Reconnaissance and Surveillances Leaders Course

Communication read ahead.

INTRODUCTION:

The purpose of this document is to provide future students of RSLC with a basic understanding of High Frequency (HF) radio wave propagation, which will be the primary means of communication during training. The Communication portion of the course has recently undergone some revision and the material has advanced to meet the demands of the Near-Peer and Peer threat. To better prepare students and avoid overwhelming them during the 3-day communication block of instruction, the material below will provide the rudimentary knowledge that the course will build upon. This material is provided by section 1 and 2 of the Field Antenna Handbook, prepared by James A. Kuch. June 1984.

SECTION 1:

HF PROPAGATION FUNDAMENTALS.

Propagation is the process by which a radio signal travels through the atmosphere from one antenna to another. This section briefly describes the propagation factors that need to be known to better understand the antenna information presented in the following sections.

HIGH FREQUENCY COMMUNICATION (3 to 30 MHz)

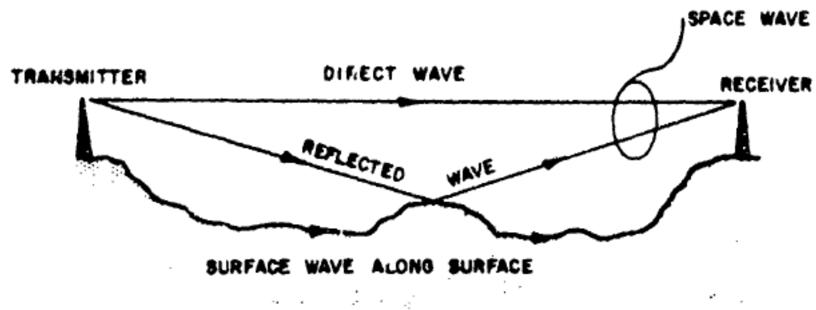
High Frequency communication is accomplished by either ground-wave or sky-wave propagation. With current low powered man pack radios, ground wave communication can be established out to 20 to 30 kilometers (km). High powered equipment (mounted) can extend that range to approximately 80 to 100 km. The Coverage from the sky-wave communication, on the other hand, can vary from several kilometers to thousands of kilometers.

GROUND WAVE PROPAGATION.

Ground-wave propagation involves the transmission of a radio signal along or near the surface of the earth. The ground-wave signal is divided into three parts: The Direct Wave, The Reflected Wave, and the Surface Wave.

The direct wave travels through the atmosphere from one antenna to the other in what is called the line-of-sight (LOS) mode. Maximum LOS distance is dependent on the height of an antenna above the ground. The higher the antenna the further the maximum LOS distance. Because the radio signal travels in the air, any obstructions, such as mountains, between the two antennas can block or reduce the signal and prevent communications. For an antenna 10 feet above the earth, a maximum LOS distance of about 6.5 to 8 km (4 to 5 miles) can be expected.

The reflected wave, like the direct wave, travels through the atmosphere but reflects off the earth as it propagates from the transmitting antenna to the receiving antenna. Together, the reflected wave and the direct wave are called the Space Wave.



Components of ground wave.

The third part of a ground wave is the surface wave. This part travels along the surface of the earth and is the usual means of ground wave communication. The surface wave is very dependent on the type of surface between the two antennas. With a good conductive surface, such as sea water, long ground-wave distance is possible. If there is a poor surface between the antennas, such as sand or frozen ground, the distance expected for the surface wave is small. The surface wave range can also be reduced by heavy vegetation or mountainous terrain.

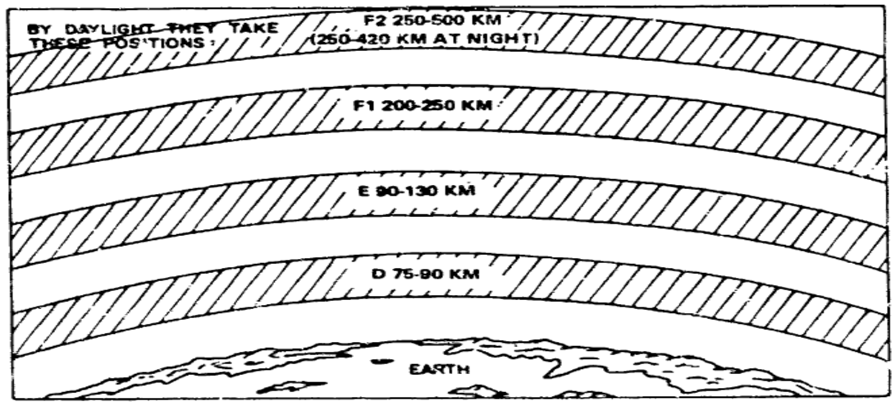
SKY-WAVE PROPAGATION:

Beyond the range covered by the ground-wave signal, HF communications are possible through sky-wave propagation. Sky wave propagation is possible because of the bending of the radio signal by a region of the atmosphere called the ionosphere.

