SUBCOURSE
SS0002

EDITION
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U S ARMY SIGNAL CENTER AND FORT GORDON

INTRODUCTION TO TACTICAL RADIO COMMUNICATIONS

DEVELOPMENT DATE: MARCH 1993

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

INTRODUCTION TO TACTICAL RADIO COMMUNICATIONS

Subcourse Number SS0002

EDITION A

United States Army Signal Center and Fort Gordon
Fort Gordon, Georgia 30905-5000

6 Credit Hours

Edition Date: March 1993

SUBCOURSE OVERVIEW

This subcourse presents the basic theory of radio operation, the different types of tactical radios currently in use, and basic tactical radio communications procedures.

There are no prerequisites for this subcourse.

This subcourse reflects the doctrine which was current at the time it was prepared. In your own work situation, always refer to the latest official publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

TERMINAL LEARNING OBJECTIVE

ACTION: Identify and describe the basic principles of radio communications and apply those principles to tactical radio communications. You will also become familiar with the tactical radio equipment and communications procedures currently in use in the field. You will also learn about the organization, equipment capabilities, and procedures for the Single-Channel Ground and Airborne Radio System and improved high frequency radio systems.

CONDITION: You will be given information from this subcourse.

STANDARD: To demonstrate competency of this task, you must achieve a minimum score of 70% on the subcourse examination.

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LESSON 1

INTRODUCTION TO TACTICAL RADIO COMMUNICATIONS THEORY

CRITICAL TASKS: 01-5878.04-0005,
01-5778.07-0003, 01-5778.07-0007

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn the basic theory of tactical radio communications including types of modulation (frequency modulation (FM) and amplitude modulation (AM)), transmission characteristics for various frequency ranges, antenna characteristics, and how to select an antenna for a specific communications task.

TERMINAL LEARNING OBJECTIVE:

ACTIONS:

a. Describe the operation of a basic frequency modulation, amplitude modulation/double sideband, and amplitude modulation/single sideband transmitter and receiver.

b. Define transmission characteristics of high frequency (HF), very high frequency (VHF), and ultra high frequency (UHF) radio waves.

c. Select tactical antennas for specific tactical radio transmission requirements.

d. Determine the antenna polarization to obtain optimum communications when using tactical radio sets.

e. Recognize and describe the four conditions that must be considered for compatibility between different radio sets.

CONDITION: You will be given information from this lesson.

STANDARD: To demonstrate competency of the terminal learning objective, you must achieve a minimum score of 70% on the subcourse examination.

REFERENCES: The material contained in this lesson was derived from the following publication: FM 24-18.

INTRODUCTION

The advent of modern transportation has changed the face of the battlefield immensely. Gone are the days when the messenger could run through the trenches to the headquarters tent with on urgent message for the Officer in Charge. Today that headquarters may be as much as 500 miles away, and that is a little too far even for the hardiest marathon runner. We must now rely on other more sophisticated means to get messages from the front lines to the "Headquarters Tent." In addition, the introduction of aircraft to the modern battlefield has added a third dimension to the way we must think about coordinating our forces.

The medium that brings all the elements of the modern battlefield together and ensures a coordinated effort is radio. The radio has become the central nervous system of the battlefield, keeping each element informed of the progress of the whole. As signal officers, it is your job to ensure that these nerves function properly and efficiently. You must be able to make the very best use of each and every piece of equipment assigned to you and to units under your cognizance. In order to do this you must first have a thorough understanding of those capabilities, and the best place to start is with the basics of radio communication theory.

1. Radio Waves.

Radio waves make up one portion of the electromagnetic spectrum. We identify a particular radio wave by its frequency. The frequency of a radio wave is the number of oscillations the wave makes in one second. The unit of measurement for radio wave frequency is the hertz (Hz) or cycles per second. One hertz equals one cycle per second. Another way to measure radio waves is by their wavelength. The wavelength of a wave is simply the distance that the wave travels as it goes through exactly one cycle. Figure 1-1 illustrates the concept of wavelength, and figure 1-2 shows a comparison of two waves of different frequencies. The relationship between a wave's frequency and its wavelength is:

$$\textbf{Wavelength (in meters)} = \frac{300{,}000{,}000}{\text{frequency (in Hz)}}$$

or

$$\textbf{Frequency (in Hz)} = \frac{300{,}000{,}000}{\text{wavelength (in meters)}}$$

In each of these expressions, the number 300,000,000 represents the speed of light in meters per second.

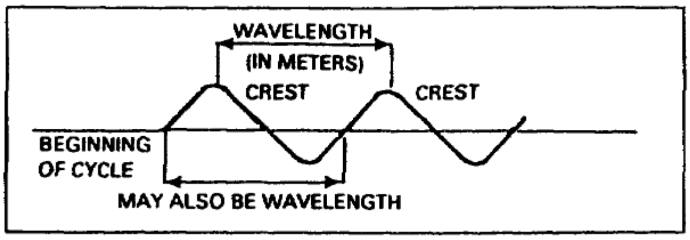

Figure 1-1. Wavelength of a radio wave

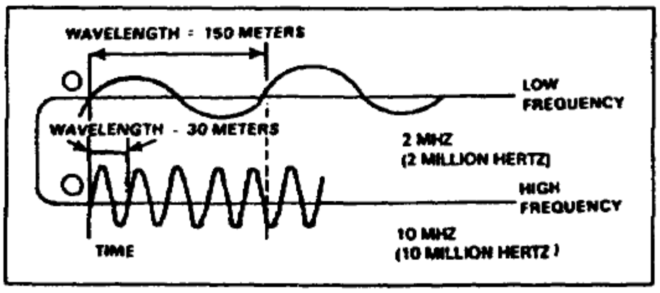

Figure 1-2. Comparison of two waves of different frequency

2. Propagation Methods of Radio Waves.

In order to use radio waves as a communications medium, the waves must travel from the sending station to the receiving station. Thus, it is important that you understand something of the propagation methods of radio waves. Electromagnetic waves travel in a straight line unless they are reflected or refracted by some outside force. In the case of radio waves, the basic paths of transmission are the ground wave and the sky-wave. Figure 1-3 illustrates these transmission paths.

a. Three Wave Types. All ground waves fall into one of three wave types. The first type is the direct wave. Direct waves travel along a line of sight (LOS) path. There must be a clear path between two stations in order to communicate using this transmission path. Communications with aircraft, satellites, and stations within sight of each other generally take place along a direct path. The second type of ground wave is similar to the direct wave and is called a ground reflected wave. Ground reflected waves also travel in straight lines. The difference between this type and the direct wave is that the ground reflected wave is reflected off the ground at some point between the sending and receiving stations. Ground reflected waves can sometimes interfere with a direct wave signal if both waves arrive at the receiving station 180 degrees out of phase.

Some of the lower frequency ranges are affected by the electromagnetic properties of the earth's surface and will actually bend around the curvature of the earth. These are surface waves. You can communicate with stations not in your LOS using systems that take advantage of these lower frequencies.

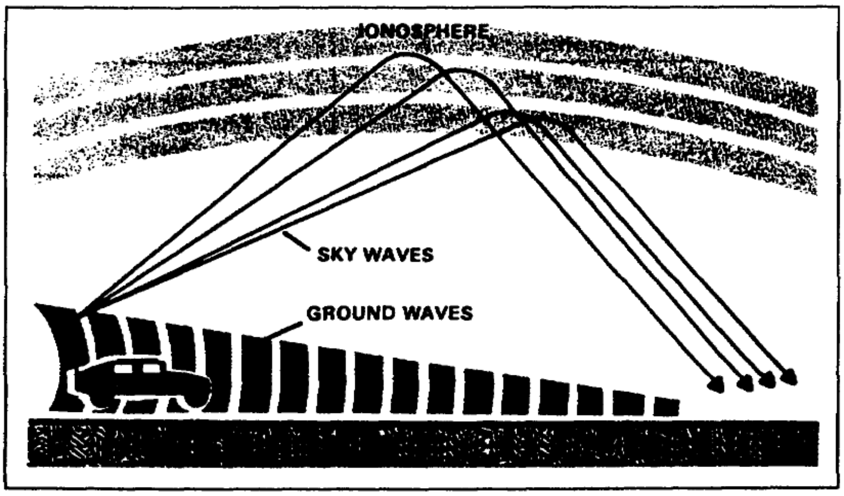

Figure 1-3. Radio wave transmission paths

b. Sky-Waves. The other type of transmission path is the sky-wave. Sky-waves are waves that have been transmitted upward and reflected back to the earth by the ionosphere. The ionosphere is a series of four layers (in daylight hours) of ion concentration in the earth's atmosphere called the D, E, Fl, and F2 regions. Figure 1-4 illustrates the ionosphere regions and their approximate heights above the earth's surface. The D region of the ionosphere serves only to attenuate the strength of radio waves and does not provide any useful reflection of the waves. This region fades out at night. The E region also fades at night but provides some reflection of radio waves during the day. Sky-waves which bounce off the E region can provide communications up to about 2,400 kilometers (1,500 miles). The F regions of the ionosphere do not fade out at night but they do combine to form a single region. You can communicate using F region sky-waves over distances of over 2,400 kilometers. This region is especially useful at night when the two intervening regions (D and E) have faded. The ionosphere is not constant and, therefore, sky-wave communications are not completely predictable. The ionosphere constantly undergoes variations which are classified as regular or irregular.

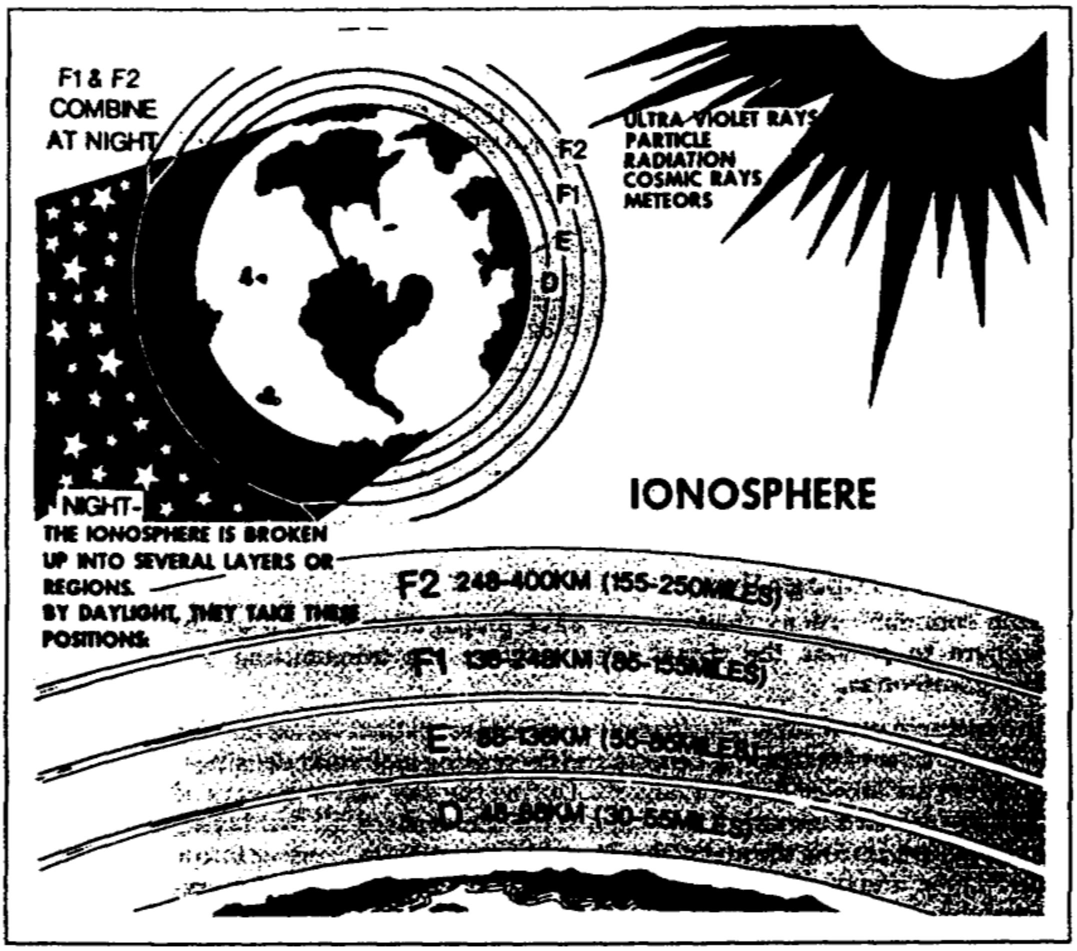

Figure 1-4. Distribution of the ionosphere

(1) Regular variations. Regular variations in the ionosphere occur as a result of the earth being a satellite of the sun and rotating about its own axis. These variations are so called because the period of variation is fairly well known from previous observation. You must account for these variations when you plan your communications system. There are four basic types of regular variations, which are:

(a) Daily variations. These are caused by the rotation of the earth.

(b) Seasonal variations. These are caused by the seasonal tilt of the earth on its axis.

(c) 27-day variations. These are caused by the rotation of the sun on its axis.

(d) 11-year variations. These are caused by the sunspot activity cycle of the sun.

(2) Irregular variations. Irregular variations in the ionosphere occur as a result of random events. Because these variations occur randomly, you cannot anticipate or plan for them. There are three basic types of irregular variations, which are:

(a) Sporadic E. This is caused by the E region becoming highly ionized and blocking out the reflections from the F regions. This can completely blank out sky-wave signals or it can result in signals traveling much further than you would normally expect.

(b) Sudden ionospheric disturbance (SID). This is caused by bright solar eruptions. The eruption causes abnormal ionization of the D region, absorbing all frequencies above approximately 1 megahertz (MHz). This results in receivers seeming to go dead, and it can last for several hours. Since it is associated with the D region of the ionosphere, this phenomenon is limited to daylight hours and does not occur after dark.

(c) Ionospheric storms. These are caused by meteorological disturbances in the ionosphere. These storms can involve the entire ionosphere and can last from several hours to several days. This phenomenon can cause low intensity in sky-wave signals and can cause a type of random "flutter fading" in sky-wave signals.

The range of sky-wave radio transmissions depends largely on the density of the ionospheric regions and the frequency of the radio signal. Because the frequency of a radio wave and its energy level are proportional, higher levels of ionization must exist in the ionosphere in order to reflect the waves back to earth. As a result, there is at any given time a frequency above which radio waves will not be reflected back to earth. This frequency is the critical frequency. The critical frequency is not a fixed value because the level of ionization in the ionosphere is constantly changing. Another limiting factor associated with the ionosphere is the critical angle. The critical angle is that angle of incidence (angle at which the radio wave meets the ionosphere) above which the radio wave will not be reflected, but will pass through the ionosphere and be lost in space.

Two other important terms you should understand when you are dealing with sky-wave transmissions are skip distance and skip zone. The skip distance is the distance that a sky-wave travels from its transmission point to the point where it returns to the earth's surface. The skip zone is the area in which no usable radio signal can be received because it is shorter than the skip distance but longer than the ground wave range. Figure 1-5 illustrates these concepts.

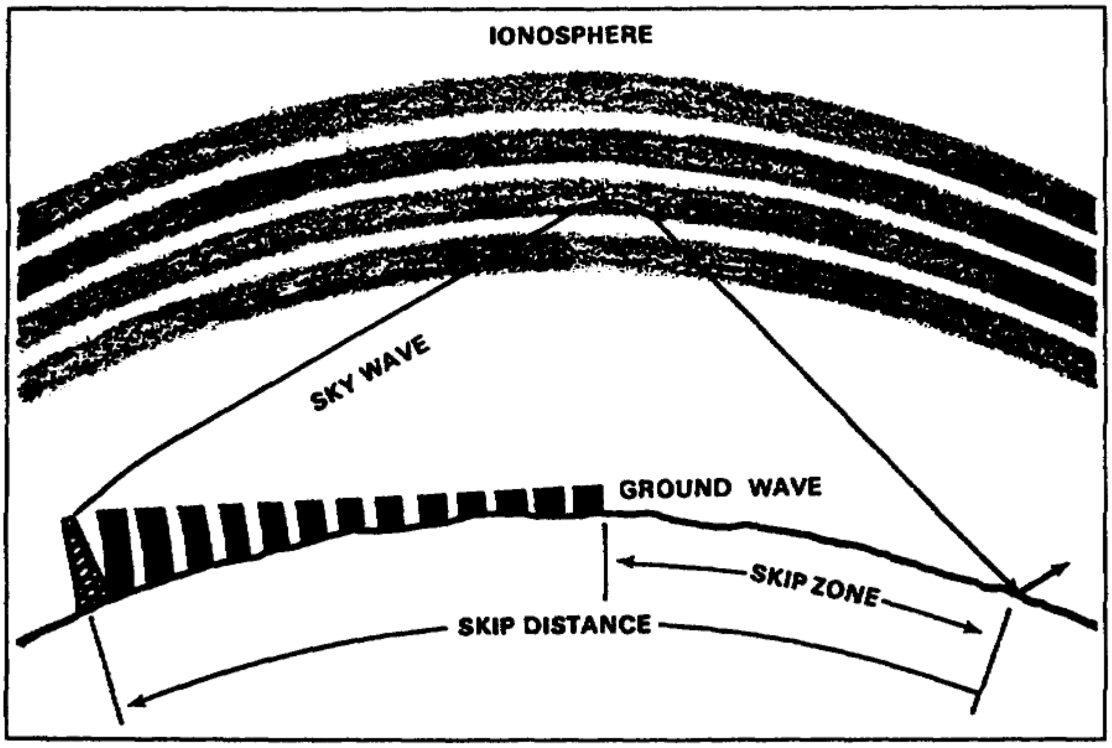

Figure 1-5. Skip zone and skip distance

You can use a piece of equipment called the AN/TRQ-35(V) Ionospheric Sounder to determine which frequencies are best for sky-wave transmission at any time of day or night.

3. Useful Frequencies.

The number of useful frequencies in radio communications is very large, spanning a range of about thirty kilohertz (30 kHz) to about 300 Gigahertz (300 GHz), or 30,000 to 300,000,000,000 Hz. Since the transmission characteristics of radio waves change as the frequency changes, it is useful to break this wide range of frequencies into smaller groups called bands. We divide the radio frequency (RF) spectrum into bands of frequencies which have similar transmission characteristics. Table 1-1 shows these frequency bands and their respective frequency ranges.

Most tactical radio sets operate within the medium frequency (MF) to UHF bands.

Band	Frequency (MHz)
Very Low Frequency (VLF)	Below .03
Low Frequency (LF)	.03 to .3
Medium Frequency	.3 to 3.0
High Frequency	3.0 to 30
Very High Frequency	30 to 300
Ultra High Frequency	300 to 3,000
Super High Frequency (SHF)	3,000 to 30,000
Extremely High Frequency (EHF)	30,000 to 300,000

Table 1-1. Frequency bands

Each of these frequency bands has different transmission characteristics. The frequency range of the band determines how the waves propagate and how far they travel. Lower frequency bands (VLF and LF), for example, will travel as surface waves and as sky-waves. Frequencies in the UHF and higher ranges, on the other hand, propagate only as direct waves. The other side of the coin is that, because the wave energy is proportional to the wave frequency, lower frequency transmitters must use higher transmission power to get a usable signal strength. Table 1-2 shows the relative ranges and transmission powers required for some of the frequency bands. These ranges are approximate and do not take into account such variables as ionospheric variations, antenna siting problems, and usable antenna orientation or polarization.

Band	Range				Power Required (kW)
	Ground Wave		Sky-Wave		
	Miles	km	Miles	km	
LF	0-1000	0-1609	500-8000	805-12872	above 50
MF	0-100	0-161	100-1500	161-2415	.5-50
HF	0-50	0-83	100-8000	161-12872	.5-5
VHF	0-30	0-48	50-150	80.5-241	.5 or less
UHF	0-50	0-83	NA	NA	.5 or less

Table 1-2. Frequency band characteristics

4. Forms of Radio Communications.

Radio communications can take one of several forms. Messages can be in the form of speech, data, radio teletypewriter (RATT), or telegraphic code. Let's first consider how a radio set transmits speech. The frequency range of normal speech is about 50 Hz to 500 Hz. Although these frequencies could be directly converted into electromagnetic energy and transmitted, the antenna required would be close to 5,000 miles long! Thus, you can see that it is not practical to conduct radio transmissions using this method. Instead, the signal used to transmit speech over radio waves is a combination of a higher frequency carrier wave and the lower frequency modulator wave. The sound of speech is converted to electromagnetic energy and this signal is used to modulate the carrier signal. Using this method you can transmit low frequency speech signals using the transmission characteristics of the higher frequency radio waves. There are two basic types of modulation in radio communications.

a. Frequency Modulation. The first type of modulation is frequency modulation. In FM transmissions, the modulating signal is used to vary the frequency of the carrier wave. The rate at which the carrier frequency varies is equal to the frequency of the audio signal, and the amount of deviation from the carrier frequency is equal to the amplitude of the audio signal. Thus, an FM transmission consists of a constant-amplitude wave with frequency varying about a central rest frequency. Between the transmitter and receiver the FM transmission may pick up amplitude variations due to outside electromagnetic interference. To compensate, most FM receivers use a limiter to exclude these amplitude variations from the received signal. Because of the variances of the carrier frequency, FM transmissions usually have fairly large bandwidths. For this reason, FM is generally used in VHF and higher frequency bands where bandwidth is not as significant as in the lower bands.

b. Amplitude Modulation. The second type of modulation is amplitude modulation. AM is the variation of RF power output of a transmitter at an audio rate. Simply put, AM is the process of varying the amplitude (and thus the output energy) of the carrier wave by superimposing the signal wave on it. In an AM transmission, the rate at which the carrier amplitude varies is equal to the frequency of the audio signal, and the amount of variation in the carrier amplitude is equal to the amplitude of the audio signal. In addition to the amplitude variations of the carrier, the superposition of the audio signal produces new RF signals with frequencies near that of the carrier frequency. For example, assume a 600 kHz carrier is modulated by a .1 kHz audio signal. The two new RF frequencies developed will be 600 kHz +/- .1 kHz, or 599.9 kHz and 600.1 kHz. These two new frequencies are called sidebands. The lower frequency is the lower sideband and the higher frequency is the upper sideband. Thus for a range of audio frequencies, the frequency range of the sidebands would be the carrier frequency plus or minus the highest and lowest audio frequencies. The total space occupied by both sidebands and the carrier frequency of an AM signal is called a channel, and the range of frequencies is the channel bandwidth. Figures 1-6 and 1-7 illustrate the concepts of AM, FM, and sidebands.

