillator in a superheterodyne-type receiver to radiate a signal which can cause interference. This is known as receiver radiation.

(5) Mutual interference may originate from many local and distant sources. Frequency relationships, geographical locations, faulty adjustment of equipment, improper operating techniques, and weather conditions are factors contributing to mutual interference. Equipment and systems that are potential generators of mutual interference include radar, radio, radio aids to navigation, and telephones.

e. Operation with high system noise.

(1) Occasionally, traffic channel noise is excessive. This may be caused by a higher noise level at one or more radio hops than at others. A hop may have relatively high path attenuation due to a long transmission path or line-of-sight obstructions. A high noise level also may be caused by external sources such as ignition or radio interference.

(2) Under such conditions, it frequently will be possible to improve the overall system signal-to-noise ratio. Better reception may be obtained by increasing the signal output of the transmitter and reducing the gain of the receiver where the high noise level occurs.

(3) There are limits to signal-to-noise improvement; however, changing a multichannel output of a certain number to a channel output of a lesser number will increase the relative signal-to-noise level. For example, a 12-channel output may be reduced to a 4-channel output, or a 4-channel output may be reduced to a 1-channel output, etc. This assumes that all of the transmitter power that was used in the higher number of channels is applied to the lower number.

(4) When a particular hop is operating with excessive noise, follow the procedure outlined in the equipment manual.

Learning Event 3:
FADING.

1. General. Fading may generally be considered a form of interference. It is not normally cause by man-made interference of sources outside of the transmission medium. Fading is the variation of radio field strength caused by changes in the transmission medium with time.

a. Violent changes in the ionosphere, known as ionosphere storms, may also cause fading, especially at frequencies higher than 1500 kHz. These disturbances are caused by vigorous sunspot activity and may last as long as several weeks.

b. All frequencies used in microwave multichannel links are subject to fading. The most common method to overcome fading is to increase the power to the transmitter. The use of automatic gain control in the receiver will compensate for minor changes in signal intensity. Though fading can occur along any transmission path, the effects of fading are not as pronounced on VHF and UHF paths as it is on microwave and tropospheric scatter paths. Other aspects of fading, and measures to combat them, are discussed in the following paragraphs.

2. Microwave multichannel fading aspects.

a. For paths above the horizon, two general kinds of microwave fading exist; inverse-bending and multipath. They differ in origin, character, locations where they are most prevalent, and effects on communications.

(1) Inverse-bending fading is typically found over water. It is rare over land, except on some foggy paths near large bodies of water. The individual fades may last for minutes or hours, until the climatic phenomena no longer exists.

(2) Multipath fading may occur over many kinds of paths. It may result from reflections from water or highly reflective earth. At the longer distances, it may be a result of refraction from an elevated layer of the toposphere. It may also result from adjacent multiple paths caused by local irregularities in the troposphere. The duration of individual multipath fades is from about a second to a minute.

(3) Both kinds of fading may occur at the same time on the same path. When the signal is weakened by inverse-bending, it is more subject to multipath effects.

b. The maximum depth of fading occurs when the air is still and humid, and the ground is warmer than the air. The minimum depth of fading occurs when the air is dry and well-stirred by winds. Therefore, deep fading is ordinarily seasonal.

c. The depth of fading tends to be greater at longer distances, but climatic conditions are fully as important as distance. The amount of fading, or its time occurrence, cannot be accurately predicted; and therefore, must be estimated.

d. Fading results in a poorer signal-to-noise ratio. When the audio signal-to-noise ratio is seriously impaired by fading, telephone communications becomes difficult, errors appear in the telephone signaling and in VF teletypewriter traffic, and facsimile reproductions show spots, blotches, or blackout. If the fade is deep enough, the signal is entirely lost in the noise.

e. In pulse modulation systems, when the RF signal weakens, the audio signal-to-noise ratio is about proportional to the RF signal-to-noise ratio until the latter reaches a low value called the breaking point. If the RF signals are weaker than this breaking point, the audio noise increases much faster than the RF signal decreases. The margin between the steady-state conditions and the breaking point is sometimes called the fade margin. When the breaking point is reached on any system, the noise has already reached a level above the 0 dB transmission level. This seriously impairs reception.