The ionosphere is an electrically charged (ionized) region of the atmosphere that extends from about 60 km (37 miles) to 1000 km (620 miles) above the earth's surface. Ionization occurs due to energy from the sun interacting with the particles in the ionosphere which causes radio signals to return to earth. Although the ionosphere exists up to 1000 km, the area important for HF communication is below about 500 km. This area is divided up into four regions: D, E, F1 and F2.

The D region is closet to earth and only exists during daylight hours. It does not have the capability to bend a radio signal back to earth, but it does play an important role in HF communication. The D region absorbs energy from the radio signal as it passes through, thereby reducing the strength of the received signals.

The E region, the next higher region, is present 24 hours a day, although during night hours it is much weaker than during the day. The E region is the first region with enough charge to bend radio signals. At times, parts of the E region become highly charged and can either help or block out HF communications. These highly charged areas are called Sporadic E and occur most often during the summer.



Structure of the ionosph^re.

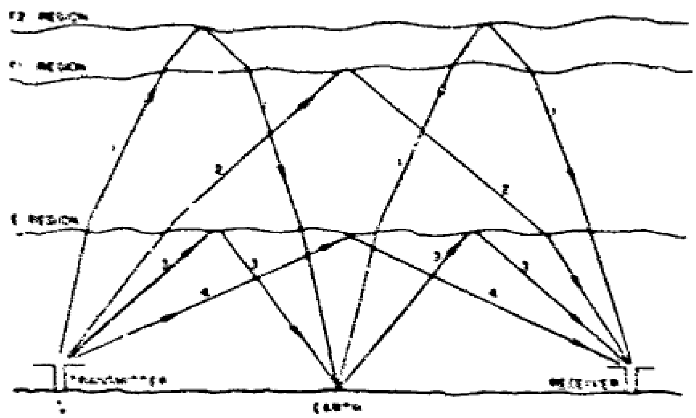
The most important regions for HF Communication are the F1 and F2 regions. The majority of HF sky wave communication depends on these regions, with the F2 region being used the most for long range daytime communication.

The bending of a radio signal by the ionosphere depends on the frequency of the radio signal. The degree of ionization in the ionosphere, and the angle at which the radio signal strikes the ionosphere. At a vertical (straight up) angle, the highest frequency that will bend back is called the critical frequency. Each region of the ionosphere (E, F1, and F2) will have a separate critical frequency. For a vertical angle, signals above the highest critical frequency will pass through all ionosphere regions and into outer space. Frequency below the critical frequency of a region will be bent back to the earth by that region; however, if the frequency is too low, the signal will be absorbed by the D region. In order to have HF sky-wave communication, a radio signal must be a high enough frequency to pass through the D region but not too high a frequency so that it does not pass through the reflecting region.

The angle at which a radio signal strikes the ionosphere plays an important part in sky-wave communications. As mentioned above, any frequency above the critical frequency will pass through the reflecting region. However, if a radio signal has a frequency above the critical frequency and is launched at an angle, instead of passing through the region it could still be bent back down to the earth's surface. This can be compared to skipping stones across a pond. If the stone was thrown straight down at the water, it would penetrate the surface. But if the angle at which the stone is thrown is lowered, an angle will be reached where, instead of going into the water, the stone will skip across the pond. For every circuit there is an optimum angle above the horizon called the take-off angle that will produce the strongest signal at the receiving station. This optimum take-off angle is used to select the appropriate antenna for a specific circuit.

Although a radio signal is actually bent by the ionosphere, the term reflection is commonly used to describe the turning back of a radio signal by the ionosphere.

Because many antennas radiate energy at several angles, more than one wave from the transmitter may reach the receiver. An example is shown in the illustration.



Multiple transmission paths.

Two important things are shown in this illustration. First, radio signals arrive at the receiver after being reflected from different ionosphere regions; and second, the path may consist of one or more reflections (hops) from the ionosphere. Any path that consists of two or more also involves a reflection off the ground somewhere between the antennas.

Path 1 is at an angle such that the wave is partially bent by both the E and F1 regions, but is reflected by the F2 region. It is reflected by the earth and again by the F region before reaching the receiver. This path is referred to as a two hop F (2F) path.

Path 2, at a smaller angle, is bent by the E region, then reflected by the F1 region. It is thus a one-hop F (1F) path.

Path 3 is at an angle small enough for the E region to reflect. It is reflected from the ground and again by the E region before reaching the Receiver and thus is called a two-hop E (2E) path.

Path 4 is reflected by the E region only once, hence it is a one-hop (1E) path.