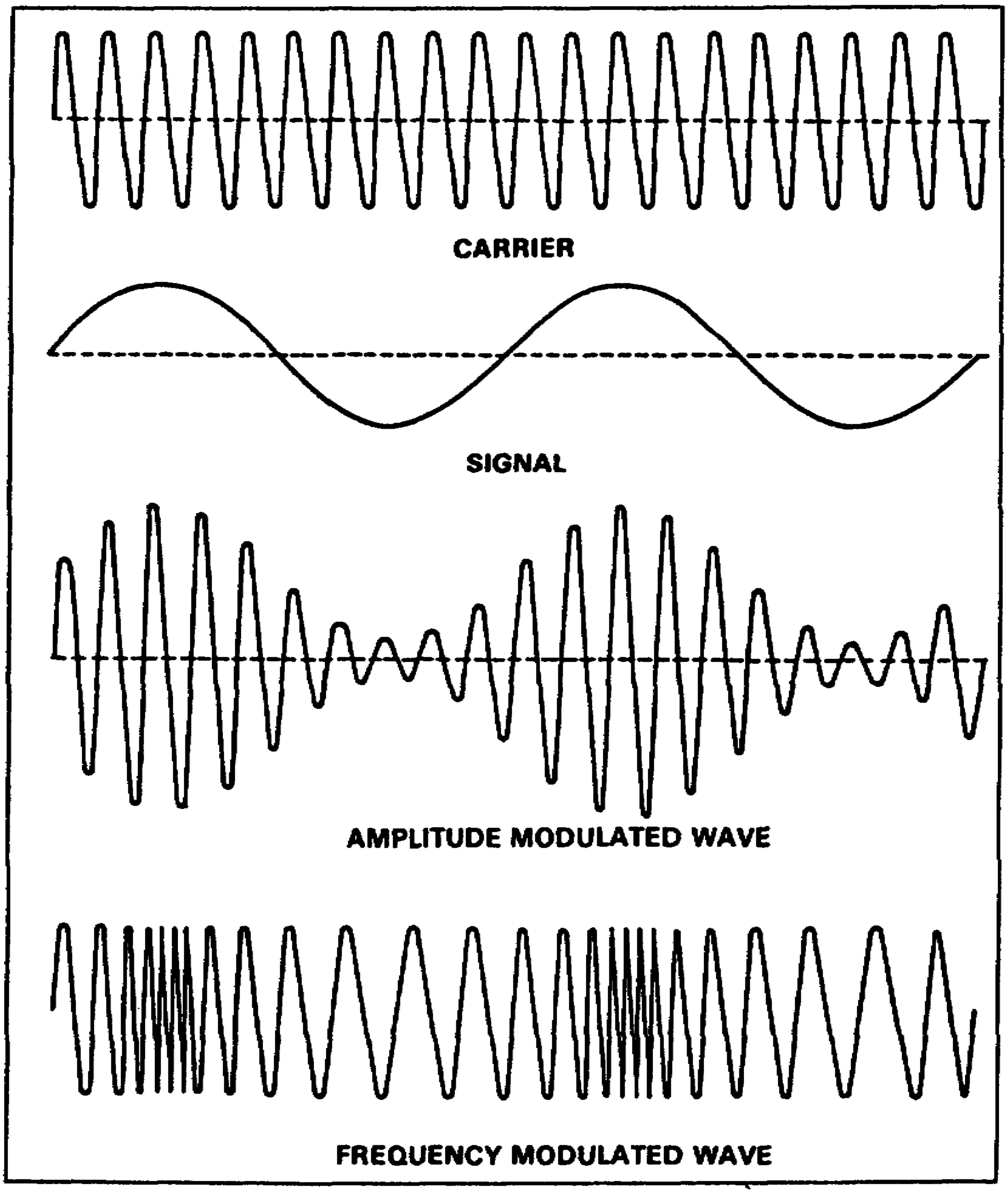

Figure 1-6. AM and FM wave shapes

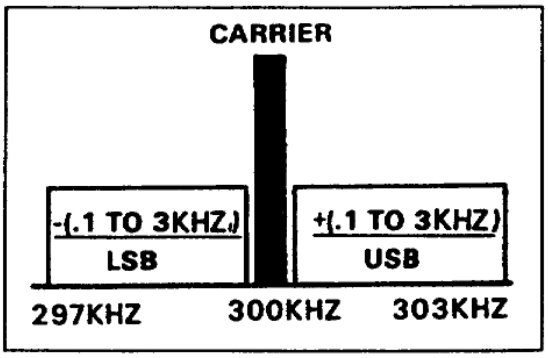

Figure 1-7. AM carrier with sidebands

You may have guessed from the previous information that the sidebands of an AM transmission contain duplicate information. In fact, the entire audio signal is contained in each sideband. Because of this, we can eliminate the carrier frequency and one sideband frequency from the transmitted signal and still transmit all the information needed for communications. This type of transmission is amplitude modulation/single sideband (AM/SSB) and is further classified as upper sideband (AM/USB) and lower sideband (AM/LSB). Standard AM transmission is also called AM double sideband (AM/DSB) transmission. One of the main advantages of an AM/SSB system is that by eliminating one sideband and the carrier frequency you make room in the frequency spectrum for extra communications channels. Other advantages of a SSB system are:

(1) AM/SSB provides greater reliability than AM/DSB.

(2) AM/SSB systems are smaller and lighter than AM/DSB systems.

(3) AM/SSB systems provide increased output without increasing antenna voltage.

(4) AM/SSB systems make it possible to operate a larger number of radio sets without heterodyne interference (whistles and squeals) from interfering RF carriers.

(5) AM/SSB systems can operate over longer ranges without loss of intelligence of the signal due to selective fading.

Because of their narrower bandwidth, AM/SSB systems are used in all frequency ranges, but are especially useful in the HF and lower frequency bands.

5. Basic Transmitter.

Now that you have learned the basic theory of radio signals, the next thing you need to learn about is how a radio set actually converts an input signal such as your voice into a radio signal that can travel to a distant station, and how the receiver at that station can convert that signal back into a recognizable voice pattern. We will start with a basic transmitter. Figure 1-8 illustrates the basic components of a simple continuous wave (CW) transmitter. The transmitter consists of a power supply, a keying device, an oscillator, and an antenna. Let's briefly look at each of these components.

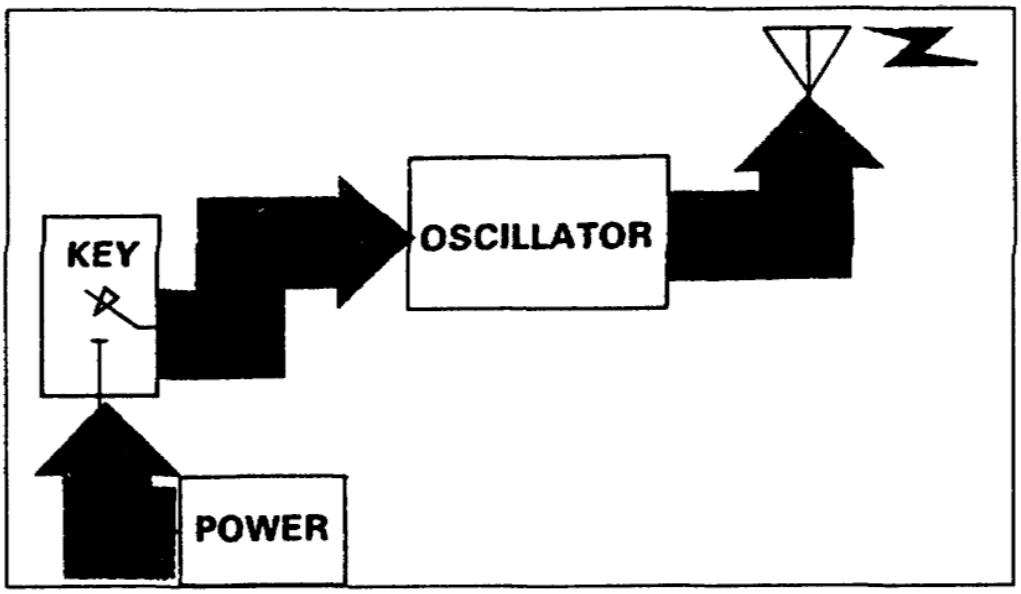

Figure 1-8. Block diagram of a simple radio transmitter

a. Power Supply. The power supply is common to all radio sets. It simply provides electrical power to all the other components in the radio set. The power supply may consist of transformers and convertors and may have multiple output voltages.

b. Oscillator. The oscillator is the device that actually produces the RF signal to be sent. In the early days of radio, these oscillators consisted of crystals that vibrated at a certain frequency when stimulated by an electric current. Some older radio sets still use crystal chips in the oscillator, but most modern radios use some type of electronic appurtenance to perform this function. Most tactical radio sets have oscillators that can be tuned to a certain frequency or channel for transmission on that channel. An oscillator may also contain filters to limit the bandwidth of the transmission to avoid interference with other radio sets.

c. Antenna. The antenna is nothing more than the device that converts RF electrical energy into radio waves that travel to the receiving station. You will learn more about antennas later in this lesson.

d. Keying Device. The keying device is the device you use to generate a message to be transmitted. In the CW transmitter, the key serves to interrupt the power to the oscillator and antenna. Thus, when the key is depressed, the power is sent to the oscillator and antenna and a signal is transmitted. When the key is released, power is interrupted and the signal stops. Using this method you can send Morse code messages by radio.

In order to transmit messages containing something besides Morse code, you need a transmitter with a few more components. Figure 1-9 illustrates a basic radiotelephone transmitter. You can see that a microphone and modulator have replaced the keying device, and that a buffer and an RF amplifier have been added. Let's look at each of these new components briefly.

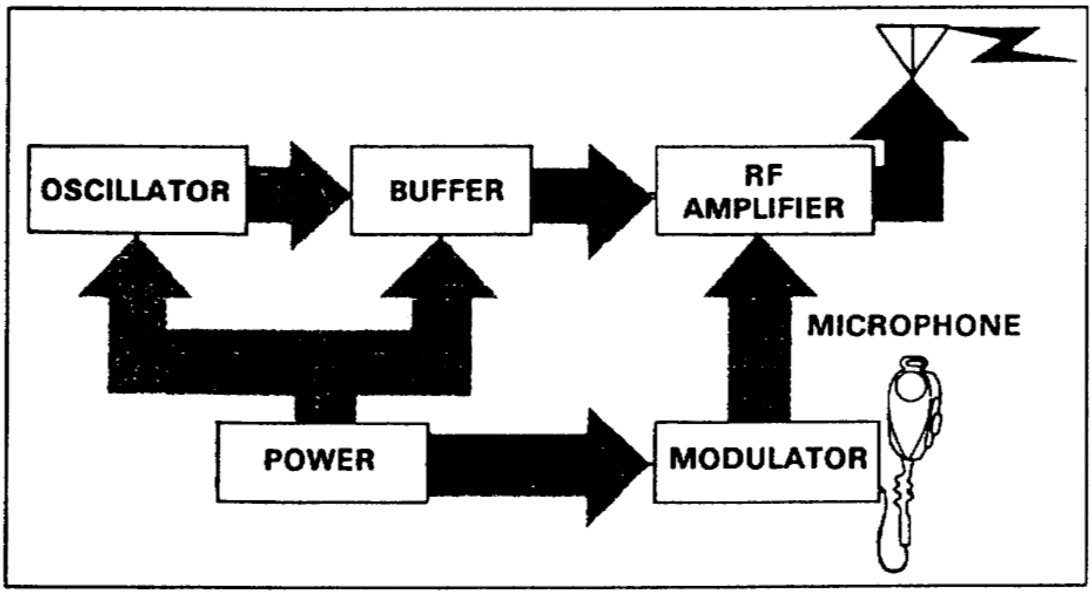

Figure 1-9. Block diagram of a radiotelephone transmitter

e. Buffer. The buffer is nothing more than a series of electronic filters and stabilizers that take the output from the oscillator and ensure that it is as stable as possible. Since the RF signal from the oscillator is what produces the carrier for the radio signal, you can see that it is extremely important for this signal to be constant and stable.

f. Microphone and Modulator. The microphone and modulator in this transmitter serve the same purpose as the keying device in the CW transmitter previously described. The microphone converts speech into electrical signals and the modulator converts these signals into an audio modulating signal. This signal can then be applied to the carrier to produce the modulated radio wave that can be received and understood by a remote receiver.

g. RF Amplifier. The RF amplifier is the stage in the transmitter where the carrier and modulating signals are combined to produce the radio signal to be transmitted. Depending on the type of transmitter (AM, FM, etc.), this combination of signals will take one of the forms we discussed previously in this lesson. The amplifier then amplifies the combined signal and sends it to the antenna for transmission.

Transmitting a radio signal is useless unless there is a receiver somewhere to receive and understand the message. The receiver, then, is equally as important to radio communications as the transmitter. Figure 1-10 shows a typical radio receiver. As with the transmitter, we will look at each of its components individually.

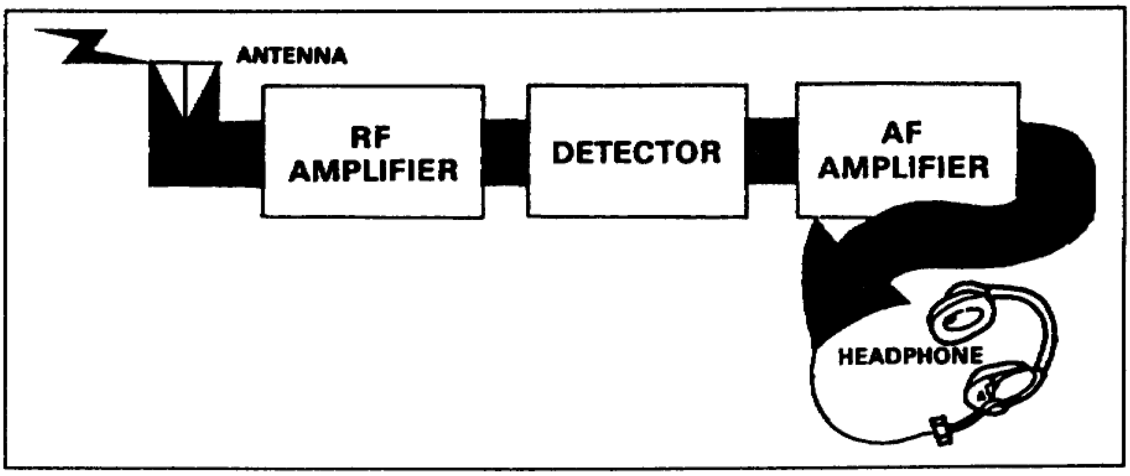

Figure 1-10. Block diagram of a radio receiver

h. Receiver Antenna. The antenna on the receiver serves much the same function that it does on the transmitter. The principal difference is that the receiver antenna absorbs the radio waves and converts them to an electronic signal to be used by the receiver.

i. RF Amplifier. In most transmitters, the energy that is transmitted through the antenna is transmitted in several directions. If the receiving station is more than a small distance from the transmitter, only a small fraction of the radiated energy of the transmitter will reach the receiver. You can guess from this that the electronic signal produced by the receiver antenna will be very small. For this reason, receivers have an RF amplifier attached to the antenna. The amplifier takes the incoming signal and amplifies it to a level that can be processed by the receiver's other components.

j. Detector. Once the received signal is amplified, the next step is to convert the modulated signal back into an audio signal that will be intelligible to the operator. The detector is the component that does this. The detector, like the modulator in the transmitter, serves to uncouple or "demodulate" the radio signal. In an FM receiver, this component is called a discriminator. As in the transmitter, the exact function of the detector depends on the type of receiver it serves.

k. Audio Amplifier. When the detector separates the audio and carrier signals, the resulting audio signal is quite small. In order to raise the audio signal to a usable level (one that can be heard), we use an audio amplifier between the detector and the speaker or headphone. This amplifier simply amplifies the audio signal so that it can drive the speaker or headphone and reproduce the sound of the original transmission.

Most modern radio sets perform the functions of transmitting and receiving in the same unit. These radios have a transmitting section and a receiving section which generally use the same antenna for both functions, though not simultaneously. Additionally, most radio sets are designed to operate in a particular frequency band and to use a particular type of modulation. For example, the AN/VRC-12 series radio set operates in the VHF band and uses frequency modulation. There are newer radio sets in use today however, that offer much more flexibility to their users. The AN/PRC-70 series radio, for example, operates in AM, SSB, and FM modes and can transmit and receive in both HF and VHF bands.

One very important thing you must consider when planning radio communications is the compatibility of the radios that will be communicating with each other. There are four basic conditions which you must meet if you desire to conduct radio communications. They are communications range, operating frequency, method of communication, and type of modulation. If two radio stations are 200 miles apart and one can only transmit up to 100 miles, it cannot be heard by the other station and communications are not possible. Similarly, a VHF radio cannot communicate with an HF radio, nor an AM radio with an FM radio. A CW radio could transmit to a RATT radio but the receiving radio would not be able to interpret the signal and would produce no output.

6. Antennas.

The object of radio communications is to be able to convey intelligence over long distances without having to use wires to carry the signal. The component of a radio set that makes this possible is the antenna. You learned previously that the antenna converts electronic signals into radio waves in a transmitter and converts radio waves to electronic signals in a receiver. The antenna, then, is the element that takes the place of thousands of miles of wires in transferring messages from radio station to radio station. It is helpful in learning about the various types and uses of antennas if you first learn some basic concepts and terminology associated with them.

a. Antenna Gain. Antennas come in many different configurations and some work much better for certain applications than others. The term we use to talk about the efficiency of an antenna is antenna GAIN. Antenna gain is simply a measure of an antenna's efficiency at transmitting or receiving certain signals. An antenna that is more efficient is said to have a higher gain than one that is less efficient.

b. Antenna Polarization. Another term you commonly hear associated with antennas is polarization. Polarization refers to the orientation of the electromagnetic fields that make up a radio wave. If the fields are perpendicular to the earth's surface, the wave is vertically polarized. If the fields are parallel to the earth's surface, the wave is horizontally polarized. Some transmitters, most notably satellites, produce fields that constantly change orientation with respect to the earth's surface. These are circularly polarized waves. If an antenna has a better gain in receiving or transmitting a certain type of wave, we say the antenna is polarized in a certain direction. Thus antennas, as well as radio waves, can be horizontally, vertically, or circularly polarized. You will learn the particular uses of each type of polarization in an antenna later in this lesson.

c. Directional Antennas. You will learn that some types of antennas have a higher gain in a certain direction than they do in another. This is called the directionality of the antenna and is dependent on the type of antenna and its orientation. We call antennas of this type directional antennas. Directional antennas can be very useful because they transmit and receive in the same direction. You could use a directional antenna to prevent a signal from being intercepted by an enemy on your flank, or to prevent a particularly noisy (RF speaking) industrial area from interfering with your reception. Another term associated with directional antennas is azimuth. The azimuth is the orientation of the directional axis of the antenna with respect to true North. You will measure azimuth in degrees. Azimuth can be very critical if the antenna you use is highly directional. It is important to know where you are in relation to the station you want to communicate with.

d.Ground Effect. Except for satellites and aircraft, all antennas are set up on or near the earth's surface. This proximity almost always has some effect on the performance of the antenna. We call this phenomena ground effect. If the ground that an antenna is connected to is a good conductor, it will act like a mirror and reflect RF energy radiated downward by the antenna. If the antenna is grounded (electrically attached to the ground) this can have the effect of making the antenna behave like it is longer than it actually is. For example, you can make a quarter-wave antenna behave like a half-wave antenna by electrically grounding it. Figure 1-11 illustrates this concept.

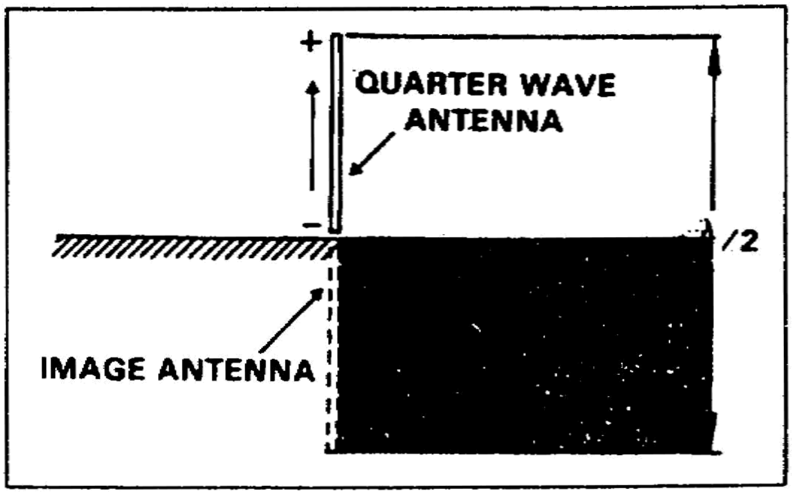

Figure 1-11. Quarter-wave antenna connected to ground

Different types of soil may have very different conductivity levels. Damp soil near a river or in a pasture may have very good conductivity, while dry sandy soil such as in a desert, or ice and frozen ground, may have very poor conductivity. Sometimes you can improve the conductivity of the soil by adding salt or other agents to it. There are several ways to ground an antenna. You can attach it to other grounded structures or to metal rods driven into the ground. You can also attach the antenna to underground systems such as pipes.