3. One percent microwave multichannel fading.

a. One percent fading is taken as the depth of face (in dB) that is exceeded only 1 percent of the total time in the worst month of the year in the locality concerned. This is approximately 7 hours, assuming 24 hours a day operation. One percent fading is the sum (total time) of all the separate intervals (times) that the depth of fade exceeds the stated amount. General fading conditions may extend over a period of several hours (usually in the early morning hours during worst month conditions). However, the deep fades that exceed the stated amount for 1 percent fading criteria are of very short duration, ranging from a few seconds to a minute or so. Thus, out of the total period that disturbing fades exist, only a total of a few minutes would exceed the stated amount for 1 percent fading criteria.

b. Microwave fading estimates are based on an expected 1 percent fading depth of 20 dB on a single 35-mile link. In the month of worst microwave fading, the dB depth of fade, with good siting, will vary above or below 20 dB based on the square root of the link length. When one link has a deep fade, the others will seldom have one at the same moment. These figures apply when there is a good clearance. At, or just above, grazing (on the basis of K = 4/3 true earth radius), the fading probably would be about 6 dB deeper.

4. General measures to combat microwave fading.

a. Avoid paths where deep fading is likely.

b. Make the path loss low enough to provide an adequate fade margin.

c. Use space diversity when needed.

d. When fading is of the inverse-bending type (slow fading), raise the antenna higher than just enough to give free space loss. Clearance (above the grazing line over the surface of the earth or the most prominent obstacle) approximately twice the clearance necessary for free space loss is recommended in this case. If fast fading also is prevalent, use space diversity.

5. Space density.

a. To use space diversity (figure 18), a second receiving antenna is so placed that when the signal at the first receiving antenna is weak, the signal at the diversity antenna is relatively strong. To do this, the two antennas must be properly spaced. Each antenna must connect to its own receiver, and the receiver outputs must be connected through a combining circuit actuated by control voltages taken from the two receivers.