Depending on the type of antennas used, signals can be received from any or all the different paths. Because each path covered a different distance, the signals arrive at the receiver at different times. When two or more signals arrive at the receiver from different paths, they can interfere with each other and can cause what is called multipath interference. This type of interference will produce echoes on circuits even though receiver's S-meter shows a strong receives signal.

Depending on the frequency, antennas and other factors, an area may exist between the longest ground-wave range and shortest sky wave range where no signal exists. This is called the skip zone.

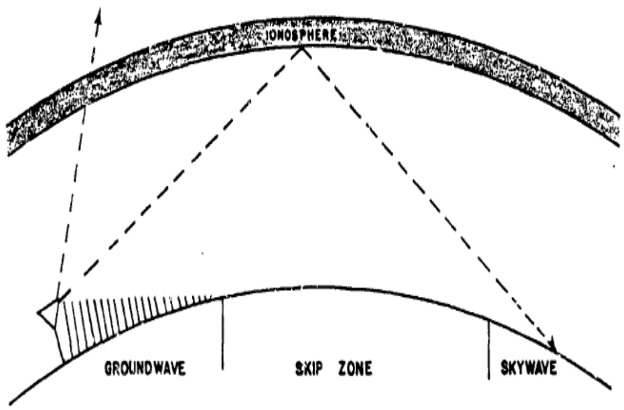


Illustration of an HF skip zone.

This Information will be expanded upon during the Radio Wave Propagation class, going into greater detail and introducing new concepts that are currently employed into the uses of HF Communication. However, establishing a basic level of understanding for the Theory will improve your ability to use HF while in the course and within your unit.

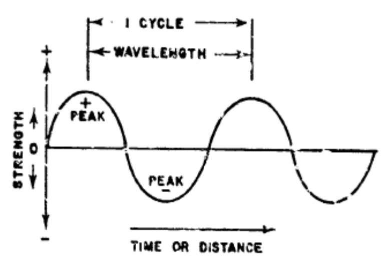
SECTION 2:

ANTENNA FUNDAMENTALS

To be able to properly select antennas for radio circuits, certain antenna concepts need to be understood. This section defines several basic terms and relationships which will help the field radio operator select the best antenna for their circuit.

WAVELENGTH AND FREQUENCY

In radio frequency communications, there is a definite relationship between antenna length and transmitter frequency wavelength. This relationship is important when constructing antennas for a specific frequency or frequency range. The wavelength of a radio signal is the distance traveled in the time it takes to complete one cycle.



Radio wave terms.

Wavelength is usually represented by the Greek Letter (λ) pronounced lambda. All radio signal travel at the speed of light. The wavelength of a frequency is equal to the speed of light divided by the frequency.

$$\text{Wavelength } (\lambda) = \frac{300{,}000{,}000 \text{ m/s}}{3{,}000{,}000 \text{ Hz}} = 100 \text{ meters or } 328 \text{ feet}$$

This means that in the time it takes to complete one cycle at 3 MHz, the signal travels 100 meters or 328 feet. This is the distance the signal will travel through air.

RESONANCE:

Antennas can be classified as either resonant or non-resonant depending on their design. In a resonant antenna, almost all the radio signal fed to the antenna is radiated. If the antenna is fed with a frequency other than the one for which it is resonant, much of the fed signal will be lost and will not be radiated. A resonant antenna will effectively radiate a radio signal for frequencies close to its design frequency, usually only 2% above or below the design frequency. In practice this means that if a resonant antenna is used for a radio circuit, a separate antenna must be built for each frequency to be used on the radio circuit. Non-resonant and resonant antennas are commonly used on tactical circuits.

If a resonant antenna is fed with a frequency outside of its bandwidth large losses of signal power occur. Signal energy from the antenna feedline is “turned back” from the antenna and causes standing waves on the feedline. A measure of these standing waves, called standing wave ratio (SWR), is used to determine if an antenna is resonant at a particular frequency. A SWR of 1 to 1 (1:1) is the ideal situation but in the real world 1.1 to 1 is about the best that can be achieved. When constructing wire antenna, the length of the antenna should be adjusted until lowest SWR is measured. A SWR of 2:1 is acceptable; however, the operator’s manual for the particular radio in use should be checked to determine the maximum WR that the radio can tolerate. In some radios, the power output of the transmitter will be automatically lowered if the SWR is too high.

Suppose the situation exists where the only antenna that can be erected is one with a large SWR that is too large for the transmitter to work. In this situation a coupler of “antenna tuner” must be used. A coupler is a device that is inserted between a transmitter and its antennas to make a transmitter think that it is connected to a lower SWR antenna. The advantage is that the transmitter can deliver its full power to the feed line even though the SWR is high. The amount of power radiated by the antenna depends on the location of the coupler. If the coupler is located at the transmitter, as it is with most tactical equipment, a large loss of power will still exist at the antenna. If the coupler is located at the antenna, a greater amount of power is radiated with less loss.