If you cannot sufficiently ground an antenna because of poor conductivity of the ground, you can use a device called a counterpoise. A counterpoise is a device generally made with wire that you erect between the antenna and the ground. The counterpoise should be insulated from the ground. The counterpoise then acts as a reflector the same way that soil of good conductivity would. The counterpoise is constructed in a simple geometric pattern and electrically connected to the antenna. Figure 1-12 illustrates different types of counterpoises. In order for a counterpoise to be effective, it should be at least as large as the antenna it is supporting, and preferably larger. If a counterpoise is not practical, you can sometimes use a large mesh screen laid over the surface of the ground under the antenna. This is called a ground screen.

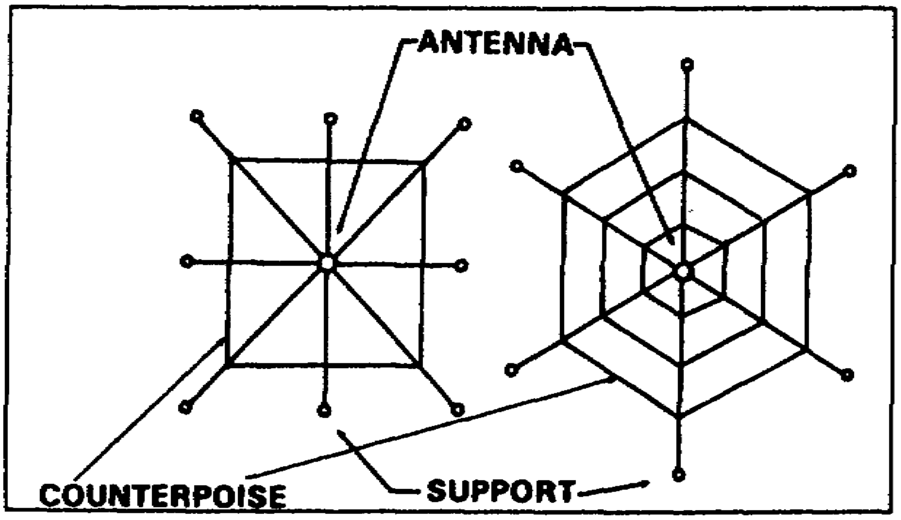

Figure 1-12. Wire counterpoises

e. Antenna Length. The length of an antenna is a very important factor to consider when you are planning communications. The length of an antenna determines what frequencies it will transmit and receive efficiently. Antennas have two lengths: physical length and electrical length. Because of the reduced velocity of the radio wave on the antenna and the capacitive effect of the end of the antenna, the electrical length of the antenna is generally longer than its physical length. Thus, if you are designing an antenna for a specific communications task, you must consider the wavelength of the communications frequency you are using and the correction factor due to the difference in the physical and electrical length of the antenna. For frequencies between 3 and 50 MHz that correction factor is 0.95. Knowing this you can calculate the required length of your antenna using the following formula (for half-wave antennas):

$$\textbf{LENGTH (in meters)} = \frac{150 \times 0.95}{\text{Frequency in MHz}} = \frac{142.5}{\text{Frequency in MHz}}$$

$$\textbf{LENGTH (in feet)} = \frac{492 \times 0.95}{\text{Frequency in MHz}} = \frac{468}{\text{Frequency in MHz}}.$$

If you desire to construct a long-wire antenna (one wavelength or longer) then the following formula applies:

$$\textbf{LENGTH (in meters)} = \frac{150 \times (N - 0.05)}{\text{Frequency in MHz}}$$

$$\textbf{LENGTH (in feet)} = \frac{492 \times (N - 0.05)}{\text{Frequency in MHz}}.$$

Where N is the number of half-wavelengths in the total length of the antenna.

7. Types of Antennas Used for Tactical Radio Communications.

Now that you know the basic theory behind antenna operation you should learn about the different types of antennas you may need to use in tactical radio communications. Figure 1-13 shows several different types of antennas and indicates the directionality of each. The next several paragraphs will discuss the abilities and limitations of these antennas.

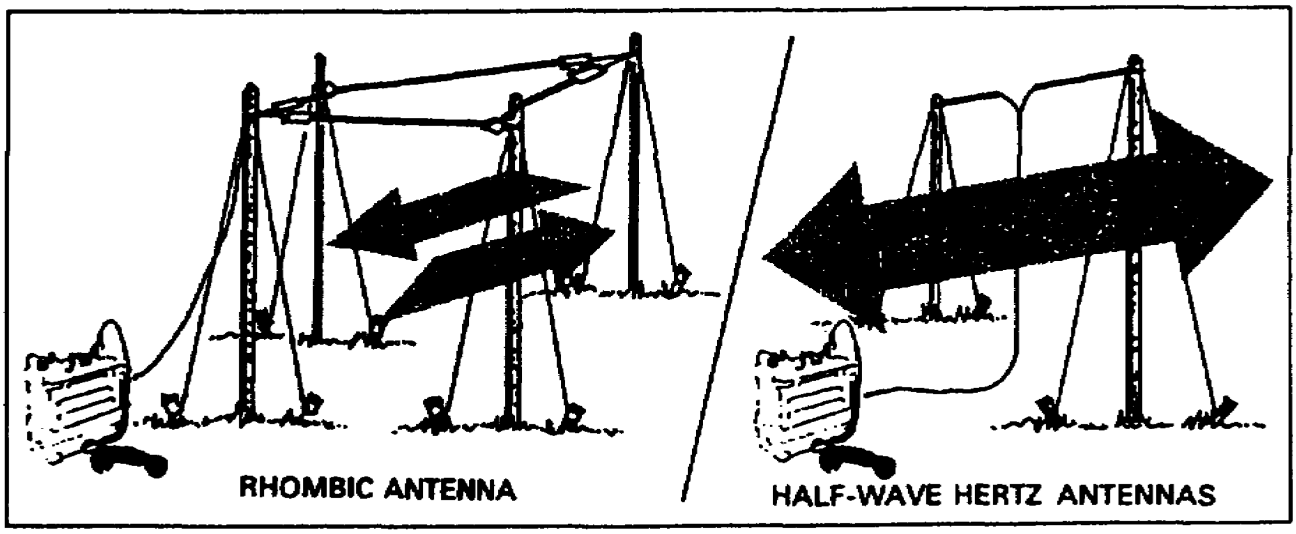

Figure 1-13. Types of antennas

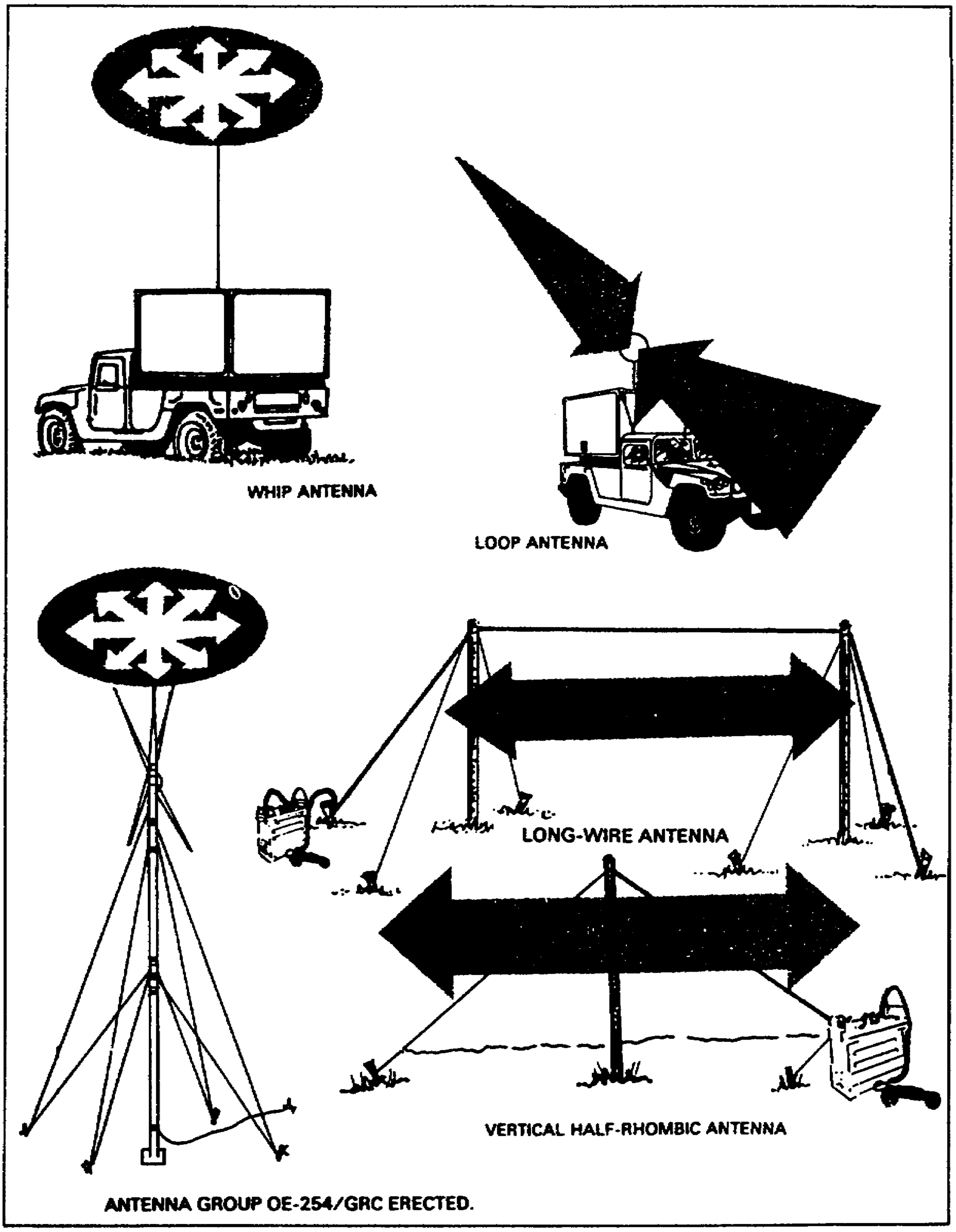

Figure 1-13. Types of antennas (cont.)

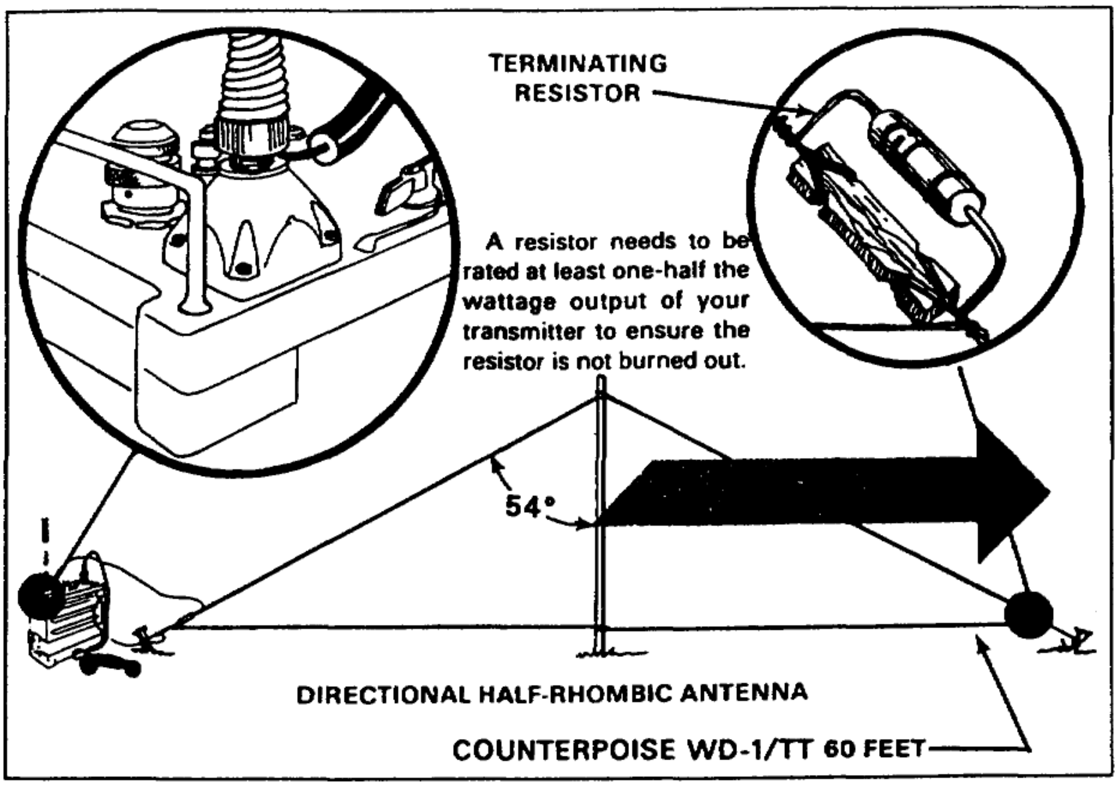

Figure 1-13. Types of antennas (cont.)

a. Rhombic Antenna. The rhombic antenna is useful in conducting HF communications between fixed points. With the radio antenna lead attached at one apex and a terminating resistor at the opposite apex, the antenna is unidirectional and has very good directionality both in the transmit and receive modes. This feature can be useful if you are trying to limit the signal sent to unfriendly forces or prevent noise interference of a nearby RF noise source (e.g., an industrial area). The drawbacks associated with this antenna are that it is fairly large and not easy to set up. The wires must be the correct lengths, and the azimuth must be properly determined. Since the antenna is fixed, it is difficult to reorient it to a new azimuth to communicate with a different radio station.

b. Hertz Antenna. The Hertz or half-wave antenna is a common configuration for field communications. This antenna is also called a center-fed doublet. You can orient the antenna either horizontally or vertically and the polarization of the antenna corresponds to the orientation. The antenna is directional, with the primary direction being perpendicular to the antenna axis. One drawback of the antenna is that it transmits perpendicular to its axis in all directions. For example, if you are transmitting a strong signal directly behind you to a rear element, you are also transmitting a strong signal directly in front of you to possible hostile forces. When you construct a Hertz antenna you must take care to construct it to the proper length for the frequency you are using. Do this using the formulas previously discussed for a half-wave antenna. The obvious disadvantage is that the antenna is tuned only for a small band of frequencies. Hertz antennas are very portable and are easy to set up and take down. You can also change the orientation of a Hertz antenna with minimum difficulty.

c. Marconi Antenna. If you take a vertical half-wave antenna and replace the lower half with a conducting plane, the upper half will continue to radiate as a half-wave antenna even though it is only a quarter wavelength long. This type of antenna is called a Marconi or quarter-wave antenna. The conducting plane mentioned can be the ground, a vehicle body, or even a shelter roof. Since it is vertical the polarization of a quarter-wave antenna is almost always vertical. The whip and the ground plane antennas are typical examples of Marconi antennas. The obvious advantage of the quarter-wave antenna is that it is shorter than the half-wave antenna of the same frequency. This makes the quarter-wave antenna ideal for portable applications such as backpack and vehicular mounted radios.

d. Whip Antenna. The whip antenna is the simplest of the Marconi family of antennas. Some whip antennas are extremely short; much shorter than a quarter wavelength. These antennas are called baseloaded whip antennas and will have a coil attached to the base of the whip. The coil contains a conductor of sufficient length to make the antenna a quarter-wavelength long. Theoretically, the whip antenna is an omnidirectional antenna. When attached to a vehicle, however, the radiation pattern shows a certain directionality depending on the placement of the antenna on the vehicle body. Figure 1-14 illustrates this concept. The whip antenna is the most portable type of antenna and, therefore, the most widely used in tactical radio communications.

e. Ground Plane Antenna. If you take a whip antenna and add horizontal elements to the vertical radiator, the horizontal elements act as a ground reflector or counterpoise. This configuration is called a ground plane antenna. You can use a ground plane antenna on any type of soil because it creates it own reflection. The ground plane antenna is omnidirectional. This makes it ideal for communicating with mobile units that do not stay in one place for a very long time. In some configurations, you can tune the ground plane antenna to a certain frequency by changing the length of the radiating and reflecting elements. The broadband omnidirectional antenna system OE-254 is in common use today for VHF-FM tactical radio sets. It is an improvement over the earlier ground plane antennas because it does not have to be reconfigured physically when you change radio frequencies. The OE-254 kit comes with antenna, mast, all supporting equipment needed to set it up, and all electrical connectors needed to operate it with most tactical radio sets in use today.

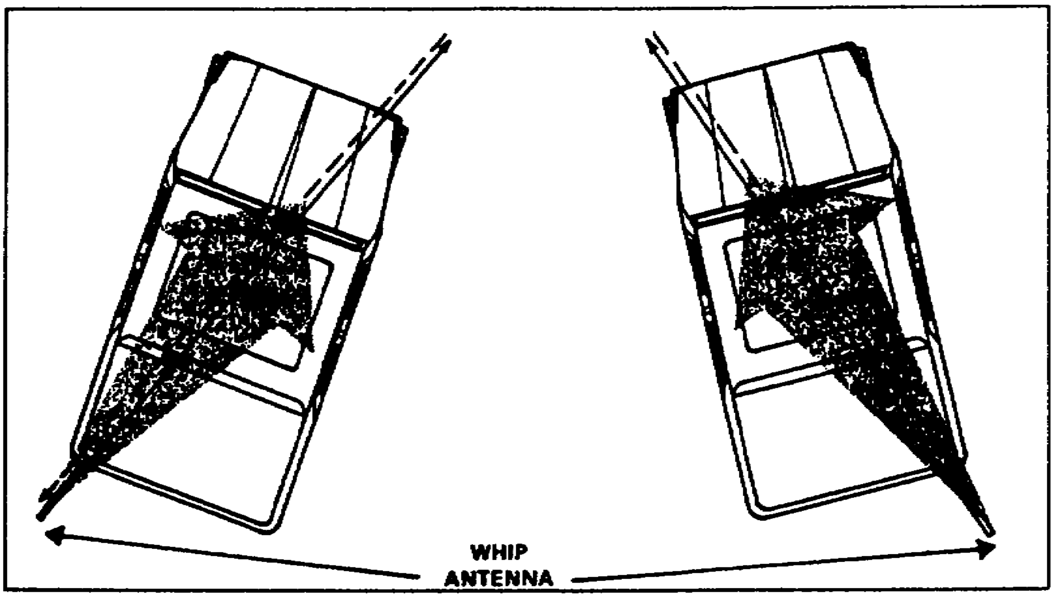

Figure 1-14. Directivity of a vehicle-mounted whip antenna

f.Directional Antennas. While omnidirectional communications are good for communicating with mobile units, they do not provide very good communications security. Any station within range can pick up the signal transmitted from this type of antenna. Occasionally you may want to communicate with another station covertly. You will of course use coded transmissions, but even the fact that you are sending a signal out can give away your position if you are not careful. In this scenario the safest method of communications is to use a directional antenna. There are three basic types of directional antennas that you can easily employ in a field environment. They are the long-wire antenna, the vertical half-rhombic antenna, and the V antenna.

The long-wire antenna is simply what the name implies. It is an antenna that you have constructed to a certain number of wave-lengths (using the previous formula). To obtain directionality, you connect the radio set to one end and terminate the other end to ground with a resistor. You should always remember when choosing terminating resistors for any antenna that the rating of the resistor should be at least half of the rated output power of the radio transmitter you are using. This will keep you from burning out the resistor. Once your long-wire antenna is configured, you orient it by pointing the terminated end toward the azimuth of the radio station with which you are communicating. You orient the antenna horizontally and as high off the ground as possible. The antenna will work as low as three feet from the ground, but efficiency will increase as it is raised.

The vertical half-rhombic antenna is a vertically-polarized directional antenna that operates between 30 and 88 MHz. It consists of two sloping segments, each about two wavelengths long, and a horizontal segment that acts as a counterpoise (refer to figure 1-13). The antenna is easy to transport, set up, and tear down. You can also change the antenna azimuth quickly and easily. The use of the vertical half-rhombic antenna can not only provide directionality, but also provide extended range over the OE-254 antenna because it sends its energy out in only one direction.

The V antenna is very similar to the rhombic antenna discussed earlier in this lesson. It consists of two horizontal legs connected in a V with the radio set connected at the apex. The free ends are terminated in the same manner as the long-wire and vertical half-rhombic antennas. The combination of radiation patterns from the two elements forms a central directional beam that bisects the two legs. Figure 1-15 illustrates the radiation pattern of a V antenna. The signal from this antenna is horizontally polarized. This makes the antenna useful in an area where there is much vertically polarized RF interference.

You can see from this discussion that you can use the V and the vertical half-rhombic antennas to complement each other in areas of high RF noise. TM 11-666 talks in detail about the configuration of the V antenna for various frequency ranges, but table 1-3 gives optimum angles of separation for the antenna legs based on their length. Review of TM 11-666 is not required for completion of this subcourse.

Antenna Length (Wavelengths)	Optimum Apex Angle (Degrees)
1	90
2	70
3	58
4	50
6	40
8	35
10	33

Table 1-3. Leg angle for V antennas

You can see from this table that a longer antenna length provides a narrower beamwidth. This has the advantage of greater directionality and the disadvantage of requiring greater accuracy in setting the antenna azimuth.