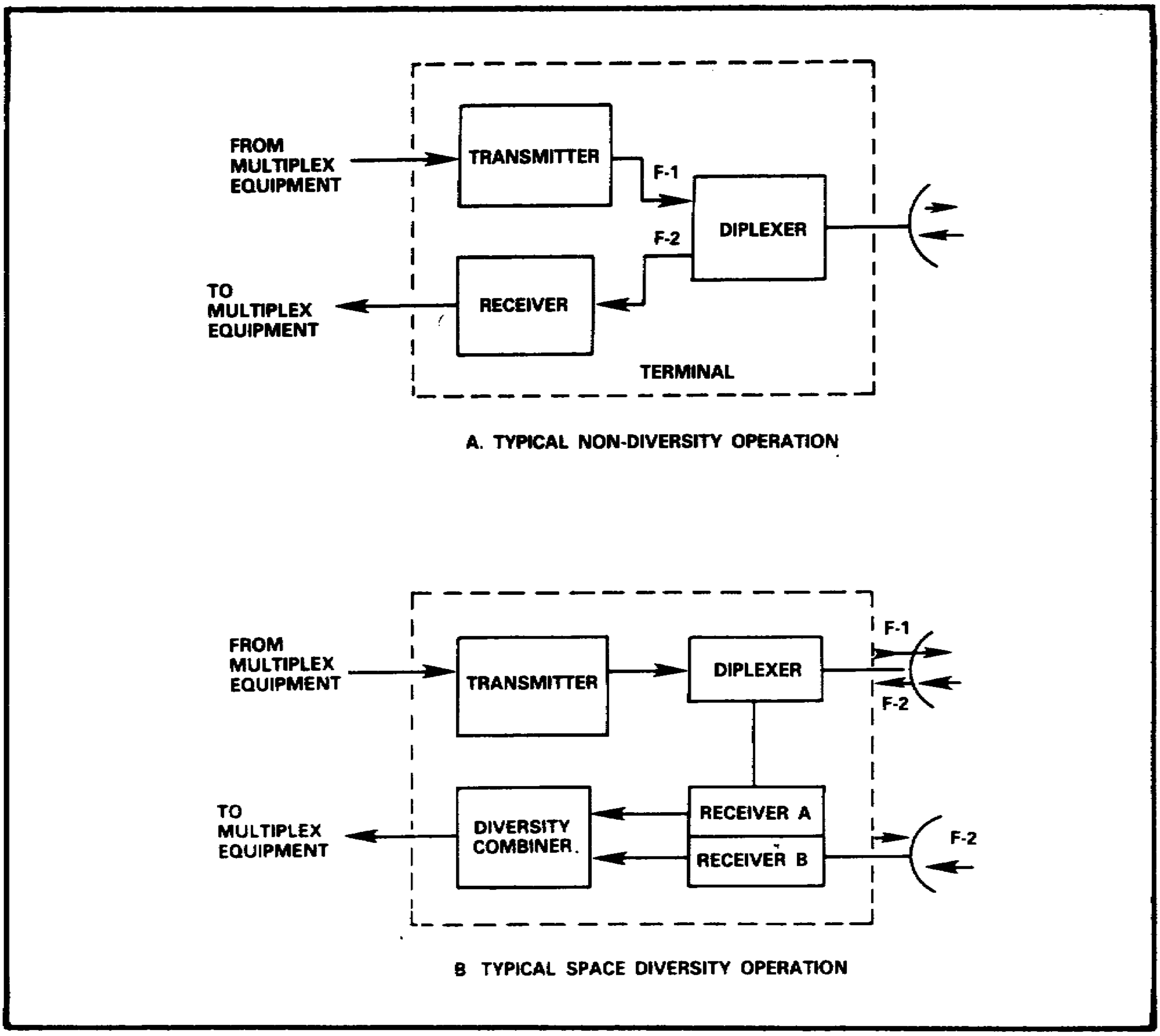


Figure 18. Examples of Space Diversity.

b. When fading is of the inverse-bending type, space diversity ordinarily is not helpful, unless the second antenna can be placed considerably above the original antenna.

c. Fading effects are not completely eliminated by the use of space diversity, but the duration of poor signal-to-noise ratio is considerably reduced.

d. The diversity antenna usually is placed from 50 to 100 feet directly below or above the first receiving antenna (figure 19). Only a rough practical rule can be used, so considerable changes in antenna spacing may be necessary. Spacing of even less than 50 feet may be effective. Frequency diversity may also be used to minimize fading on microwave systems.

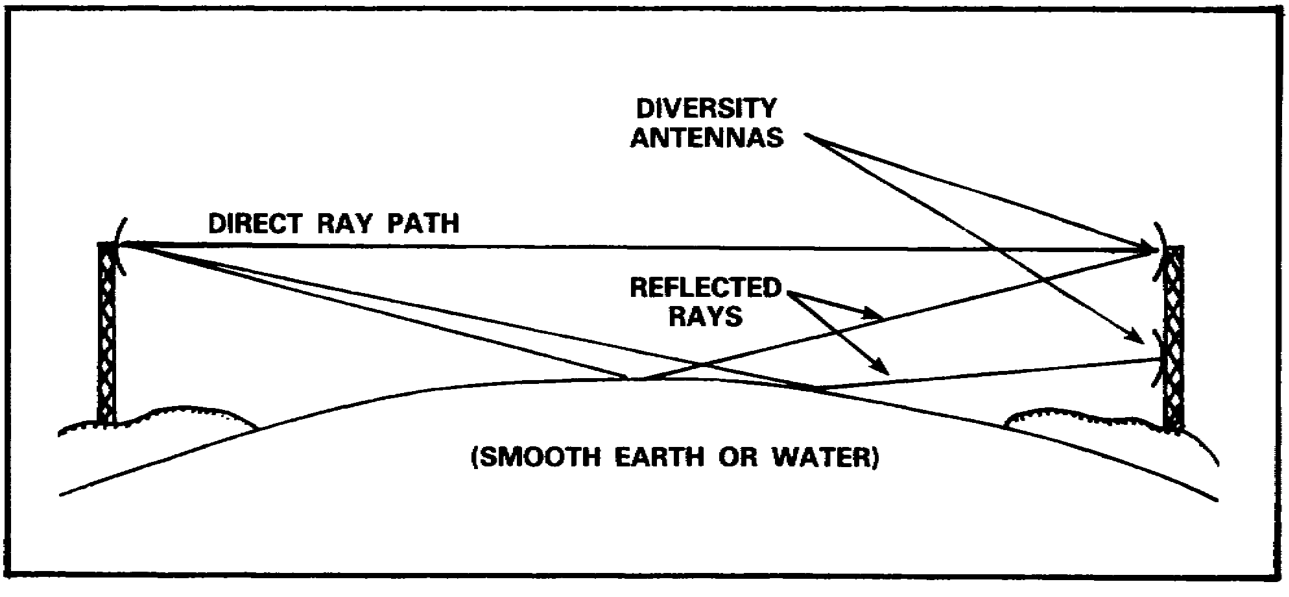


Figure 19. Space Diversity Antenna Arrangement.

e. Frequency diversity. In frequency diversity, the same information is sent simultaneously on more than one frequency. Because of lack of correlation of fast fading over a path on different frequencies, a strong likelihood exists that the carrier and all sidebands will not fade out together, and at least one frequency will nearly always be received. Such a system is wasteful of bandwidth, but offers advantages in certain applications where a space diversity system is not feasible. It can be combined with space diversity further to reduce error rates.

f. Space diversity. This is the only technique that has been used extensively on long-range tropospheric scatter circuits. It is the most commonly used form of diversity when sufficient ground is available. Dual space diversity (use of two paths) receiver-antenna configuration provides approximately 99.9 percent reliability in a 100-mile point-to-point communications circuit, providing the scatter volume height and scatter angle are kept low. To obtain the same circuit reliability with a single receiver-antenna system would require either an increase in transmitter power, a decrease in receiver noise figures, or an increase in overall antenna gain. In a space diversity system, the outputs of the individual receivers are switched or combined in such a manner as to ensure the best possible signal-to-noise ratio in the final diversity signal.