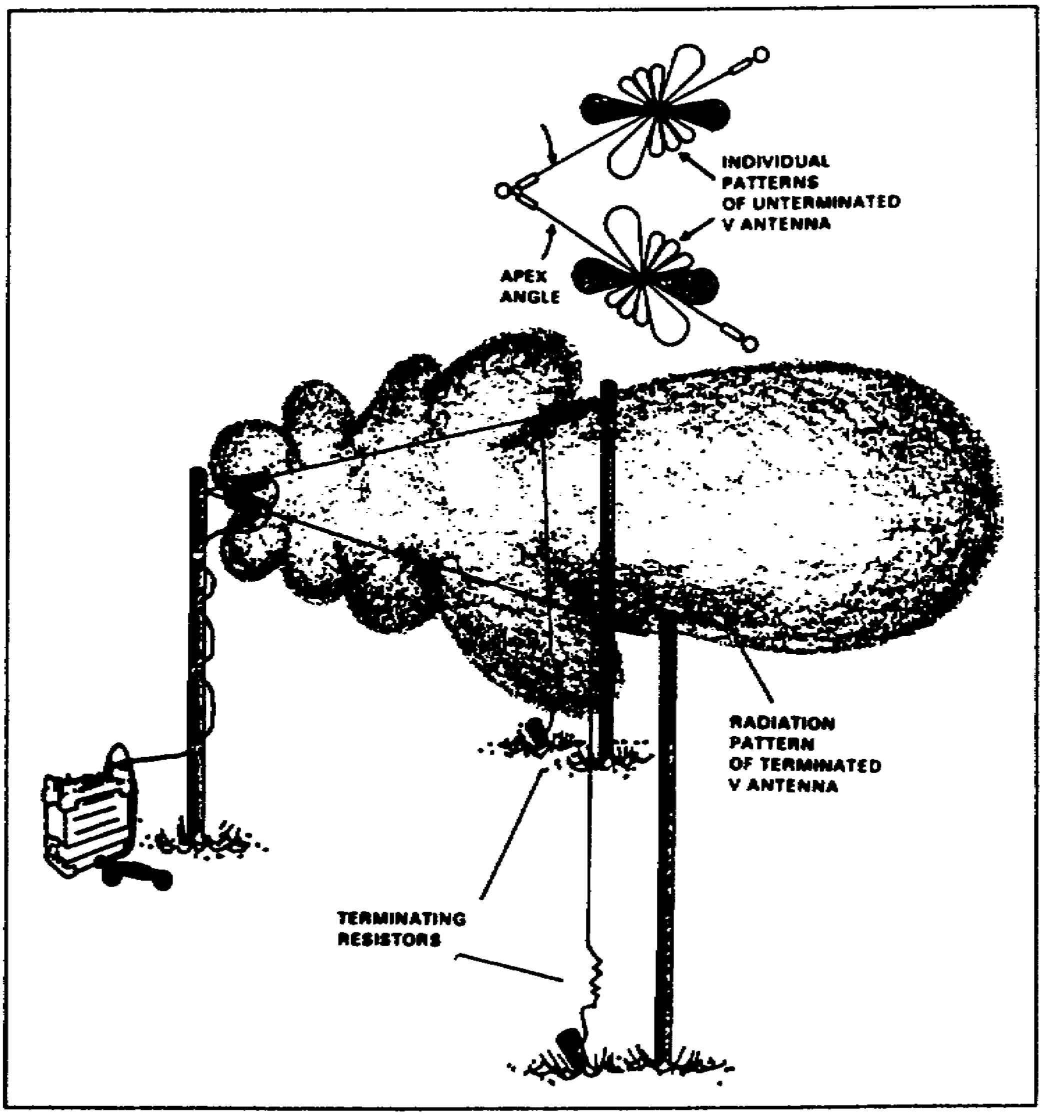

Figure 1-15. Radiation pattern of a V antenna

8. Field Expedient Measures.

While you are field-deployed it will happen that some portion of your antenna will break. It may be the radiating element, the antenna mast, or simply an insulator. It is important that you be ready for this, and that you be able to improvise replacements for the failed component so that you do not lose communications capability. The most important thing to remember is that when a particular item breaks, look around for items with similar physical and electrical properties to replace it. Figure

1-16 shows that a tree makes a very good replacement for a broken antenna mast as does a wooden pole (e.g., broom handle). You can take ordinary antenna wire and fabricate almost all the antennas you have learned about in this section. Remember, the formulas for determining the length of your antenna and your field expedient can be just as good as the original.

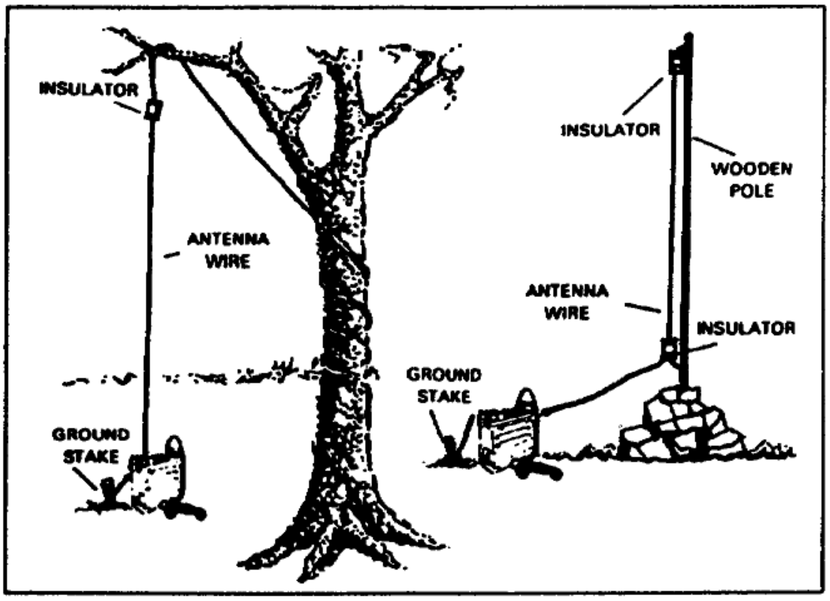

Figure 1-16. Field substitutes for antenna supports

Figure 1-17 will give you an idea of the wide variety of items you can use to replace things like broken insulators. A knife or bayonet can also serve as a good substitute for a ground stake that has been lost or broken. You can repair a broken whip antenna by attaching a length of wire to it to make its total length a quarter wavelength again. Remember, the best tool to have in an emergency situation is your imagination.

9. <u>Improvement of Marginal Communications</u>.

Just as you are destined to have equipment failure, so are you destined to be in positions where communications is only marginal at best. This may be because of terrain obstructions, interference due to jamming or other RF noise, or even range limitations of your equipment. The following paragraphs provide some guidance on what to do when you find yourself in this situation. Interference can be caused by many different things. Electronic jamming, industrial machinery, air traffic, other radio sets operating in your area, high tension lines, and even solar and cosmic disturbances can interfere with your radio communications. One way to compensate for this is by checking your radio system for any loose connections and by making sure your radio and antenna are properly tuned. Sometimes switching to another channel may help, but you may also lose communications with the station you are trying to communicate with.

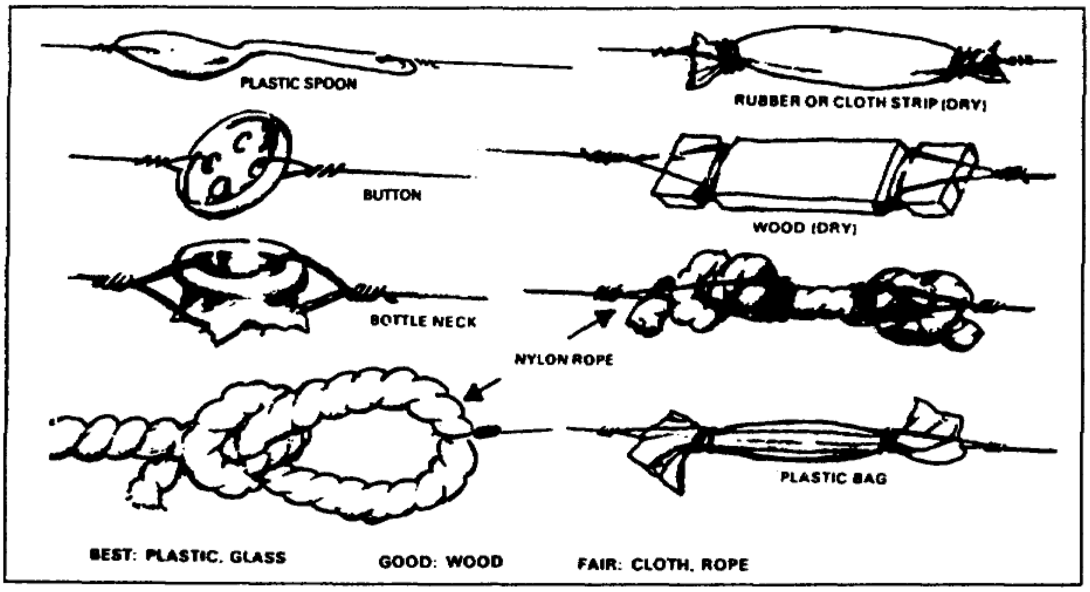

Figure 1-17. Field improvised insulators

If you can determine the source of the interference you may be able to use a directional antenna to eliminate some of it. This will only work, however, if the interference source and the station you are communicating with are on different azimuths.

Determining the source of interference may also tell you how the interfering signal is polarized. Most man-made RF noise is vertically polarized. Using a horizontally polarized antenna can do a lot to lessen the effect of interference. Likewise, in a forest vertically polarized waves tend to be absorbed by the trees more than horizontally polarized waves. RF interference caused by aircraft or commercial radio and television transmissions, on the other hand, is usually horizontally polarized. You should use a vertically polarized antenna if you are experiencing interference from one of these sources.

If you are having trouble communicating due to range fading, a directional antenna may help. It can boost your signal in the direction of the station you are talking to and will also increase your receiver sensitivity.

If none of the previous measures improve your communications, you should also try moving your antenna or raising or lowering your antenna. If you are still having trouble communicating there may be nothing to do but move to a different location and try again.

10. Summary.

In this lesson you have learned the basics of radio theory. You have learned how a basic radio transmitter and receiver work and how amplitude modulation differs from frequency modulation. You have also learned about the different types of antennas used in tactical radio communications and how to select and use the best antenna for a given job. In the next lesson you will learn about the different types of tactical radios in use and how to select a certain radio for a certain communications task.

LESSON 1

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

Situation: You are conducting training on basic radio and antenna theory.

1. Which of the following types of waves is most likely to be affected by sunspots?

   A. Sky-waves.
   B. Ground waves.
   C. Direct waves.
   D. Line of sight waves.

2. Which of the following statements about AM/SSB radios is NOT true?

   A. AM/SSB provides greater reliability than AM/DSB.
   B. AM/SSB systems are larger and heavier than AM/DSB systems.
   C. AM/SSB systems provide increased output without increasing antenna voltage.
   D. AM/SSB systems can operate over longer ranges without loss of intelligence due to selective fading.

3. You are constructing a long-wire antenna three wavelengths long to communicate on a channel frequency of 29.274 MHz. How long should you make your antenna?

   A. 50.0 feet.
   B. 50.4 feet.
   C. 100.0 feet.
   D. 100.8 feet.

4. You are in the field and one of your antenna insulators has broken. Which of the following items will make the best replacement?

   A. A shoelace.
   B. A tree branch.
   C. A plastic shirt button.
   D. The top from a soft drink can.

LESSON 1

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item Correct Answer and Feedback

1. A. Sky-waves.

Since sky-waves propagate by reflecting off the ionosphere, any disturbance in the ionosphere can cause a disturbance in a sky-wave transmission. The 11-year regular variations in the ionosphere are caused by sunspots, and these variations will affect sky-wave transmission. Since the other types of waves are not affected by the ionosphere, they should not be affected by sunspots. (page 1-6, para 2b(1)(d)).

2. B. AM/SSB systems are larger and heavier than AM/DSB systems.

In fact, one advantage of AM/SSB systems is that, because they electronically suppress one sideband and the Carrier, less energy is required for the same power transmission. This means that power supplies do not have to be as large, making the overall radio smaller and lighter than a comparable AM/DSB system. (page 1-11, para 4b(2)).

3. C. 100.0 feet.

Three wavelengths is six half-wavelengths. Using the formula for long-wire antennas gives:

LENGTH (in feet) =

$$\frac{492 \times (6 - 0.05)}{29.274 \text{ MHz}} = \frac{492 \times 5.95}{29.274 \text{ MHz}} = \frac{2927.4}{29.274 \text{ MHz}}$$

LENGTH = 100 feet. (page 1-19, para 6e).

4. C. A plastic shirt button.

In order of preference, the items to use would be the button, then the tree branch (if it was not still green), then the shoelace. The can top or a green tree branch would not work because they would conduct too much current to the ground. (page 1-26, para 8).

LESSON 2

TACTICAL CONTINUOUS WAVE AND VOICE RADIO EQUIPMENT

CRITICAL TASKS: 01-5878.04-0005,
01-5778.07-0003, 01-5778.07-0007

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn the different types of tactical radio sets currently in use and how to select a particular set for a given communications task.

TERMINAL LEARNING OBJECTIVE:

ACTIONS:

a. Identify the tactical frequency modulation, amplitude modulation/double sideband, and amplitude modulation/single sideband radio sets in the field.

b. Determine which tactical radio set best meets a specific communications requirement.

c. Select tactical radio sets that are compatible for point-to-point, system, and net operation.

CONDITION: You will be given information from this lesson.

STANDARD: To demonstrate competency of the terminal learning objective, you must achieve a minimum score of 70% on the subcourse examination.

REFERENCES: The material contained in this lesson was derived from the following publications: FM 24-18 and TC 24-24.

INTRODUCTION

The rapid changes in communications technology are constantly bringing new and better equipment to the market for use in the field. This lesson will present some of the equipment currently used as well as equipment which is being phased-out. Even though a piece of equipment may be outdated, you may still run across it in reserve units or you may have occasion to use a piece as a backup to a failed modern unit. It is important, therefore, that you know how this older equipment operates and what its capabilities are. Since this lesson is merely an overview and is in no way a complete technical description of any piece of equipment, you are encouraged to read the technical manuals on each piece of equipment in order to become thoroughly familiar with its capabilities. However, review of these technical manuals is not required for completion of this subcourse.

1. Transmitting Set AN/PRT-4, AN/PRT-4A.

TM 11-5820-549-12 details this equipment. The AN/PRT-4 and 4A are hand-held, low-power FM transmitters. These sets are generally considered obsolete and are no longer in much use. They transmit over a relatively short distance in the low VHF region (47 to 57 MHz). They were formerly used primarily at the squad and platoon level for the leader to communicate with unit personnel.

2. Receiving Set AN/PRR-9.

TM 11-5820-549-12 details this equipment. This is the receiver that was used in conjunction with the AN/PRT-4 transmitter in the squad or platoon. It mounts on the soldier's helmet or webbing and has an earphone jack for quiet reception. As with the AN/PRT-4, this equipment is obsolete.

3. Radio Sets AN/PRC-25, AN/VRC-53, and AN/GRC-125.

TM 11-5820-398-12 (PRC-25) and TM 11-5820-498-12 (VRC-53, GRC-125) details these sets. This family is the earliest group of FM transmitter-receiver radio sets still in use. All three versions utilize the RT-505 transmitter-receiver operating in the lower VHF band (30 to 52.95 MHz and 53 to 75.95 MHz). The PRC-25 is a portable manpack version. The VRC-53 adds amplifier OA-3633 to make a vehicular-based unit, and the GRC-125 is a portable or vehicular based model. All three configurations are used for short-range communications. This family of radio sets has no secure transmission capability.

4. Radio Sets AN/PRC-77, AN/VRC-64, and AN/GRC-160.

TM 11-5820-667-12 details these sets. This family of radio sets is replacing the PRC-25, VRC-53, and GRC-125 series respectively. The transmission characteristics are exactly the same as the earlier radio sets. The difference is that the newer sets use transmitter-receiver RT-841 which is completely transistorized. Another feature incorporated into the new sets is the capability of secure voice transmission using the VINSON device.

5. AN/VRC-12 Family of Radio Sets.

These sets and their components are detailed in TM 11-5820-401-12. The radio sets in the AN/VRC-12 family are short-range vehicular and fixed radio sets designed for general tactical use. They provide FM voice communications and can be used with secure voice and digital data equipment using the X MODE facility. Two of the sets (AN/VRC-45 and AN/VRC-49) have retransmission capability. The radio sets of the AN/VRC-12 family will net with each other and with other FM radio equipment operating in the 30 to 75.95 MHz frequency range. Each of the eight configurations in this family is made up of a combination of receiver-transmitters RT-246/VRC and RT-524/VRC and receiver R-442/VRC along with support equipment.

a. Receiver-transmitter RT-246/VRC and RT-524/VRC. These two receiver-transmitters are the heart of the AN/VRC-12 family of radios. They operate in two bands; Band A - 30 to 52.95 MHz, and Band B - 53 to 75.95 MHz. They are capable of transmission up to about 41 kilometers (km). Each member of the AN/VRC-12 family contains at least one of these units. The primary differences between the two units are that the RT-246 has ten automatic channel presets and the RT-524 has a built-in loudspeaker.

b. Receiver R-442/VRC. This receiver is used in several of the AN/VRC-12 configurations to allow monitoring one net while transmitting in another. The R-442 operates in the same frequency range as the RT-246 and RT-524.

(1) AN/VRC-12. This configuration includes one RT-246, one R-442, and two antennas. You can use this configuration to monitor one net while you conduct communications in another. You can easily switch transmitting frequencies of the R-246 to transmit in the R-442's net.

(2) AN/VRC-43. This configuration consists of one RT-246 and one antenna and it is used for communications in a single radio net.

(3) AN/VRC-44. This configuration consists of one RT-246, two R-442s, and two antennas. With this set you can communicate in one net and monitor two additional nets. As with the VRC-12, you can change transmitting frequency on the RT-246 and transmit into either of the other two nets.

(4) AN/VRC-45. This configuration consists of two RT-246s, two antennas, and a C-2299/VRC Retransmission Cable Kit. You should use this configuration to provide retransmission facilities for two stations that are too far apart to talk to each other directly. You can also use this set to retransmit information from one net into another net by tuning the two RT-246s to different frequencies.

(5) AN/VRC-46. This configuration uses one RT-524 and one antenna and is essentially identical in function to the AN/VRC-43.

(6) AN/VRC-47. This configuration uses one RT-524, one R-442, and two antennas. It functions the same way as the AN/VRC-12.

(7) AN/VRC-48. This set consists of one RT-524, two R-442s, and two antennas. It functions the same way as the AN/VRC-44.

(8) AN/VRC-49. This configuration consists of two RT-524s, two antennas, and the C-2299/VRC. It serves the same retransmission functions as the AN/VRC-45.

All the AN/VRC-12 family configurations are secure voice capable. You can secure the sets using either VINSON (KY-57) or NESTOR (KY-38) security devices.

6. Radio Set Control AN/GSA-7.

TM 11-5135-15 details this equipment. The AN/GSA-7 is an electronic switching device. You use it to interface FM radio equipment with local push-to-talk wire telephone circuits. The GSA-7 is the basis of the Net Radio Interface (NRI) system. The unit acts as an automatic keying device so that when a remote telephone operator keys his telephone set he also keys the transmitter of the FM radio set. This allows his wire telephone message to transmit over the FM frequency to a receiver that can also be attached to another GSA-7 to convey the message into another wire telephone net at a remote site. You can control a radio set with the GSA-7 from as far away as 16 km (7.3 miles).

7. Control Group AN/GRA-6.

TM 11-5038 details this equipment. Occasionally you may want to locate your radio transmitter in a site where communications are good, but the site does not offer a good tactical position. When this happens the best thing to do is set the radio up so you can operate it remotely. The GRA-6 is the piece of equipment that allows you to do this. The GRA-6 consists of a local and remote unit used at the radio site and the remote control site respectively. The two units are connected by field wire and can be separated by up to 3.2 km or 1.5 miles.

8. Radio Set Control Group AN/GRA-39B.

TM 11-5820-477-12 details this equipment. The GRA-39B is another remote control set similar to the GRA-6. It also is used with FM radio sets and has a range of 3.2 km. The principal difference between the GRA-39B and the GRA-6 is that the 39B is fully transistorized and the 6 is not.

9. Retransmission Cable Kit MK-456A/GRC.

This kit is used with the AN/PRC-25 and AN/PRC-77 series of radios for retransmission. You can also use it with the AN/VRC-12 series if the standard C-2299/VRC kit is unavailable.

10. Radio Set AN/GRC-19.

TM 11-5820-295-10 details this equipment. The AN/GRC-19 is a medium-power voice and continuous wave radio set designed for vehicular installations. It forms the central unit for several of the older RATT sets. The GRC-19 is being phased-out of use and replaced with the newer GRC-106 radio set. You can also use the GRC-19 to perform retransmission functions. Both transmitter and receiver operate in the HF band. The transmitter operates between 1.5 and 20 MHz, and the receiver operates between 0.5 and 32 MHz. The AN/GRC-19 operates in AM/DSB mode.

11. Radio Set AN/GRC-106.

TM 11-5820-520-12 details this equipment. As stated previously, the AN/GRC-106 is replacing the AN/GRC-19 in its mobile retransmission role. It is also the central unit for the newer family of radio teletypewriter sets currently in use. The GRC-106 operates in the HF band between 2.0 and 29.999 MHz and uses the AM/SSB mode. There are two basic configurations of this equipment, the GRC-106 and GRC-106A. The former uses receiver-transmitter RT-662/GRC which has a channel spacing of 1 kHz. The A variation uses receiver-transmitter RT-834/GRC which has channel spacing of 100 Hz. You can see from this that the A variation has ten times as many channels available as the standard GRC-106. The AN/GRC-106 has both voice and CW capability.

12. Radio Set AN/FRC-93.

TM 11-5820-554-15 details this equipment. The FRC-93 is a commercial type of AM/SSB (upper or lower) radio set adapted for military use. You can also perform CW communications using the FRC-93. The radio set operates in two regions of the HF band, from 3.4 to 5.0 MHz and from 6.5 to 30 MHz. This type of radio set uses crystal sets for tuning.

13. Radio Set AN/PRC-74.

TM 11-5820-590-12 and TM 11-5820-590-12-1 details this equipment. The AN/PRC-74 is a low-power, transistorized AM/SSB/USB radio set designed for voice and CW communications. The PRC-74 is configured as a manpack and is primarily designed for communications in areas where LOS communications is not possible due to terrain or other obstructions. The AN/PRC-74 comes in four variations: basic, A, B, and C. The basic and A versions operate between 2.0 and 11.999 MHz. The B and C versions extend the upper frequency limit to 17.999 MHz. The AN/PRC-74 adds the versatility of being able to communicate with remote sites that you could not communicate with using the AN/PRC-25 or 77 series of FM radios.

14. Radio Set AN/PRC-70.

TM 11-5820-553-10 details this equipment. The AN/PRC-70 was originally designed to give special forces, ranger, long-range reconnaissance patrol, and selected engineering units a light-weight multimode means of communications. The unit operates over a range of 2.0 to 75.999 MHz in the HF and VHF bands. The PRC-70 can operate in AM/DSB, AM/SSB, FM, CW, and frequency-shift keying (FSK) modes. This flexibility allows the unit using this device to travel almost anywhere they need to go and still be able to provide real-time intelligence information to command and control units in the corps and theater areas. The AN/PRC-70 usage has been expanded to battalion communications stations as well as forward deployed units. The AN/PRC-70 can be operated in secure mode using both VINSON and NESTOR security devices. Another great advantage of the PRC-70 is that it can communicate with any of the AM, AM/SSB, or FM radios discussed previously in this lesson. You can also set up retransmission stations using the PRC-70 as illustrated in figure 2-1. The combination of its light weight, ruggedness, and wide range of capabilities makes the AN/PRC-70 an ideal radio set for units that require great freedom of movement and activity. In a fixed site, one AN/PRC-70 can serve as a backup for almost all other tactical communications systems.

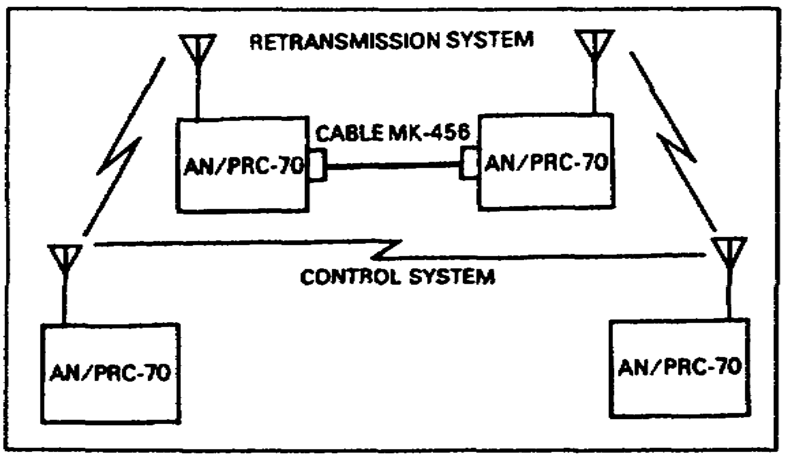

Figure 2-1. AN/PRC-70 retransmission configuration

15. Summary.

This lesson has introduced you to the various pieces of equipment used in tactical radio communications, along with the uses for and capabilities of each piece of equipment. In the next lesson you will learn the basic procedures of voice communication over tactical radio channels.

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LESSON 2

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

Situation: You are responsible for managing communications for a field exercise.

1. You are using the AN/VRC-43 set to communicate with a special forces unit that is using the AN/PRC-70 set. The unit moves over a large hill, cutting off communications. Which of the following radio sets should you use to reestablish communications with the unit?

   A. AN/VRC-46.
   B. AN/GRC-106.
   C. AN/GRC-125.
   D. AN/GRC-160.

2. While the special forces unit is still on the other side of the large hill, it experiences a failure in its AN/PRC-70 set. Which of the following sets can the unit use to reestablish communications with you?

   A. AN/PRT-4A.
   B. AN/PRC-25.
   C. AN/PRC-74.
   D. AN/PRC-77.

3. You are directed to set up a net radio interface using your AN/VRC-12 series radio. Which of the following pieces of auxiliary equipment should you use to accomplish this?

   A. AN/GSA-7.
   B. AN/GRA-6.
   C. AN/GRC-19.
   D. AN/GRA-39B.

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4. While you are in your exercise area, some civilian trucks with citizens' band radios enter your exercise area. Which radio set should you use to inform them that they are in a restricted area?

   A. AN/VRC-12.
   B. AN/PRC-25.
   C. AN/FRC-93.
   D. AN/GRC-160.

LESSON 2

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item Correct Answer and Feedback

1. B. AN/GRC-106.

Since communications was cut off as the unit moved over the hill, you have an indication that the direct path of communication is no longer available. Most VHF communications take place along the direct path, so you must try another propagation path to communicate with the unit. The AN/GRC-106 is an HF radio, so it can use the sky-wave transmission path. The AN/PRC-70 has the capability to communicate in both HF and VHF bands and using both AM and FM modes. This feature makes it capable of taking advantage of whatever communications paths and equipment are available. (page 2-5, para 11).

2. C. AN/PRC-74.

The unit is still out of the range of a VHF line-of-sight radio. If their AN/PRC-70 fails, they must use some other HF AM radio set. The AN/PRC-74 is the only choice that matches those criteria. (page 2-5, para 13).

3. A. AN/GSA-7.

The AN/GSA-7 is a switching device designed to provide NRI for AN/VRC-12 series radios. The AN/GRA-6 and GRA-39B are both remote radio control devices and the AN/GRC-19 is an AM radio set. (page 2-4, para 6).

4. C. AN/FRC-93.

The AN/FRC-93 is a military derivative of the commercial citizens' band radio. The other choices are all VHF radios and would not be compatible with the truck's radios. (page 2-5, para 12).

LESSON 3

TACTICAL RADIO VOICE OPERATION

CRITICAL TASKS: 01-5878.04-0005,
01-5778.07-0003, 01-5778.07-0007

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn the basic procedures for operating a voice radio including: operating rules, phonetic alphabet, correct pronunciation, procedure sign (PROSIGN) usage, authentication procedures, and operations within a radio network.

TERMINAL LEARNING OBJECTIVE:

ACTIONS:

a. Describe the necessity for using proper radiotelephone procedures.

b. Define the uses of the phonetic alphabet and the numerical pronunciation.

c. Describe the use and meaning of the more commonly used PROSIGNs.

d. Define the necessity for and give examples of authentication.

e. Describe the procedures for opening and closing a net using authentication.

CONDITION: You will be given information from this lesson.

STANDARD: To demonstrate competency of the terminal learning objective, you must achieve a minimum score of 70% on the subcourse examination.

REFERENCES: The material contained in this lesson was derived from the following publications: FM 11-32, FM 11-50, FM 24-18, and SOI KTV 1600 C Supplemental Instructions.

INTRODUCTION

The tactical effectiveness of any communications equipment is no greater than the skill of the operators. By the same token, the most efficient communications within a net or command is attained when the operators habitually use proper procedures in transmitting and receiving messages. This lesson will introduce you to the basic procedures and protocol associated with tactical radio communications.

1. Preparations.

Before attempting any communication, there are certain preparations that any operator should perform. These preparations ensure that the equipment is properly set up, that the operator is familiar with the operation of the equipment, and that the operator is familiar with the signal operation instructions and proper communications procedures.

2. Equipment Checkout.

Before operating any piece of radio equipment you should be certain it is properly configured and that you are familiar with its operation. The equipment technical manual is the best place to begin when you check an equipment configuration. The technical manual will have directions, diagrams, and procedures for aligning and operating the equipment. If the technical manual is not available, you should at least have some sort of abbreviated checklist that you can use to verify the setup of your system. Things to check should include tuning, power settings, ensuring all connections are tight and insulated, and ensuring that all components of your communications system can handle the power output of the transmitter.

3. Signal Operation Instructions.

The SOI and the standing operating procedures (SOPs) contain instructions pertaining to radio communications. The SOP is a standard document that governs the routine signal operations of a unit. It should include such items as communications systems priorities and general guidance on communications protocol. The SOI is a unit-specific document that deals with actual communications organizations in much more detail. The SOI contains such information as organization of stations into radio nets, assigning of net control stations (NCSs), and assigning of primary and alternate operating frequencies for each net. The SOI also provides guidance on authentication procedures and other communications security measures. FM 24-16 provides additional information about the SOP and FM 24-35 provides additional information on the SOI. Review of these manuals is not required for completion of this subcourse.

4. Phonetic Alphabet.

If radio communication was as clear and understandable as face-to-face communication, there would be no need to use special procedures when talking on the radio. Radio communications, however, can vary widely from extremely clear to barely intelligible. Because of this, there are certain rules of pronunciation when you are talking on a radio circuit. The phonetic alphabet employs these rules. Many times during radio communications you may need to say letters or numbers in the course of conversation. For example, call signs (which will be discussed later in this lesson) are made up of letters and numbers. If you only pronounce the name of the letter or number, the operator on the other end could confuse it with another letter or number. Spoken, the letter B sounds very much like P, V, or D. Likewise, the numbers nine and five often sound alike. The phonetic alphabet was designed to eliminate this confusion. Each letter and number has a distinct and understandable word associated with it. Tables 3-1 and 3-2 list the letters and numbers and their phonetic pronunciation.

Letter	Word	Spoken	Letter	Word	Spoken
A	Alfa	<u>Al</u> fah	N	November	No <u>vem</u> ber
B	Bravo	<u>Brah</u> voh	O	Oscar	<u>Oss</u> cah
C	Charlie	<u>Char</u> lee	P	Papa	Pah <u>pah</u>
D	Delta	<u>Dell</u> tah	Q	Quebec	Keh <u>beck</u>
E	Echo	<u>Eck</u> oh	R	Romeo	<u>Row</u> me oh
F	Foxtrot	<u>Foks</u> trot	S	Sierra	See <u>air</u> rah
G	Golf	Golf	T	Tango	<u>Tang</u> go
H	Hotel	Ho <u>tell</u>	U	Uniform	<u>You</u> nee form
I	India	<u>In</u> dee ah	V	Victor	<u>Vik</u> tah
J	Juliett	<u>Jew</u> lee <u>ett</u>	W	Whiskey	<u>Wiss</u> key
K	Kilo	<u>Key</u> loh	X	Xray	<u>Ecks</u> ray
L	Lima	<u>Lee</u> mah	Y	Yankee	<u>Yang</u> key
M	Mike	Mike	Z	Zulu	<u>Zoo</u> loo

Table 3-1. Phonetic alphabet

As you can see, in each instance the emphasized syllable is underlined. For example, the letters BPV would be pronounced "Bravo Papa Victor." The use of the phonetic alphabet makes the letters clear to the receiving operator.

5. <u>Procedure Words and Procedure Signs</u>.

Along with being understood in radio transmissions, another very important point is that messages be as brief as possible. Lengthy messages run the risk of becoming garbled at some point and losing the meaning of the message. In today's world of electronic countermeasures and electronic homing devices, the less time a radio station is transmitting, the less likely it is to be discovered and targeted by enemy forces. In order to standardize certain common phrases used in radio transmissions, a set of procedure words (PROWORDs) has been devised and is recognized as a standard in radio communications. The same factors that make it desirable for spoken messages to be short and concise also apply to typewritten messages. Most PROWORDs have a corresponding PROSIGN to help abbreviate teletype messages. Table 3-3 lists some common PROWORDs and their corresponding PROSIGNs and meanings. Where no PROSIGN is listed there is not a common PROSIGN associated with that PROWORD.

Number	Spoken
0	Zee roh
1	Wun
2	Too
3	Tree
4	Foh wer
5	Fife
6	Six
7	Sev en
8	Ait
9	Nin er

Table 3-2. Number pronunciation guide

PROWORD	PROSIGN	Explanation
ALL AFTER	AA	The portion of the message to which I have reference is all that which follows ____.
ALL BEFORE	AB	The portion of the message to which I have reference is all that which precedes ____.
AUTHENTICATE	INT ZNB	The station called is to reply to the challenge that follows.
AUTHENTICATION IS	ZNB	The transmission authentication of this message is ____.

Table 3-3. PROWORDs and PROSIGNs

PROWORD	PROSIGN	Explanation
BREAK	$\overline{\text{BT}}$	I hereby indicate the separation of the text from other portions of the message.
BROADCAST YOUR NET		Link the two nets under your control for automatic rebroadcast.
CALL SIGN	PT	The group that follows is a call sign.
CORRECT	C	You are correct, or what you have transmitted is correct.
CORRECTION	EEEEEEEE	An error has been made in this transmission. Transmission will continue with the last word correctly transmitted.
	C	An error has been made in this transmission (or message indicated). The correct version is ____.
	C	That which follows is a corrected version in answer to your request for verification.
DISREGARD THIS TRANSMISSION-OUT	EEEEEEEE$\overline{\text{AR}}$	This transmission is in error. Disregard it. This PROWORD shall not be used to cancel any message that has been completely transmitted and for which receipt or acknowledgment has been received.

Table 3-3. PROWORDs and PROSIGNs (cont.)

PROWORD	PROSIGN	Explanation
DO NOT ANSWER	F	Stations called are not to answer this call, receipt for this message, or otherwise to transmit in connection with this transmission. When this PROWORD is employed, the transmission shall be ended with the PROWORD "OUT."
EXECUTE	IX (5 sec dash)	Carry out the purpose of message or signal to which this applies. To be used only with the Executive Method.
EXECUTE TO FOLLOW	IX	Action on the message or signal that follows is to be carried out upon receipt of the PROWORD "EXECUTE." To be used only with the Delayed Executive Method.
EXEMPT	XMT	The addressees immediately following are exempted from the collective call.
FIGURES		Numerals or figures follow.
FLASH	Z	Precedence FLASH.
FROM	FM	The originator of this message is indicated by the address designator immediately following.

Table 3-3. PROWORDs and PROSIGNs (cont.)

PROWORD	PROSIGN	Explanation
GROUPS	GR	This message contains the number of groups indicated by the numeral following.
GROUP NO COUNT	GRNC	The groups in this message have not been counted.
I AUTHENTICATE	ZNB	The group that follows is the reply to your challenge to authenticate.
IMMEDIATE	O	Precedence IMMEDIATE.
IMMEDIATE EXECUTE	IX	Action on the message or signal following is to be carried out on receipt of the word EXECUTE. To be used only with the Immediate Executive Method.
INFO	INFO	The addressees immediately following are addressed for information.
INTERROGATIVE	INT	The following is a question.
I READ BACK		The following is my response to your instructions to read back.
I SAY AGAIN	$\overline{\text{IMI}}$	I am repeating transmission or portion indicated.
I SPELL		I shall spell the next word phonetically.

Table 3-3. PROWORDs and PROSIGNs (cont.)

PROWORD	PROSIGN	Explanation
I VERIFY		That which follows has been verified at your request and is repeated. To be used only as a reply to VERIFY.
MESSAGE		A message that requires recording is about to follow. Transmitted immediately after the call. (This PROWORD is not used in nets primarily employed for conveying messages. It is intended for use when messages are passed on tactical or reporting nets.)
MORE TO FOLLOW	B	Transmitting station has additional traffic for the receiving station.
NET NOW	ZRC2	All stations are to tune their radios on the unmodulated carrier wave that I am about to transmit.
NUMBER	NR	Station serial number.
OUT	$\overline{AR}$	This is the end of my transmission to you and no answer is required or expected.
OVER	K	This is the end of my transmission to you and a response is necessary. Go ahead; transmit.
PRIORITY	P	Precedence PRIORITY.

Table 3-3. PROWORDs and PROSIGNs (cont.)

PROWORD	PROSIGN	Explanation
READ BACK	G	Repeat this entire transmission back to me exactly as received.
RELAY (TO)	T	Transmit this message to all addressees (or addressees immediately following this PROWORD). The address component is mandatory when this PROWORD is used.
ROGER	R	I have received your last transmission satisfactorily.
ROUTINE	R	Precedence ROUTINE.
SAY AGAIN	IMI	Repeat all of your last transmission. Followed by identification data means "Repeat _____ (portion indicated)."
SERVICE	SVC	The message that follows is a SERVICE message.
SIGNALS		The groups that follow are taken from a signal book. (This PROWORD is not used on nets primarily employed for conveying signals. It is intended for use when tactical signals are passed on nontechnical nets.

Table 3-3. PROWORDs and PROSIGNs (cont.)

PROWORD	PROSIGN	Explanation
SILENCE (Repeated three or more times)	$\overline{\text{HM HM HM}}$	Cease transmission on this net immediately. Silence will be maintained until lifted. (When an authentication system is in force, the transmission imposing silence is to be authenticated.)
SILENCE LIFTED		Silence is lifted. (When an authentication system is in force, the transmission lifting silence is to be authenticated.)
SPEAK SLOWER		Your transmission is at too fast a speed. Reduce speed of transmission.
STOP REBROADCASTING		Cut the automatic link between the two nets that are being rebroadcast and revert to normal working.
THIS IS	DE	This transmission is from the station whose designator immediately follows.
TIME		That which immediately follows is the time or date-time-group of the message.
TO	TO	The addressees immediately following are addressed for action.

Table 3-3. PROWORDs and PROSIGNs (cont.)

PROWORD	PROSIGN	Explanation
UNKNOWN STATION	$\overline{\text{AA}}$	The identity of the station with whom I am attempting to establish communication is unknown.
VERIFY	J	Verify entire message (or portion indicated) with the originator and send correct version. To be used only at the discretion of or by the addressee to which the questioned message was directed.
WAIT	$\overline{\text{AS}}$	I must pause for a few seconds.
WAIT-OUT	$\overline{\text{AS AR}}$	I must pause longer than a few seconds.
WILCO		I have received your signal, understand it, and will comply. To be used only by the addressee. Since the meaning of ROGER is included in that of WILCO, the two PROWORDs are never used together.
WORD AFTER	WA	The word of the message to which I have reference is that which follows ______.
WORD BEFORE	WB	The word of the message to which I have reference is that which precedes ______.

Table 3-3. PROWORDs and PROSIGNs (cont.)

PROWORD	PROSIGN	Explanation
WORDS TWICE		**Communications is difficult. Transmit (transmitting) each phrase (or each code group) twice. This PROWORD may be used as an order, request, or as information.**
WRONG		**Your last transmission was incorrect. The correct version is _____.**

Table 3-3. PROWORDs and PROSIGNs (cont.)

When you are conducting radio communications it is important that you and your operators use the proper PROWORDs and PROSIGNs so that your messages will be clear and concise to the receiving station.

6. Call Signs.

In radio communications it is not only important to know what is in a message, but it is also important to know who sent the message. A system of CALL SIGNS has been developed so that stations can identify themselves and to the stations they are talking. A call sign normally consists of a three-character letter-number-letter basic call sign followed by a two-digit suffix. If the command issuing call signs has more than 99 users, an expander letter may appear after the suffix. This total of five or six characters is called the complete call sign. The last letter of the basic call sign plus the two suffix numbers (and expander letter if applicable) is called the abbreviated call sign and should be used except when entering a net or when requested by the net control station. The following is an example of a complete and abbreviated call sign.

Complete call sign - C 3 T 8 5

Abbreviated call sign - T 8 5

Always pronounce call signs phonetically. For example, the above complete call sign should be pronounced "Charlie tree tango ait fife" and the abbreviated call sign "Tango ait fife." Your command will issue call signs in its SOI. Each call sign will have a certain duration, usually 24 hours.

7. Authentication.

You have many means of Secure communications at your disposal. It is not unreasonable to suspect, however that an enemy might somehow be able to break into your net and provide misinformation or give false orders. The SOI provides a transmission authentication system to prevent this. The only authentication systems authorized for use are those produced by the National Security Agency (NSA) and provided in your SOI supplement. The SOI will also define the period of validity for each authentication system. There are two types of authentication: challenge and reply authentication and transmission authentication. You should conduct authentication on your net when any of the following circumstances occur.

a. When any station suspects imitative deception on any circuit. For example, when contacting a station following one or more unsuccessful attempts to contact that station.

b. When any station is challenged or requested to authenticate. This is not to be interpreted as requiring stations to break an imposed silence for the sole purpose of authenticating.

c. When directing radio silence, listening silence, or requiring a station to break an imposed silence (this requires the use of transmission authentication).

d. When transmitting contact and amplifying reports in plain language.

e. When transmitting operating instructions that affect the military situation. For example, closing down a station or watch, changing frequency other than normal scheduled changes, directing establishment of a special communications guard, requesting artillery fire support, and directing relocation of units.

f. When transmitting a plain language cancellation.

g. When making initial radio contact or resuming contact after prolonged interruptions.

h. When transmitting to a station that is under radio listening silence.

i. When authorized to transmit a classified message in the clear.

j. When forced, because of no response by the called station, to send a message in the blind (transmission authentication).

8. Challenge and Reply.

Whenever possible, you should use challenge and reply authentication as it can validate both the transmitting and receiving stations. Figure 3-1 is a reproduction of the challenge and reply and transmission authentication tables. Refer to this figure in the following discussion of authentication procedures. When two stations establish radio contact, the station being called should always issue the first challenge. This prevents an enemy from entering your net just to get a valid authentication to use in another net. When the called station has challenged and the calling station has replied, the calling station should challenge in order to also validate the called station. The following paragraphs detail the challenge and reply process. For illustration purposes, assume that station M21 is calling station M35.

M21 issues the call "Mike tree fife, this is mike too wun, over." This establishes the identities of both the calling and the called stations.