LESSON 3

PRACTICE EXERCISE
(PERFORMANCE-ORIENTED)

1. Which terminal controls all alignments?

   a. C.
   b. A.
   c. B.
   d. D.

2. What must the controlling terminal ensure?

   a. No more than 10 dB of change.
   b. No more than 7 dB of change.
   c. No more than 5 dB of change.
   d. No more than 2 dB of change.

3. Which direction is the radio alignment first made?

   a. B-C.
   b. B-A.
   c. A-B.
   d. A-C.

4. What type of noise is always present in a system?

   a. Intermodulation noise.
   b. Idle noise.
   c. Cosmic noise.
   d. High noise.

5. What is one of the basic types of noise existing within line-of-sight or tropospheric scatter relay systems?

   a. Solar noise.
   b. Precipitation noise.
   c. Intermodulation noise.
   d. All of the above.

6. What is it called when one communication system interferes with another?

   a. Mutual inductance.
   b. Mutual interference.
   c. Mutual capacitance.
   d. Mutual murial.

7. What happens to communication equipment when there are eruptions on the sun and other stars?

   a. Atmospheric interference.
   b. Cosmic interference.
   c. Precipitation interference.
   d. Increase signal strength.

8. What type of interference is caused by charged particles in the atmosphere?

   a. Atmospheric interference.
   b. Cosmic interference.
   c. Precipitation interference.
   d. None of the above.

9. What may cause fading in the 1500 kHz range and above?

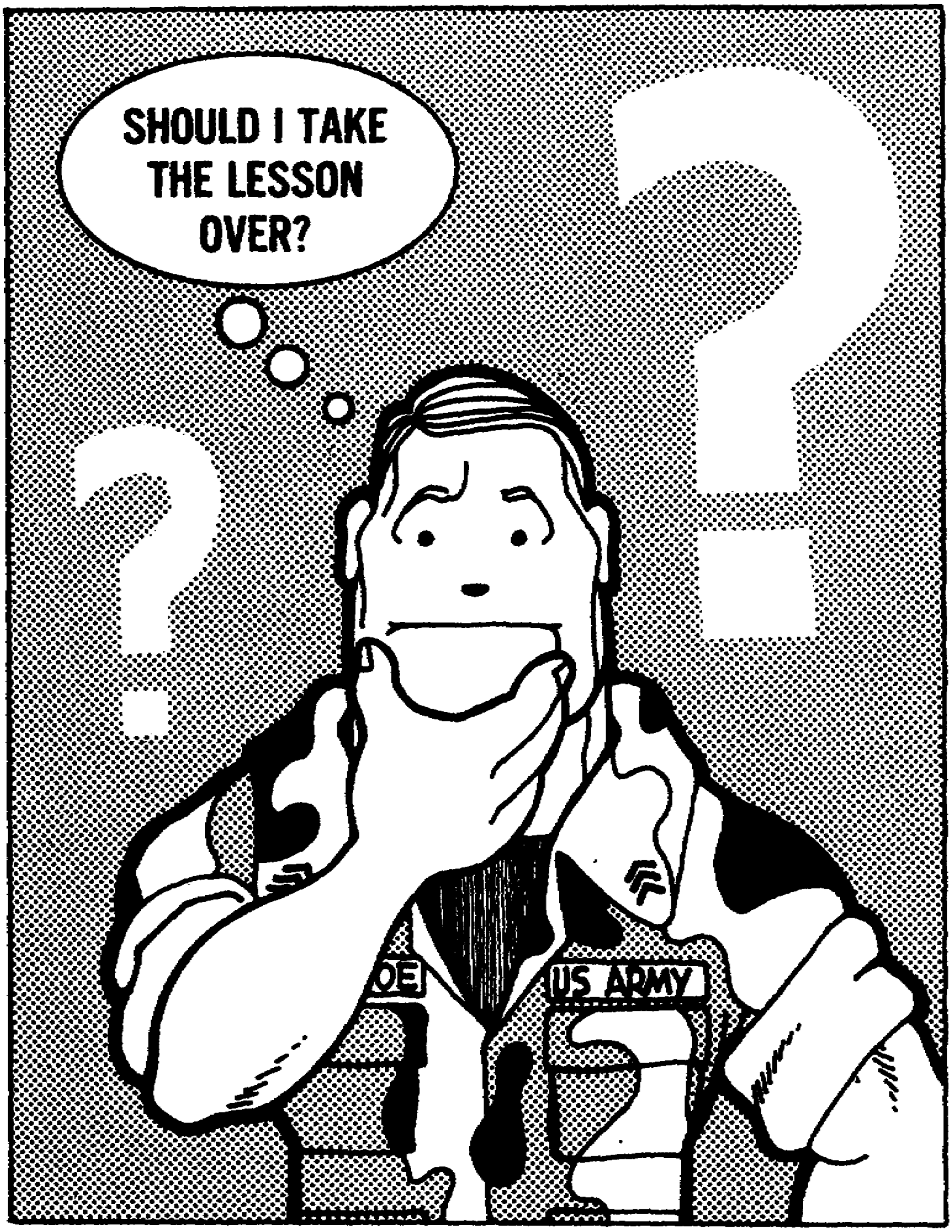
    a. Tropospheric storm.
    b. Stratospheric storm.
    c. Ionospheric storm.
    d. Rain storm.