M35 must now issue an authentication challenge. Looking at the challenge and reply system, he chooses a letter from the far left column. This is the line indicator column. He then chooses another letter from the row indicated by the first letter he chose. These two letters make up the challenge. Thus, his transmission would be "Mike too wun, this is mike tree fife, authenticate delta golf, over." M35 has chosen delta and golf as his two letters to challenge.

M21 must now reply to the challenge and issue a challenge of his own. To reply, he must have the same table as M35. He looks up the letter Delta in the left-hand column. He then looks up the letter Golf in Delta's row (row 4 in this case). His reply should be the letter directly beneath Golf on the table. In this case it would be Bravo. He then chooses two different letters to issue as a counter challenge to M35. His transmission should be "Mike tree fife, this is mike too wun, I authenticate bravo, authenticate yankee victor, over."

M35 must now respond to M21's challenge. He looks up yankee on his authentication table, and then finds victor in yankee's row. Since yankee is the last row on the table he gets the reply from the first row on the table as if it wrapped around. His reply letter, then, is tango, and his transmission is "Mike too wun, this is mike tree fife, I authenticate tango, over." At this point, both stations have authenticated and they may continue to communicate and pass whatever traffic they need to pass.

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	ABC	DEF	GHIJ	KL	MN	PQR	ST	UV	WX	YZ
	0	1	2	3	4	5	6	7	8	9
A	ERSQ	WOJ	NKI	PB	YD	MTA	GU	HV	XF	LC
B	GJNH	ULF	EKA	OY	VB	STC	DI	QP	WR	XM
C	DAFH	CUB	TKM	OR	NE	GXQ	VY	IL	SP	JW
D	RMXF	IVO	TQY	WS	JP	LBD	CK	GE	HU	MA
E	IATL	DVO	SWX	MH	KQ	EYF	RN	BC	PU	JG
F	RCMX	AGO	TIE	NF	PH	YDB	QV	LK	UJ	SW

	ABC	DEF	GHIJ	KL	MN	PQR	ST	UV	WX	YZ
	0	1	2	3	4	5	6	7	8	9
G	TYKN	AHE	VUQ	IN	FD	RCW	BO	XP	JS	LG
H	AHOG	CKS	PNU	BR	DT	MYX	EQ	FL	VW	JI
I	OWGJ	SXC	DAP	RE	LY	QUF	MV	NB	TH	IK
J	YNAT	GBD	LOF	EJ	RS	MIK	WH	PQ	XU	VC
K	LYQE	UVN	JIC	HM	AG	KTP	DW	OX	SR	FB
L	GQCN	HUI	SMR	JB	FO	XWY	VT	EA	KL	PD

	ABC	DEF	GHIJ	KL	MN	PQR	ST	UV	WX	YZ
	0	1	2	3	4	5	6	7	8	9
M	CLUR	TJN	VAF	EX	DW	QKH	MP	GB	YI	OS
N	RPJU	QHX	CTN	OW	MA	KBV	EL	IG	SD	FY
O	QTOY	XMK	AWN	RJ	EF	PLS	DV	HB	CI	UG
P	PWMR	IEJ	ADK	GH	TS	QYC	ON	BU	LP	VX
Q	JRDA	QFN	BOI	SM	WH	KCX	GP	VL	YT	EU
R	MPBR	WXC	VJD	UN	XG	HQF	SE	LI	AY	TO

	ABC	DEF	GHIJ	KL	MN	PQR	ST	UV	WX	YZ
	0	1	2	3	4	5	6	7	8	9
S	YPFV	DLU	QKT	HR	EO	ASI	CG	XN	MJ	WB
T	NCRT	DOG	UYX	BE	WJ	FSH	QP	LI	VM	AK
U	EBJR	IHV	YGL	AQ	NC	WPS	UX	KD	FO	TM
V	JOTC	VAB	DIR	FS	LW	QHU	EP	XY	KN	GM
W	AOCN	WJL	KDB	PI	RV	PGQ	UH	SM	XT	YE
X	SVHC	EML	YOA	GU	DK	FXI	JN	WT	PB	RQ
Y	EBOH	STL	FIM	GW	PY	JVA	UR	DN	KX	QC

TRANSMISSION
AUTHENTICATION TABLE

01	02	03	04	05	06	07	08	09	10
CK	OW	NP	PR	LV	AA	DB	DR	XR	MB
RL	KF	GO	IM	TK	XU	AY	ST	AL	EA
LE	TT	DO	MJ	UA	LX	JB	QT	HB	FS
II	ZY	QG	SW	ND	BR	NW	CX	NT	XZ
AW	FV	DW	BI	HT	CK	UG	WR	OP	IR

11	12	13	14	15	16	17	18	19	20
TM	WZ	VA	UU	CR	IT	XN	WE	RG	SO
GE	RX	WP	RP	BF	HK	EM	AK	TC	NY
VI	RO	ZH	RV	VJ	IQ	JK	FY	JT	GG
HO	HL	KA	CJ	AP	XK	TG	OL	LL	QL
DI	RW	QN	WQ	LG	GB	FG	QY	MC	IN

21	22	23	24	25	26	27	28	29	30
SA	GJ	HE	JC	IJ	ES	EZ	LB	SI	LZ
AF	DF	UY	EF	JD	PP	IW	FA	IY	MY
JE	ZC	QJ	NK	NA	DM	PZ	GV	SL	RC
MQ	QB	GP	KR	ZV	XV	RQ	LM	VC	SZ
UV	QH	LO	BT	YR	WL	QD	XO	NR	FP

31	32	33	34	35	36	37	38	39	40
RN	JS	KC	CU	MH	KT	WI	WW	HZ	NN
NF	CF	OG	RF	JM	KS	FO	QS	SG	QQ
SQ	PK	OX	WD	XL	EG	FL	XQ	EW	IF
ZS	NG	RU	EJ	XW	CN	FH	ZA	CH	CY
ZM	JV	JH	RD	NO	KJ	WB	YJ	AI	OO

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Figure 3-1. Authentication tables

9. Transmission Authentication.

You should only use transmission authentication when the station you are calling cannot answer because of some problem or silence condition that has been imposed. The transmission authentication system is based on the second table in figure 3-1. The table consists of 40 numbered columns of five, two-character combinations. Each station will be assigned certain columns to use if transmission authentication is necessary. When you need to use this system, you take the first column you are assigned and use the first two-character combination in that column that you have not already used. Those two characters then become the authentication for the message. Once used, you cross out the particular authentication code so that you do not reuse it. If you need to send another transmission authentication, you use the next code in the column. For example, you are assigned column 33 and have already sent two transmission authentication messages. Your next transmission authentication code would be OX. Your authenticated transmission should be "(Call sign), this is (your call sign), authentication is oscar xray, (your message), out." You would not end a transmission authenticated message with "over," because that would imply that the other station should reply. If the other station could reply, you should use challenge and reply authentication instead.

10. Radio Nets.

A group of radio stations that communicate on the same frequency is called a network or net. Radio stations are generally divided into nets according to the function that each station serves within the command. Figure 3-2 shows a typical HF operations voice net and figure 3-3 shows a VHF tactical employment division command operations net. The station in charge of maintaining the net is called the NCS and is usually a station in a superior unit communicating with stations in one or more subordinate units. Each station on a particular net will have its own unique call sign. The net will also have a call sign which is the basic call sign of the NCS. Thus, for a net whose NCS is A6V58, the net call sign would be A6V. Nets will be assigned on a command level, along with call signs for each net station.

11. Opening a Net.

The NCS is responsible for opening and closing the net. Normally upon initial opening or reopening of the net the NCS will initiate authentication procedures. The following paragraphs detail this process.

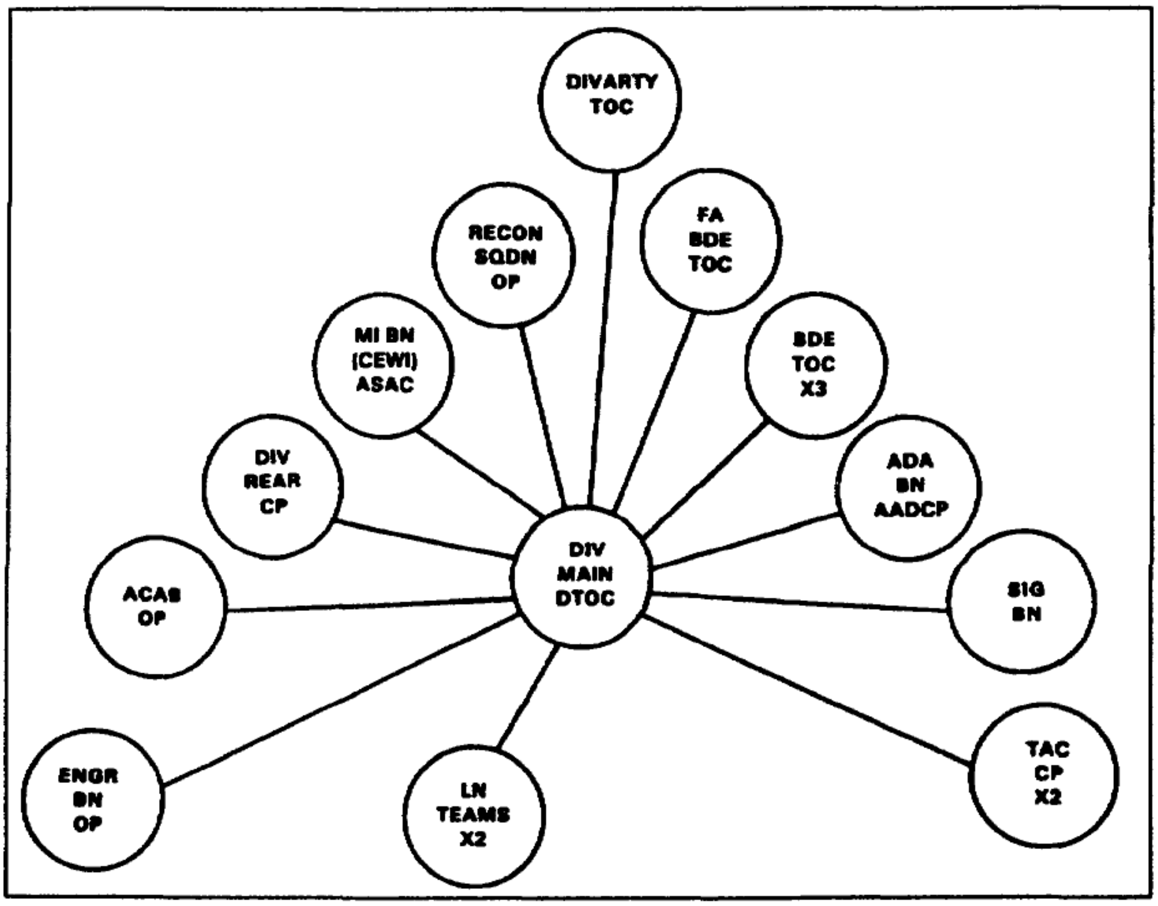

Figure 3-2. Typical HF operations voice net

a. The NCS will call the stations on the net using the net call sign and will issue the first authentication challenge using the challenge and reply system.

b. The station with the first call sign in alphabetical order will answer the NCS's call and reply to the challenge. He will then issue a challenge to the NCS.

c. The NCS will reply to the first station's challenge and issue a second challenge.

d. The station with the next alphabetical call sign will reply to the NCS's second challenge and issue a challenge of his own.

e. The station with the third alphabetical call sign will reply to the challenge issued by the second station and will issue a challenge to the fourth station.

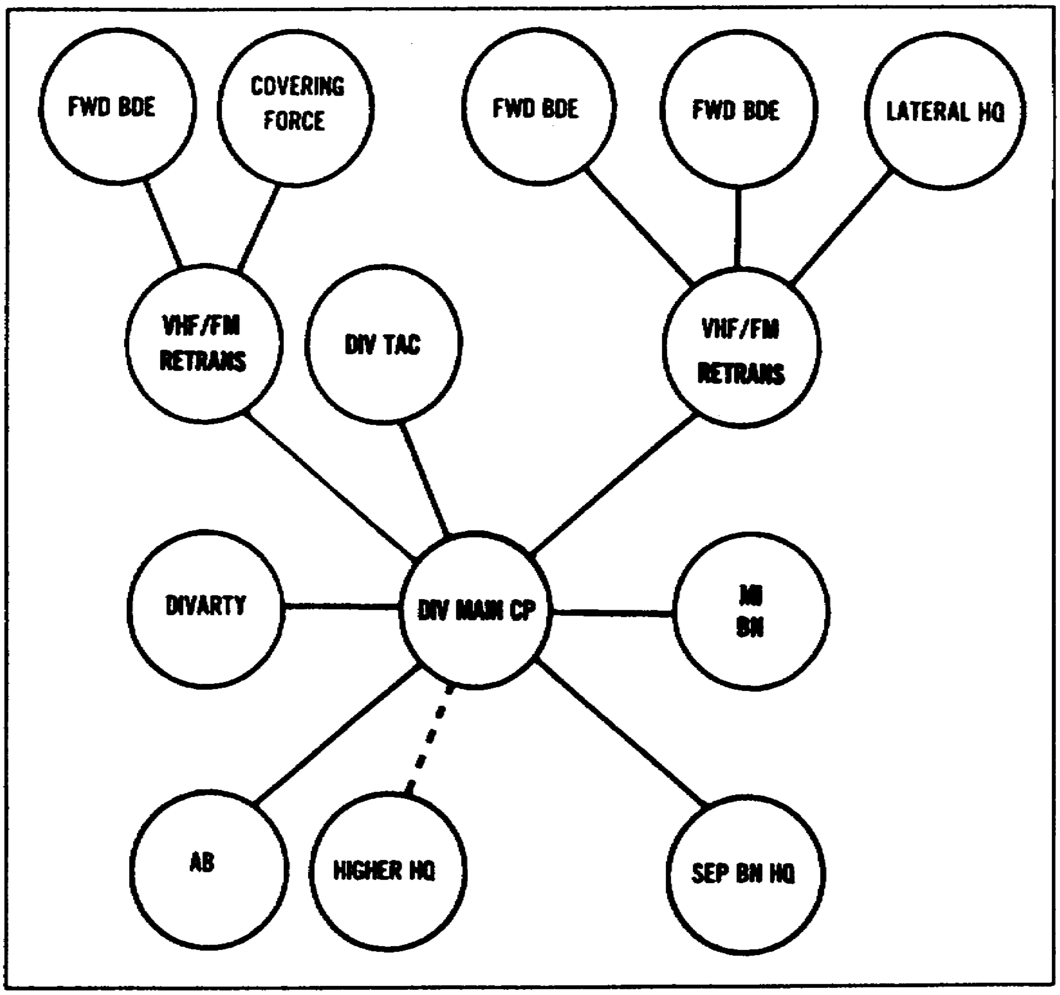

Figure 3-3. Tactical employment division command operations net VHF/FM

f. This process will continue until the last station in alphabetical order has replied to a challenge. The last station will not issue a challenge of his own.

g. Once all stations have authenticated, the NCS will issue instructions on the operation of the net.

12. Closing a Net.

As in opening a net, the NCS is also responsible for closing the net. When opening the net you recall that all stations were required to authenticate. When you close down a net, however, only the station ordering the net to close is required to authenticate. This is because the net will not be operating and it is only necessary to determine if the order to close down is necessary. The procedure for closing the net is outlined in the following paragraphs.

a. The NCS calls the net and issues the order to close down the net.

b. The first alphabetical station calls the NCS and issues an authentication challenge.

c. The NCS replies to the authentication challenge.

d. The stations, in alphabetical order, will call the net and acknowledge the order to shut down.

e. Once all stations have receipted the order, stations may shut down.

13. Summary.

In this lesson you have learned the basic organization and procedures for operating voice tactical radios. The next lesson will introduce you to radio teletypewriter equipment and procedures.

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LESSON 3

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

<u>Situation</u>: You are the NCS for a communications exercise. Use the authentication tables in figure 3-1 in answering the following items.

1. Which of the following documents should you consult to determine the assigned call signs for the exercise?

   A. The SOI.
   B. The SOP.
   C. FM 11-32.
   D. FM 24-18.

2. You are opening your net using authentication. You issue the challenge "Authenticate Juliett Victor." What reply do you expect?

   A. "I authenticate Tango."
   B. "I authenticate Bravo."
   C. "I authenticate Foxtrot.”
   D. "I authenticate Juliett Victor as Tango."

3. You are assigned column six on the transmission authentication table. What authentication will you use to order radio silence on your net?

   A. Alfa Alfa.
   B. Charlie Kilo.
   C. Golf Uniform.
   D. Six Alfa Alfa.

4. You are in the middle of a transmission and realize that you have made a mistake and passed an incorrect piece of data. What PROWORD should you use to indicate this to the rest of the net?

   A. Break.
   B. Correction.
   C. I say again.
   D. Do not answer.

LESSON 3

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	A. The SOI.
	The SOI contains unit-specific information pertaining to communications. It will contain call signs, authentication tables, and any special instructions concerning communications within your unit. (page 3-2, para 3).
2.	C. "I authenticate Foxtrot."
	Look up Juliett in the leftmost column on the challenge and reply authentication table. Find Victor in Juliett's row. The letter directly below Victor is Foxtrot. Therefore, responses A and B are incorrect. Response D is self-authentication and is a breach of security. (page 3-14, para 8).
3.	A. Alfa Alfa.
	Since this is the first time you have used transmission authentication, you look up the first code in the column you have been assigned to use. If you looked at the challenge and reply table instead of the transmission authentication table, you probably chose letter C as your answer. Answer D is also considered self-authentication. (page 3-16, para 9).
4.	B. Correction.
	Correction is the appropriate PROWORD to use if you make a mistake during a transmission. After using the PROWORD, you continue with the last correct information in your transmission. (page 3-5, table 3-3).

LESSON 4

TACTICAL RADIO TELETYPEWRITER EQUIPMENT

CRITICAL TASKS: 01-5878.04-0005,
01-5778.07-0003, 01-5778.07-0007

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn the principles of radio teletypewriter operations and will become familiar with the components and characteristics of various radio teletypewriter sets.

TERMINAL LEARNING OBJECTIVE:

ACTIONS:

a. Define the basic principles of tactical radio teletypewriter communications.

b. Describe the most popular tactical radio teletypewriter sets in the field.

c. Determine which tactical radio teletypewriter set best meets a specific communications requirement.

d. Select the tactical radio teletypewriter sets that are compatible for point-to-point net operation.

e. Describe how to open and close a radio teletypewriter net using authentication.

CONDITION: You will be given information from this lesson.

STANDARD: To demonstrate competency of the terminal learning objective, you must achieve a minimum score of 70% on the subcourse examination.

REFERENCES: The material contained in this lesson was derived from the following publication: FM 24-18 and TC 24-24.

INTRODUCTION

While voice communications is essential to the rapid dissemination of vital information in a tactical situation, you may also have the need to send hardcopy (paper) messages from time to time in your duties as a signal officer. It 'is important, then, that you have some means of transmitting this hardcopy message from one point to another. The equipment you will use for this is radio teletypewriter equipment.

1. Theory of RATT Operation.

RATT systems operate on a system of electronic pulses. Each RATT unit consists of a keyboard, transmitter, receiver, and printer combination. The keyboard converts the keystrokes entered by the operator into electronic pulses. Each character transmitted is actually made up of a start pulse, five intelligence pulses, and a stop pulse. All the pulses are 22 milliseconds in duration except for the stop pulse which is 31 milliseconds. The intelligence pulses are a combination of spacing impulses and marking impulses. Depending on the combination of these two types, the receiver-printer will decode the signal and print the corresponding character. Figure 4-1 shows the combinations of intelligence pulses for each character in the RATT character set. In most RATT sets, the marking and spacing impulses are transmitted on slightly different frequencies. This is called frequency-shift keying. FSK has an advantage in that it does not require any carrier modulation. Thus, RATT equipment can transmit messages more clearly in marginal conditions than voice radio. Figure 4-1 also shows the perforated tape that some RATT equipment uses. The perforated tape allows you to pre-record a message on the tape and then transmit it by running the tape through the RATT transmitter. Likewise, the receiver can print out on perforated tape if necessary. The perforated tape acts like a backup to the regular printer. Most RATT equipment also has voice communications capability built in so you have another backup for ensuring that messages are received.

2. RATT Equipment.

The following paragraphs present an overview of some of the more popular RATT equipment currently in use. As with the section on voice equipment, some of the RATT equipment may no longer be in use in regular units but may be used by some reserve units. Again, this course is not designed to teach you every aspect of each piece of equipment, and you are encouraged to read the technical manuals referenced for the various equipment presented. However, review of the technical manuals is not required for successful completion of this subcourse. Table 4-1 is a comparison of operating frequencies for each of the different pieces of equipment discussed. When netting old and new equipment, you must take into consideration the operating frequencies of the equipment with which you are trying to communicate.

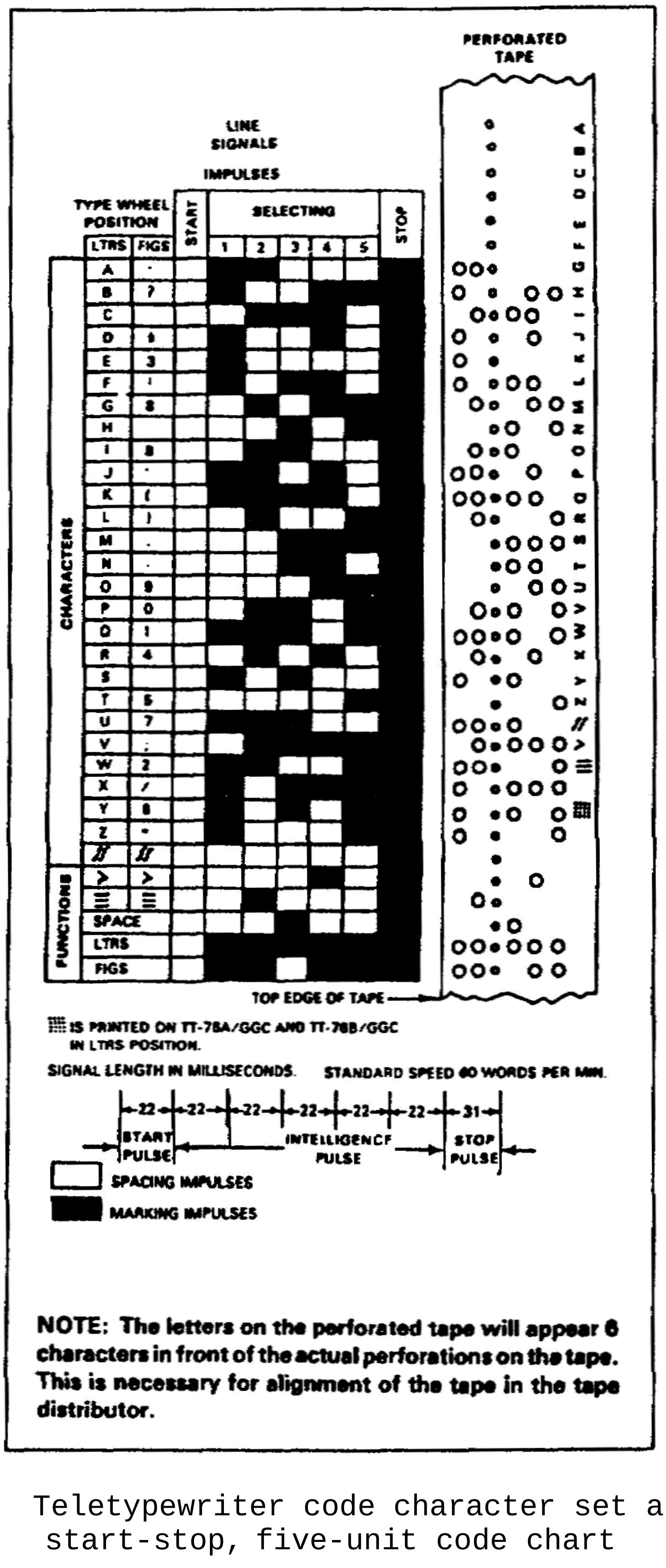

Figure 4-1. Teletypewriter code character set and standard start-stop, five-unit code chart

Configuration	Radio Set	Operating Frequency	
		Transmit	Receive
AN/GRC-46	AN/GRC-19	1.5 - 20 MHz	0.5 - 32 MHz
AN/VRC-29	AN/GRC-19	1.5 - 20 MHz	0.5 - 32 MHz
AN/VSC-1	*AN/GRC-19*	*1.5 - 20 MHz*	*0.5 - 32 MHz*
AN/GRC-26D	AN/GRC-19	1.5 - 20 MHz	0.5 - 32 MHz
AN/GRC-122	AN/GRC-106	2.0 - 29.999 MHz	
AN/GRC-142	AN/GRC-106	2.0 - 29.999 MHz	
AN/VSC-3	AN/GRC-106	2.0 - 29.999 MHz	
AN/VSC-2	AN/GRC-106	2.0 - 29.999 MHz	

Table 4-1. Comparison of operating frequencies

a. Teletypewriter Set AN/PGC-1. TM 11-5815-206-12 details this equipment. The PGC-1 is the most basic RATT system currently in use. It is a small transportable unit consisting of a keyboard and a printing device. The PGC-1 is used in fixed and transportable configurations.

b. Teletypewriter Set AN/FGC-20. TM 11-5815-200-12 details this equipment. The FGC-20 is similar to the PGC-1 with the exception of being larger and more durable. This unit is found primarily in fixed sites where portability is not a requirement.

c. Radio Teletypewriter Sets AN/GRC-46, AN/VSC-1, and AN/VRC-29. TM 11-5815-204-10 details this equipment. The GRC-46, VSC-1, and VRC-29 are older RATT sets that are used in mobile communications applications. They all use the AN/GRC-19 radio set as the basic transmitter-receiver, and they have the same operating frequencies and modes as that unit. The Army is replacing these units with the AN/GRC-106 based RATT sets.

(1) GRC-46. The GRC-46 consists of one GRC-19 and two teletypewriter units. One of these units is a tape reperforator type unit. The GRC-46 is shelter-housed and found in 3/4-ton mobile communications stations.

(2) VRC-29. The VRC-29 is identical to the GRC-46 except that it is not shelter-housed. This version is carried in armored personnel carriers (APCs).

(3) VSC-1. The VSC-1 contains the AN/GRC-19 and a single teletypewriter (non-reperforating). This set is designed to be lightweight and is carried in jeeps.

d. Radio Set AN/GRC-26D. TM 11-5820-256-10 details this equipment. The GRC-26D is a high-power RATT station designed for use in fixed, semifixed, or mobile applications. The set consists of a transmitter, two receivers, and three teletypewriters. The GRC-26D operates in the same frequency bands and operational modes as the GRC-46 family. In its mobile configuration, the GRC-26D is shelter-mounted in a 2½ ton vehicle. The GRC-26D is generally considered obsolete and has been replaced in regular units by the GRC-106 based AN/GRC-122.

e. Radio Teletypewriter Sets AN/GRC-122, AN/GRC-142, AN/VSC-2, and AN/VSC-3. TM 11-5815-334-12, TM 11-5815-331-14, and TM 11-5815-332-14 details this equipment. These RATT sets are replacing the older AN/GRC-19 based systems described previously. They are based on the more modern and versatile AN/GRC-106 transmitter-receiver, and they have the same frequency and mode characteristics as that equipment. The following paragraphs briefly discuss the differences in each of these pieces of equipment.

(1) AN/GRC-122. The GRC-122 has replaced the AN/GRC-26D as the long-distance shelter mounted RATT station for fixed, semifixed, and mobile applications. It consists of two receiver-transmitters and three teletypewriters. The GRC-122 is much lighter than the GRC-26D and can be carried on a 3/4 ton vehicle.

(2) AN/GRC-142. The GRC-142 is replacing the AN/GRC-46 in the 3/4 ton vehicular installations. In addition to the ability to use AM/SSB, the GRC-142 also has the added ability to perform secure voice communications which the older equipment does not. The GRC-142 consists of one receiver-transmitter and two teletypewriter units.

(3) AN/VSC-3. The VSC-3 is replacing the AN/VRC-29 for installation in armored personnel carriers. The set consists of one receiver-transmitter and two teletypewriters. Except for being shelter-mounted, the VSC-3 is essentially identical to the GRC-142.

(4) AN/VSC-2. The VSC-2 is replacing the VSC-1 as the jeep-mounted version of the RATT set. Like its predecessor, the VSC-2 consists of a receiver-transmitter and a non-reperforating teletypewriter. As with the more robust members of its family, the VSC-2 is capable of AM/SSB secure voice communications.

3. RATT Network Communications.

As with voice radios, RATT stations are set up in networks according to the station's function within the command. The SOI and unit command structure will designate how these nets are set up. The procedures for communicating on a RATT net are very similar to those for communicating on a voice net. Proper training of operators and adherence to procedures are, if anything, more crucial in RATT communications. PROSIGNs must be used whenever possible to minimize the size and length of messages. Table 3-3 in lesson 3 lists most of the common PROSIGNs. Table 4-2 lists some additional PROSIGNs that are unique to RATT communications.

PROSIGN	Meaning
INT ZBK	How do you copy me?
ZBK1	I copy you clear.
ZBK2	I copy you garbled.
ZKJ1	Close down.
ZUJ	Stand by.

Table 4-2. Additional PROSIGNs

4. RATT Authentication and Net Procedures.

You should use authentication procedures for RATT communications just as you would for voice. The same rules of challenge and reply and transmission authentication apply. The one difference in authentication procedures between the two systems is that, in RATT communications, the reply to a challenge is sent twice. The following paragraphs illustrate opening and closing a RATT net using challenge and reply authentication.

The NCS calls the net, tells them to tune their radios, and asks how each station copies his transmission. His transmission is: "(Net call sign) DE (NCS call sign) ZRC2 INT ZBK K." The voice equivalent would be: "(Net call sign) this is (NCS call sign) net now, how do you copy me, over." You can see that the use of PROSIGNs significantly shortens the message and reduces the possibility of typographical errors.

The first substation in alphabetical order calls the NCS and reports that he reads the NCS clear or garbled. He then asks the NCS how he copies the substation's transmission. His transmission is: "(NCS call sign) DE (station call sign) ZBK1 INT ZBK K."

The NCS answers that he reads the substation clear or garbled and tells the substation to standby. His transmission is: "(Station call sign) DE (NCS call sign) ZBK1 (or ZBK2 if garbled) ZUJ AR." He ends his transmission with the PROSIGN for "Out" to indicate that he does not want the substation to reply.

The second substation in alphabetical order repeats the above procedure, and so on for the third and any additional substations on the net. When all stations have established contact with the NCS, the NCS will open the net using authentication. His transmission is: "(Net call sign) DE (NCS call sign) INT ZNB A J K." The NCS in this case has chosen A and J as his first authentication challenge.

The first substation in alphabetical order replies to the NCS's challenge and issues a counter challenge to the NCS. His transmission would be: "(NCS call sign) DE (Station call sign) ZNB F F INT ZNB P L K." Notice that the first substation transmitted the reply F twice in keeping with RATT procedures.

The remainder of the authentication process is like the same procedure in voice net operations. The NCS replies and issues a new challenge. The second substation replies to the challenge and issues another challenge that is replied to by the third substation and so on. When all substations have authenticated, the NCS will issue instructions on how the net will operate and pass message traffic.

When the net is ready to close down, the NCS will issue the close down order. His transmission will be: "(Net call sign) DE (NCS call sign) ZKJ1 K." As in voice operations, the first substation will challenge the NCS and the NCS will reply, validating the order to close the net. Each substation will then call the NCS in alphabetical order and acknowledge the order to close the net. When the last substation has acknowledged the close down order, all stations may secure their RATT stations.

5. Summary.

In this lesson you have learned about the operation of RATT systems. You have also learned about the main RATT systems currently in use for tactical radio communications and about the basic communications procedures associated with RATT communications. In the next lesson you will learn about some of the most modern tactical radio equipment currently in use.

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LESSON 4

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

Situation: You are communicating via RATT. Use the authentication tables in figure 3-1 to answer the following items.

1. You are communicating with an armored personnel vehicle. Which of the following sets should he be using?

   A. AN/VSC-2.
   B. AN/VSC-3.
   C. AN/GRC-122.
   D. AN/GRC-142.

2. You have just received a replacement radio set for your old AN/GRC-26D. What radio set did you receive?

   A. AN/VSC-2.
   B. AN/VSC-3.
   C. AN/GRC-122.
   D. AN/GRC-142.

3. You are communicating with another station when you receive the transmission INT ZBSHDYTKWU12483 XDSGDJ TWG DKJ. What do you reply?

   A. INT ZBK.
   B. ZBK1.
   C. ZBK2.
   D. ZUJ.

4. You are opening your RATT net. What PROSIGN should you use to tell the net stations to tune to your signal?

   A. INT ZBK.
   B. ZRC2.
   C. ZBK2.
   D. ZBK1.

LESSON 4

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	B. AN/VSC-3.
	The AN/VSC-3 is the armored personnel carrier version of the newer AN/GRC-106 based RATT sets. (page 4-5, para 2e(3)).
2.	C. AN/GRC-122.
	The AN/GRC-122 is the GRC-106 based replacement equipment for the older AN/GRC-26D. (page 4-5, para 2e(1)).
3.	C. ZBK2.
	You have received a garbled transmission. You transmit ZBK2 to tell the station calling you that his transmission was garbled. This allows him to retransmit the message if necessary. (page 4-6, table 4-2).
4.	B. ZRC2.
	ZRC2 is the PROSIGN for net now. It means for the radio stations to tune to your frequency and prepare to enter the net. {page 4-6, para 4).

LESSON 5

SINGLE-CHANNEL GROUND AND AIRBORNE RADIO SYSTEM (SINCGARS)
AND IMPROVED HIGH FREQUENCY RADIO (IHFR) OPERATION

CRITICAL TASKS: 01-5878.04-0005,
01-5778.07-0003, 01-5778.07-0007

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn about the newest generation of tactical radio equipment (SINCGARS and IHFR) including equipment capabilities and characteristics, equipment selection and configuration, and the role of this equipment within the Army Tactical Command and Control Systems.

TERMINAL LEARNING OBJECTIVE:

ACTIONS:

a. Describe the purpose of combat net radio (CNR) in support of Army Tactical Command and Control Systems.

b. Describe the purposes and capabilities of SINCGARS and IHFR.

c. Identify the planning/management factors for single-channel radios.

d. Describe CNR nets and equipment placements within signal organization command posts (CPs).

CONDITION: You will be given information from this lesson.

STANDARD: To demonstrate competency of the terminal learning objective, you must achieve a minimum score of 70% on the subcourse examination.

REFERENCES: The material contained in this lesson was derived from the following publication: FM 11-32.

INTRODUCTION

Advances in electronic technology have brought about many changes in the way we view communications in a very short time. New products are constantly being developed to enhance the various aspects of radio communications. In addition, we have made great progress in effectively integrating electronic counter-countermeasures technologies into radio equipment. This makes the vital command and control (C2) functions of radio more survivable in an RF hostile environment. The introduction of frequency hopping (FH) equipment allows us to transmit messages over a spread RF spectrum. This ability degrades the enemy forces' abilities to locate, monitor, jam, or destroy friendly radio systems. As these new technologies become field operational, they are replacing the older single-channel radio systems. The new systems provide the maneuver force commander with a reliable multifaceted C2 communications system. The new radio equipment gives him a combination of HF, VHF, and UHF communications capabilities. This provides him with three separate systems, each capable of using a different transmission path to pass the same information. The result is that the probability of any one system operating under any adverse RF conditions is greatly enhanced, directly enhancing force C2 functions.

1. Combat Net Radio.

The new radio systems being brought into use demand a new structure for communications. The combat net radio (CNR) network was designed to integrate and take full advantage of the enhancements in modern radio technology in support of C2. The CNR net is based around three basic radio systems, each with its own distinctive capabilities and characteristics. The three systems are: improved high frequency radio, Single-Channel Ground and Airborne Radio System, and single-channel tactical satellite (TACSAT). This subcourse deals with IHFR and SINCGARS systems. Subcourse SS 0060 explains the TACSAT system, however, review of SS 0060 is not required for completion of this subcourse.

2. The Role of CNR.

The primary role of the CNR network is voice communications for C2. It also performs a secondary role as a backup for data transmission when requirements exceed the capacity of the Army Data Distribution System or Mobile Subscriber Equipment services. In CNR networks, voice C2 information has priority except when SINCGARS is used with the Tactical Fire Direction System or Advanced Field Artillery Tactical Data System.

3. CNR Network Structure.

The CNR system generally establishes three categories of VHF-FM networks. They are C2, Administrative/Logistics, and Intelligence. The C2 network (the primary CNR net) is subdivided into functional areas of maneuver, fire support, aviation, air defense artillery (ADA), and engineers. Figure 5-1 shows the typical network structure for the division or brigade level.

NET STATIONS	CMD OP FM NET	INTEL FM NET	REAR OP CEN FM NET	OP HF VOICE NET (IHFR)
CDR	*	*		
ASST CDR	*	*		
OP G3/S3	**	*	*	**
G2/S2		**		
TAC G3/S3	*			*
TAC G2/S2		*		
DISCOM	*		**	
SUBORD CP	*	*	*	*
MSB/FSB				
AVN UNITS	*	*	*	*
ENGR UNIT	*	*	*	*
MI UNIT	*	*		*
ADA UNIT	*	*		*
ARTY	*	*	*	*
MP	*		*	
REAR OP CEN	*		*	*
SIG	*	*	*	
LO	*			
LONG-RANGE RECON DET		*		

*NET MEMBER
**NCS

Figure 5-1. Radio net structure

4. SINCGARS.

SINCGARS equipment is replacing the AN/PRC-77 and AN/VRC-12 series equipment currently in use. SINCGARS is a modular system, allowing components of one piece of equipment to serve as replacements for another. This feature provides increased reliability of communications overall. SINCGARS has two basic modes of communication: single-channel or FH. In the single-channel mode, it can communicate with any of the older VHF-FM equipment currently in use. In this mode, SINCGARS equipment can hold up to eight single-channel frequencies. The SOP will generally specify what frequencies will be stored.

When you shift the SINCGARS equipment to FH mode, it shifts operating frequencies about 100 times per second in the 30-87.975 MHz range. The audio signal is then modulated on the shifting carrier to produce an output signal that moves about the VHF spectrum. This "hopping" of the frequency makes the signal very difficult for enemy forces to detect, locate, or jam. If the changing of frequencies was completely random, there would be no way for two sets to communicate. The receiving set has to change frequencies in the same manner as the transmitter. To accomplish this synchronous frequency hopping, the SINCGARS equipment stores up to six separate hopsets. Each hopset is a code that tells the unit how and when to change frequencies in a repeating pattern.

In order to establish communications, two stations would make contact in single-channel mode and then switch to their designated hopset to conduct FH operations. As with the single-channel presets, the SOP defines the hopsets to be stored. One additional feature of SINCGARS equipment that makes it better than its predecessors is the ability to control output power of the unit. You can change power settings to transmit from 300 meters to 35 km (22 mi). This feature is advantageous both in field applications where detection is undesirable and in command post applications where many radios are operated simultaneously. You should always take care to operate at the minimum power required to ensure effective communications. The following paragraphs will describe the components and some of the various configurations of SINCGARS equipment.

a. Receiver-Transmitters RT-1523 and RT-1439. All ground-based SINCGARS configurations use either the RT-1523 or the RT-1439 as the basic component. Both units transmit and receive between 30 and 87.975 MHz. Both units are capable of FM, FSK, FH, and digital data input modes of operation. The RT-1523 has an internal integrated communications security (ICON) module built into it. The RT-1439 is a non-ICON radio but it can be secured using the KY-57 VINSON secure device. As stated previously, both units can store up to eight single-channel presets and six hopsets. Two of the eight single channel frequencies are the manual and cue frequencies. The manual frequency is the frequency that stations will establish communications on to activate the network. After communications have been established, stations will shift to the designated frequency hopset. Once the network has been established, a station desiring to enter the net will contact the net on its cue frequency. The net control station must then shift to the cue frequency to communicate with the new station and inform him of the frequency hopset parameters to use to join the net. Figure 5-2 shows the receiver-transmitter and its supporting components in a typical mobile installation.

b. Manpack Radio AN/PRC-119. This SINCGARS manpack radio is replacing the AN/PRC-25 and AN/PRC-77 manpack radios currently in use. The unit consists of one receiver-transmitter and a battery pack. If you use the RT-1439 then you must also use the VINSON security device. Figure 5-3 shows the various parts of the PRC-119 configuration.

c. Vehicular Short-Range Radio AN/VRC-87. The VRC-87 is replacing the AN/GRC-53 and AN/GRC-64 as the short-range vehicular tactical radio. This unit is essentially the same as the PRC-119 with extra cabling and no battery.

d. Dismountable Short-Range Radio AN/VRC-88. The VRC-88 adds the components to the VRC-87 necessary to make it a portable unit. This unit is replacing the AN/GRC-125 and AN/GRC-160.

e. Vehicular Long-Range/Short-Range Radio AN/VRC-89. The VRC-89 adds a second receiver-transmitter and a power amplifier to the VRC-87 configuration. This configuration allows the unit to monitor one net while communicating in another. This configuration is replacing the AN/VRC-12 and AN/VRC-47 configurations. Figure 5-4 shows the SINCGARS equipment in the VRC-89 configuration.

f. Vehicular Long-Range Radio AN/VRC-90. The VRC-90 is essentially a VRC-87 with a power amplifier added for long-range capability. The VRC-90 is replacing the AN/VRC-43 and AN/VRC-46.

g. Vehicular Short-Range/Long-Range dismountable radio AN/VRC-91. This unit is essentially identical to the VRC-89 except that it adds the necessary components to be operated as a manpack radio, providing manpack long-range capability. The VRC-91 does not replace any current equipment. The closest current configuration would be an AN/PRC-77 and either a VRC-43 or a VRC-46 in the same vehicle.