10. Where is inverse-bending fading typically found?

    a. Cities.
    b. Farms.
    c. Mountains.
    d. Water.

LESSON 3

SYSTEM ALIGNMENT



ANSWERS TO
PRACTICE EXERCISES
(SOLUTION SHEET)

ANSWERS			REFERENCES
LESSON 1			
1.	(d)	Power Supply and Oscillator	Lsn 1, LE 1, Para 2 Pg 2
2.	(a)	Generator	Lsn 1, LE 1, Para 2 Pg 2
3.	(b)	Tune circuit	Lsn 1, LE 1, Para 2 Pg 2
4.	(a)	Extract intelligence from RF signal	Lsn 1, LE 1, Para 4a Pg 3
5.	(c)	Increases the radio frequency	Lsn 1, LE 1, Para 4b Pg 3
6.	(b)	300,000 kilometers per second	Lsn 1, LE 2, Para 1 Pg 4
7.	(c)	Lower	Lsn 1, LE 2, Para lb Pg 6
8.	(d)	50 to 150 miles	Lsn 1, LE 2, Para d Pg 8
9.	(b)	Side-bands	Lsn 1, LE 3, Para b(4) Pg 10
10.	(a)	Constant amplitude	Lsn 1, LE 3, Para c(5) Pg 12
LESSON 2			
1.	61 miles		Lsn 2, LE 1, Para la Pg 18
2.	Between the troposphere and ionospheric		Lsn 2, LE 1, Para lb Pg 18
3.	Induction and radiation fields		Lsn 2, LE 1, Para 2a Pg 19
4.	You can concentrate the radiation.		Lsn 2, LE 1, Para 3 Pg 20
5.	Straight.		Lsn 2, LE 2, Para la(3) Pg 25

ANSWERS	REFERENCES
6. 1000 MHz and above	Lsn 2, LE 2, Para 1a(4) Pg 25
7. COMSEC	Lsn 2, LE 2, Para 1 Pg 21
8. Vertically polarized	Lsn 2, LE 3, Para 1e(1) Pg 29
9. Receive is vertical, transmit vertical.	Lsn 2, LE 3, Para 1e(2) Pg 29
10. Increases antenna gain	Lsn 2, LE 3, Para 1h Pg 30
LESSON 3	
1. A	Lsn 3, LE 1, Para 2a Pg 38
2. No more than 2 dB of change	Lsn 3, LE 1, Para 2c Pg 38
3. A-B	Lsn 3, LE 1, Para 3b Pg 39
4. Idle noise	Lsn 3, LE 2, Para 1a(l) Pg 40
5. Intermodulation noise	Lsn 3, LE 2, Para 1a(2) Pg 40
6. Mutual interference	Lsn 3, LE 2, Para 1d(1) Pg 41
7. Cosmic interference	Lsn 3, LE 2, Para 1c(b) Pg 40
8. Precipitation interference	Lsn 3, LE 2, Para 1c(c) Pg 40
9. Ionospheric storm	Lsn 3, LE 3, Para la Pg 42
10. Water	Lsn 3, LE 3, Para 2a(1) Pg 43