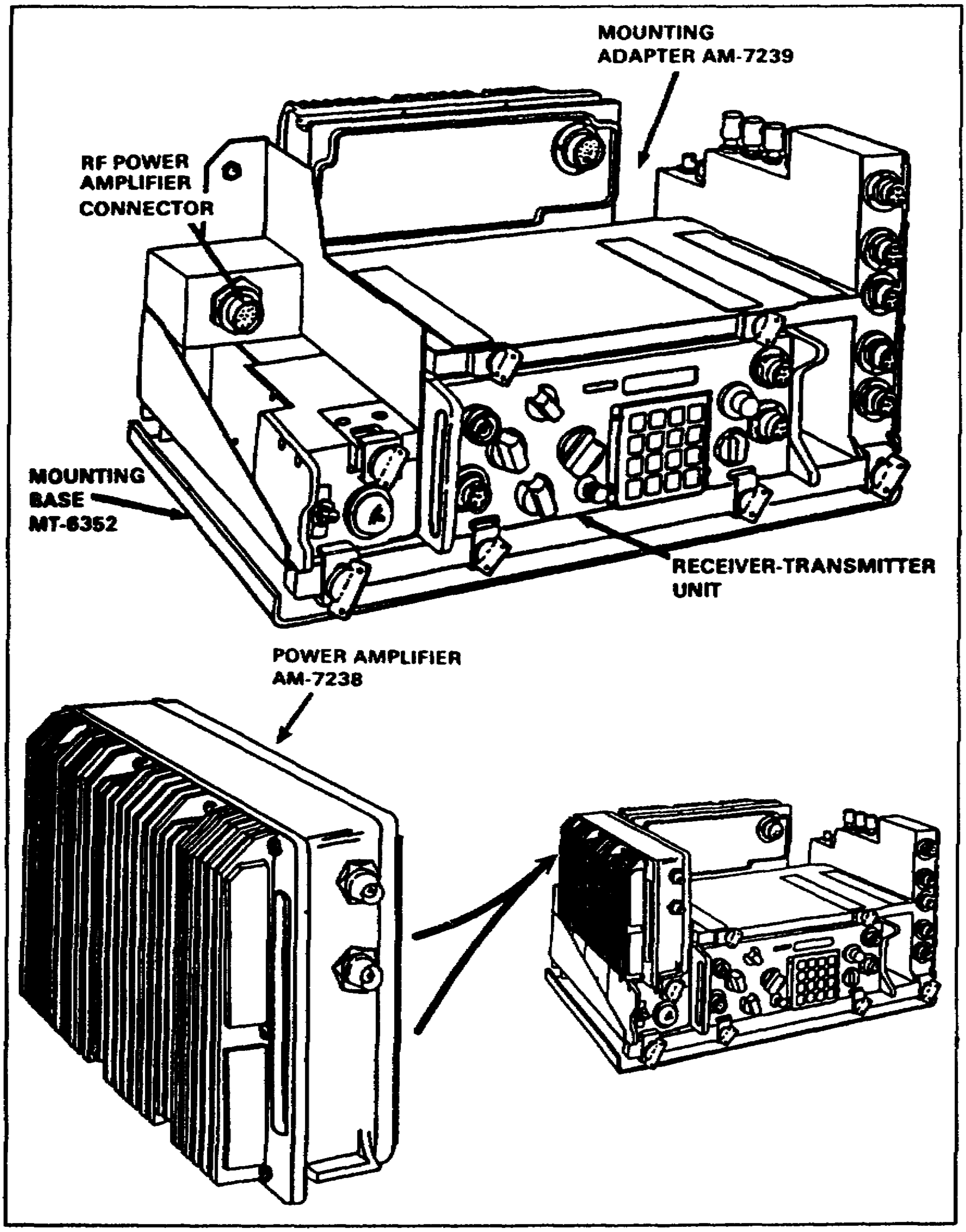

Figure 5-2. Radio set components

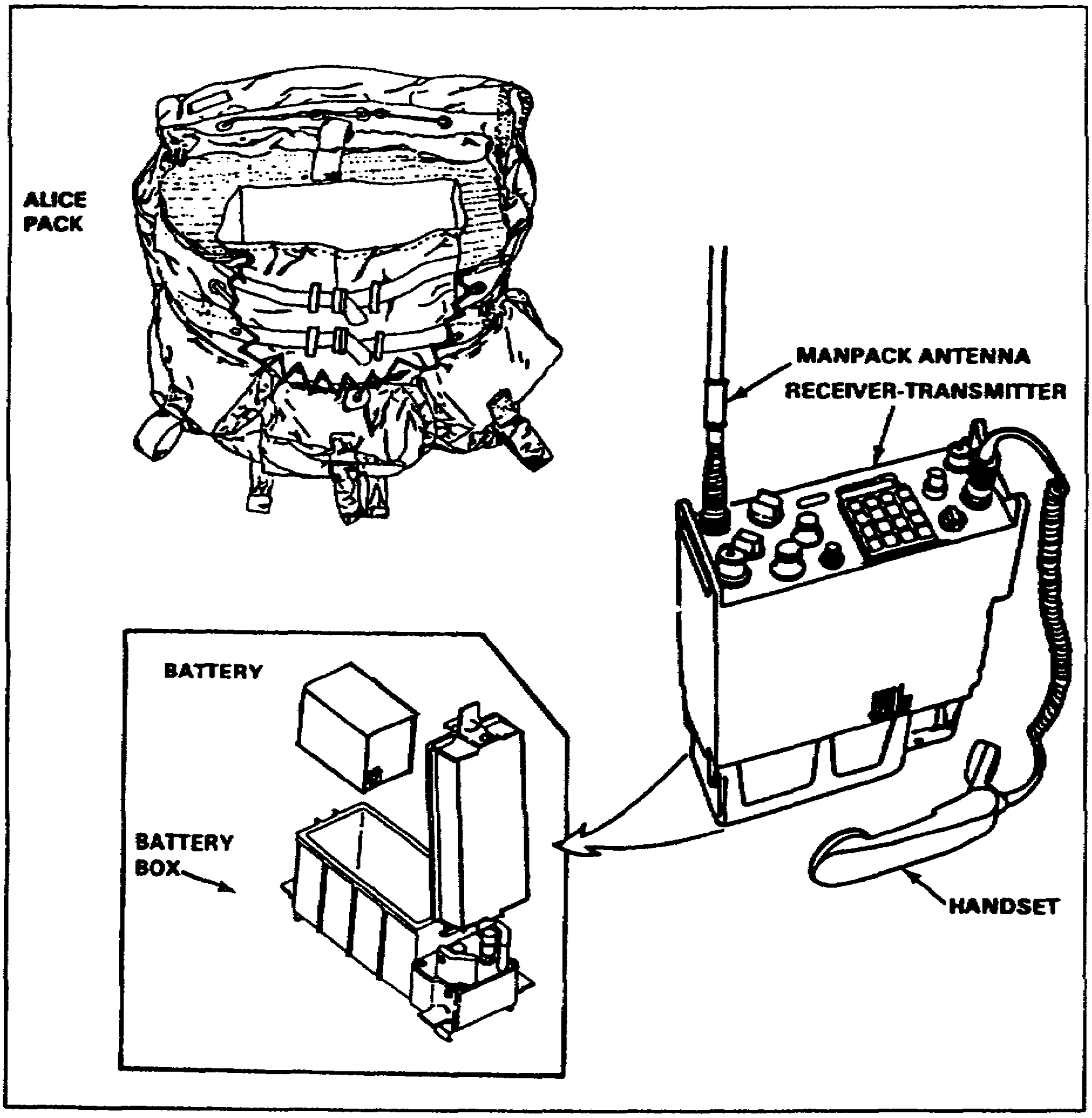

Figure 5-3. Manpack radio AN/PRC-119

h. Vehicular Dual Long-Range/Retransmission Radio AN/VRC-92. The VRC-92 replaces the AN/VRC-45 and AN/VRC-49 as the vehicular station capable of acting as a retransmission station. It is the same as the AN/VRC-89 with an additional power amplifier. This configuration provides high-power capability for both receiver-transmitters.

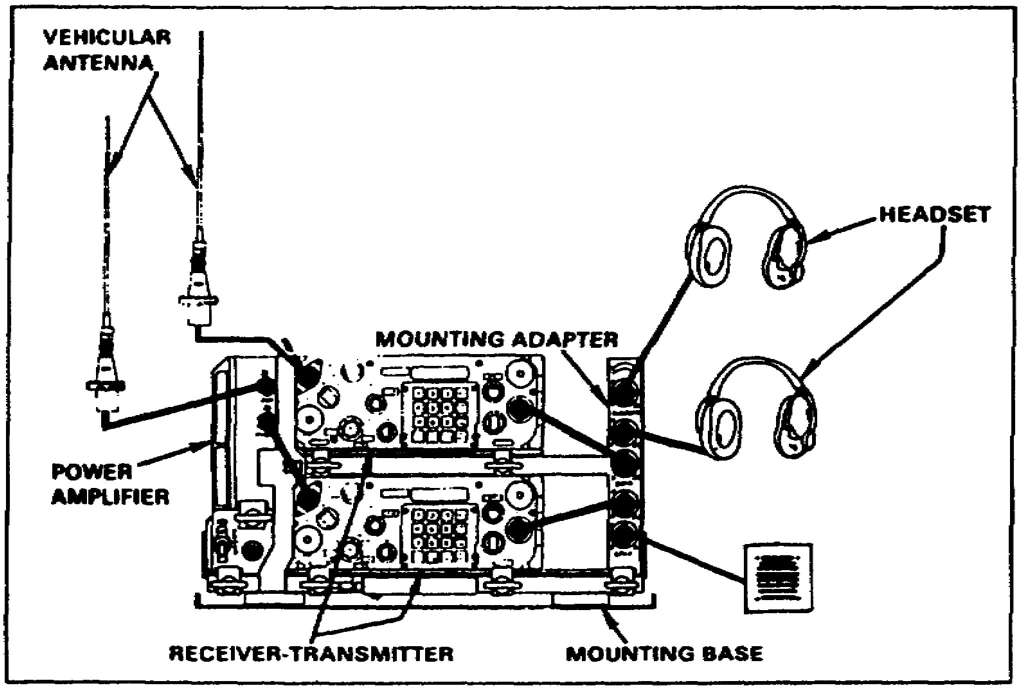

Figure 5-4. Vehicular long-range/short-range radio AN/VRC-89

i.Intravehicular Control Unit IVRCU C-11291. This device allows the operator to control up to three separate radios in armored vehicles. It can control all radio functions and can be used with ICOM and non-ICOM radios. The unit can also be set up so that three different operators can control the radio from their respective positions in the vehicle.

j.SINCGARS Remote Control Unit (SRCU). This device allows you to remotely operate your radio from up to 4 km (2.4 mi) away. The SRCU allows for secure remote operation including the control lines from the radio to the SRCU. It also provides intercom facilities between the radio and the remote site. All radio functions can be controlled remotely with the SRCU. The AN/GRA-39 can also be used to remotely control SINCGARS radios, but it only allows remote keying of the radio set.

k.Data Fill Devices MX-10579 and MX-18290. Data fill devices contain hopset and transmission security key (TSK) information for use with SINCGARS in FH mode. The TSK information actually tells the unit how to control the frequency hopping sequence. The MX-10579 holds up to 13 hopsets and 2 TSKs and you must use it with non-ICOM radios only. The MX-18290 holds 13 hopsets and 6 TSKs. Currently, you must have two fill devices to operate a secure SINCGARS radio in FH mode. One fill device is needed to load the radio and the second loads the security device (VINSON or ICOM).

l. VINSON and ICOM Secure Devices. Secure devices provide the means for secure voice communications between remote stations. The ICOM device is built into the ICOM transmitter. It contains one traffic encryption key (TEK) for each hopset. This means that in addition to frequency changing constantly, the information being passed is also encrypted. The VINSON device is an external device and is used with the non-ICOM radios. It has six preset positions, five for TEKs and one for a key encryption key (KEK). The five TEKs used with the radio allow secure operations in up to five different networks at one time. The KEK allows the VINSON device to be loaded by over-the-air (radio transmission) fill. In other words, several field units could carry VINSON devices and not carry any encryption codes. A transmitter located at a safe location could transmit the TEK information to all field units simultaneously. Thus, the units could set up secure networks without carrying any cryptographic codes with them. Both the VINSON device and the ICOM radio set are considered cryptographic material and should be destroyed if a unit possessing them is overrun.

5. IHER.

The IHFR system is another new-technology modular system being introduced into operation. The system is designed to replace the AN/PRC-70, AN/PRC-74, and AN/GRC-106 systems currently in operation. The following paragraphs describe the major components and configurations for IHFR equipment.

a. Receiver-Transmitter RT-1209. The heart of the IHFR system, RT-1209 is an AM/SSB (USB or LSB) radio set. It is compatible with the AM/SSB sets currently in use but is not directly compatible with the older AM/DSB equipment. An experienced DSB operator may still be able to pick up the SSB transmissions however. The RT-1209 operates between 2 and 30 MHz in the HF band.

b. Manpack Radio AN/PRC-104A. This portable unit will replace the AN/PRC-70 and AN/PRC-74 radios currently in use. It consists of a basic receiver-transmitter and support equipment. The PRC-104A also uses a tunable antenna and has an automatic antenna tuning feature built into the unit.

c. Low-Power Vehicular/Manpack Radio AN/GRC-213. Shown in figure 5-5, the GRC-213 combines the features of the older GRC-106 into a unit capable of vehicular or manpack use. Depending on the application, different amplifiers, power supplies, and antennas are attached. An important note on these radio sets is that your operators should always avoid excessive keying of the radio. The low-power IHFR radio has a maximum key down time of one minute and a ratio of one minute transmit to nine minutes receive. Exceeding this key down time can damage the radio set.

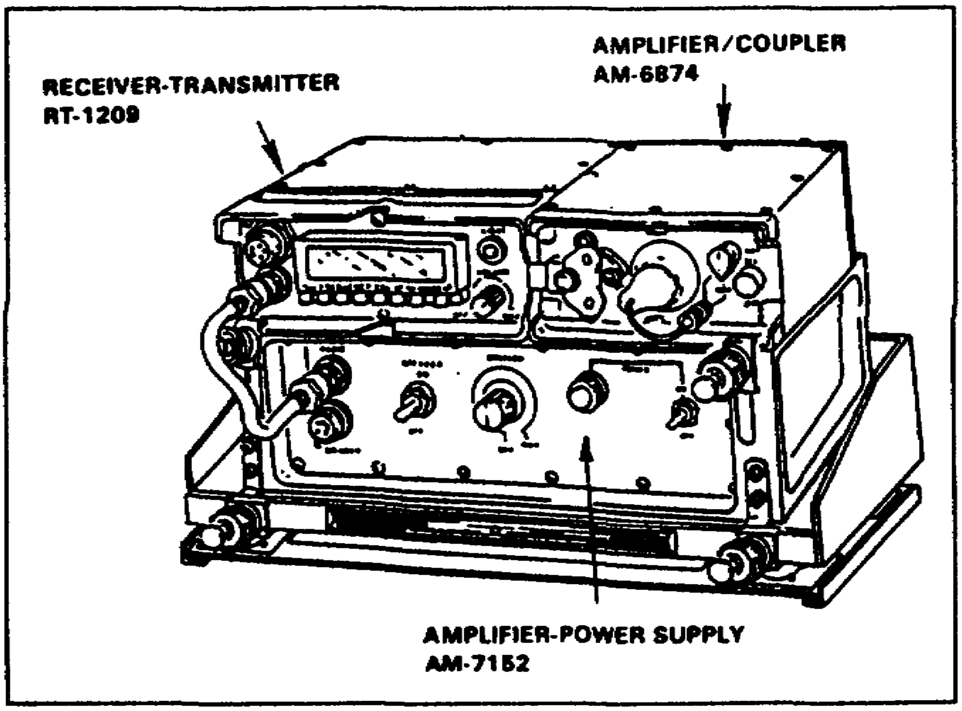

Figure 5-5. Radio set AN/GRC-213

d. High-Power Vehicle Radio AN/GRC-193A. The GRC-193A is a basic RT-1209 with a high-power supply and support components. Figure 5-6 illustrates this configuration. The AN/GRC-193A is replacing the AN/GRC-106.

6. Siting Considerations.

A CP in a modern battlefield scenario is a central clearing house for information. Many radio sets are operated in a relatively small geographical area. It stands to reason that these various radios will, from time to time, interfere with each other. The various combinations of SINCGARS, IHFR, and Mobile Subscriber Radiotelephone Terminal/Radio Access Unit (MSRT/RAU) equipment produce interference in three basic categories: IHFR to IHFR, SINCGARS to SINCGARS, and SINCGARS to MSRT/RAU. Since IHFR operates in a different frequency band, it is not likely that you will experience interference between it and either of the other two systems. Interference you experience as a result of having co-located radio sets is called cosite interference. There are three basic methods of controlling communications and managing the CP so that cosite interference is minimized. They are spectrum sharing, antenna separation, and network time sharing. The following paragraphs describe each of these methods.

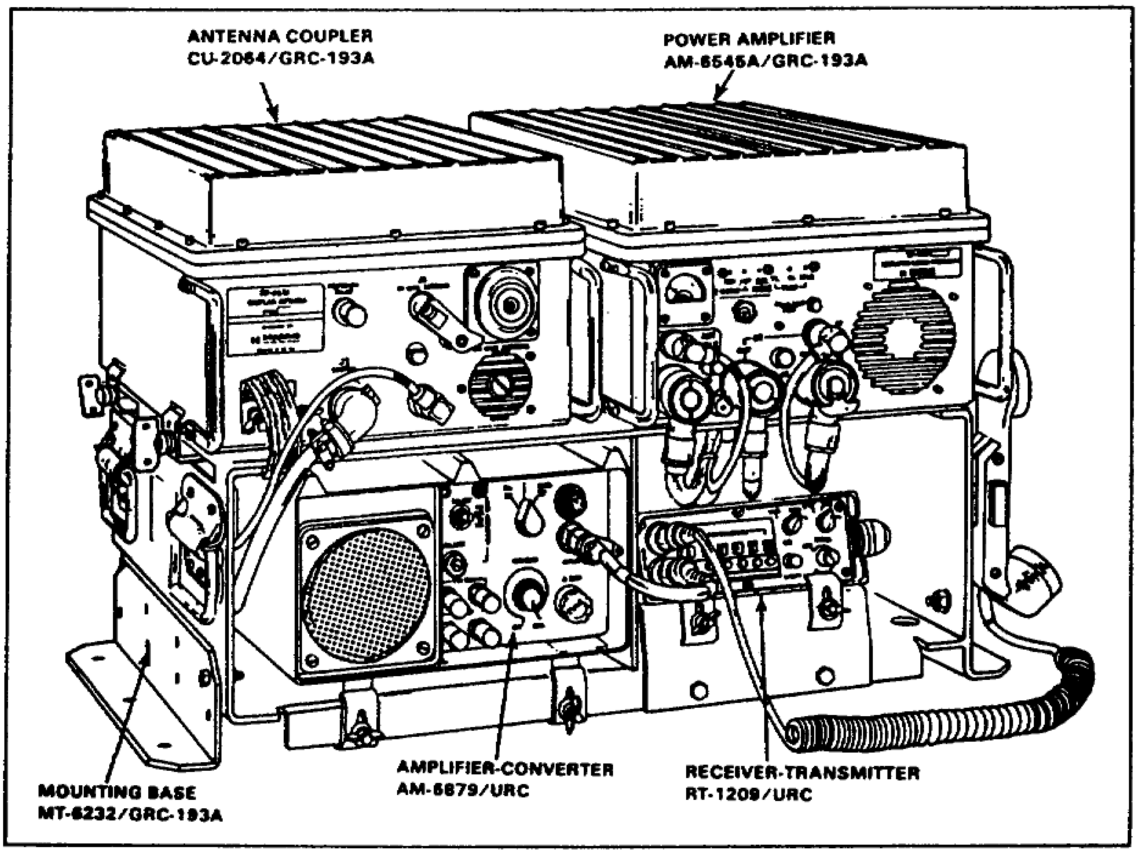

Figure 5-6. Radio set AN/GRC-193A

a. Spectrum Sharing. The Battlefield Spectrum Manager (BSM) is responsible for providing spectrum sharing to minimize cosite interference. In the case of SINCGARS and MSRT/RAU systems, he must ensure that different hopsets operate on different frequencies and that MSRT/RAU frequencies are not included in any SINCGARS hopset. The particular pattern for spectrum sharing depends on the transmission requirements and the RF conditions that exist at the CP. The BSM has overall responsibility to correct any interference problems that arise from co-located radio sets.

b. Antenna Separation and Network Time Sharing. Each command should decide on an individual basis when to use antenna separation and time sharing as a means of minimizing cosite interference. In a strategic CP that is fixed in one position, it may be possible to plan out antenna separation schemes and remotely locate the antennas that are most likely to interfere with each other. On the other hand, in a tactical CP that moves fairly often, it may not be feasible to remotely locate antennas due to the time required to set up all the equipment. In the latter case you may want to use just network time sharing, having the frequencies that are close enough to produce interference operate at different times of day. The preferred method of reducing cosite interference is to combine some form of antenna separation and network time sharing.

7. Summary.

In this lesson you have learned some of the basic information about two of the newest tactical radio systems the Army will introduce into field operations. You have also learned about the net structure and some of the basic problems you may encounter using this equipment.

LESSON 5

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

<u>Situation</u>: You are in charge of implementing the new CNR equipment for your unit.

1. Using your SINCGARS equipment, how many different FH nets can you communicate in without having to reload your radio set?

   A. Four.
   B. Five.
   C. Six.
   D. Eight.

2. You are sending a unit into the field to test a new ICOM radio set. What is the maximum number of frequency hopsets they can carry using only the radio and one MX-18290 device?

   A. 21.
   B. 19.
   C. 13.
   D. 6.

3. You must issue replacement radios for a special forces unit. Which of the following sets should you issue?

   A. AN/PRC-119.
   B. AN/PRC-104A.
   C. AN/VRC-92.
   D. AN/VRC-90.

4. Which of the following radio sets should you use to replace your AN/GRC-106 set?

   A. AN/GRC-193A.
   B. AN/GRC-213.
   C. AN/PRC-104.
   D. AN/PRC-119.

LESSON 5

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	C. Six.
	Both the ICOM and non-ICOM versions of the SINCGARS transmitter are capable of holding six frequency hopsets for use in the radio. This would allow you to talk in six different FH nets using a different hopset in each net. (page 5-4, para 4).
2.	B. 19.
	The SINCGARS radio can carry 6 hopsets loaded. The MX-18290 can carry 13 hopsets. If you carried both pieces of equipment, you could carry up to 19 different hopsets. An important factor to remember is that once you load a hopset from the MX-18290 into the SINCGARS radio, you would lose the ability to use the hopset that had been previously stored in that position. (page 5-9, para 4k).
3.	B. AN/PRC-104A.
	The AN/PRC-104 is replacing all of the older AM/DSB and AM/SSB manpacks. It is also replacing the AN/PRC-70 multimode radio set currently carried by special forces units. (page 5-9, para 5b).
4.	A. AN/GRC-193A.
	The AN/GRC-193A is the IHFR replacement set for the older AN/GRC-106 unit. (page 5-10, para 5d).