POLARIZATION:

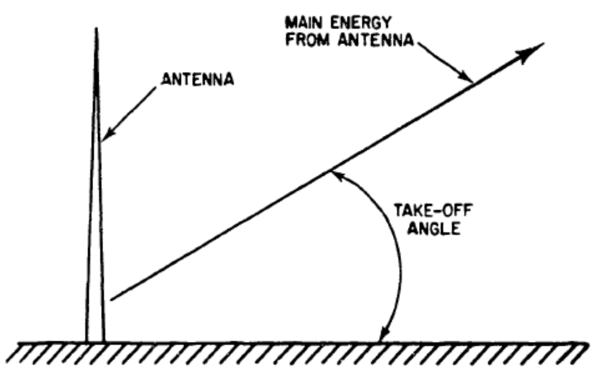
Polarization is the relationship of the radio energy radiated by an antenna to the earth. The most common polarizations are horizontal (parallel to the earth’s surface) and vertical (perpendicular to the earth’s surface), however, others such as circular and elliptical also exist. A vertical antenna normally radiates a vertically polarized signal, and a horizontal antenna normally radiates a horizontal signal. In HF ground-wave and VHF-LOS propagation, both the transmitter and receiver antennas should have the same polarization for the best communications. In cases of HF ground-wave propagation, vertical polarization should be used. Either vertical or horizontal polarization can be used in VHF-LOS. For HF sky-wave propagation the polarization of the transmitting and receiving antennas does not have to be the same because of the random changing of the signal as it is bent by the ionosphere. This random changing allows the use of either vertical or horizontal polarization at the transmitting or receiving antenna.

GAIN:

Gain is the term used to describe how well an antenna radiates power. It is necessary to know what the gain of an antenna is, before two can be compared. In some cases, an antenna is said to have gain compared to an isotropic antenna and the gain is expressed in dBi. An isotropic antenna is a theoretical mathematical antenna. Other times, gain is referenced to a horizontal half-wave dipole in free space whose gain over an isotropic antenna is 2.14 dBi. To determine the isotropic gain of an antenna whose gain is given as 2 dBi compared to a dipole. Its gain compared to an isotropic antenna is 4.14 dBi (2 dBi + 2.14 dBi).

TAKE-OFF ANGLE:

The take-off angle of an antenna is the angle above the horizon that an antenna radiates the largest amount of energy. For VHF communication, antennas are designed so that the energy is radiated parallel to the earth. (Do not confuse take-off angle and polarization). In HF communications, the take-off angle of an antenna can be determined whether a circuit is successful or not.



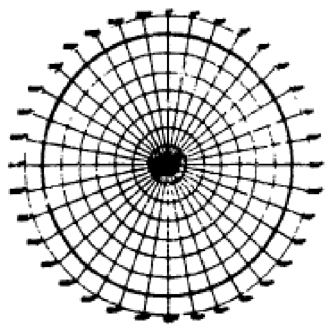
HF sky wave antennas are designed for specific take-off angles depending on the circuit distance. High take-off angles are used for short range communications and low take-off angles are used for long range communication.

PATTERNS:

Antennas are classified according to how radio energy is radiated; Omni-Directional, Bi-Directional, or Directional. An omnidirectional antenna radiated radio energy in a circular pattern, which means all directions on the ground (360 degrees) receive an equal amount of radiation. A Bidirectional antenna has two main lobes opposite each other with nulls between. A directional antenna has a single large lobe in one direction.

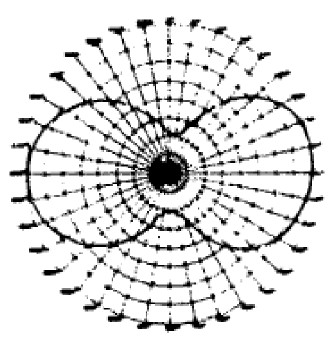
OMNI-DIRECTIOINAL PATTERN:

Radiates energy equally well in all compass directions, the omnidirectional antenna is used when it is necessary to communicate in several separated directions at once. Since the omnidirectional antenna radiates equally well in all directions, it also receives from all directions. For the multiple point circuit this is desirable, however, it also allows for interference from any direction to the received signal.



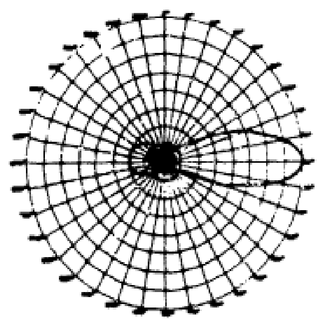
BI-DIRECTIONAL PATTERN:

Bidirectional antennas produce a stronger signal in two favored directions while reducing the signal in other directions. Tactical bidirectional antennas are usually field expedient, like sloping wires, random length wires, and half-wave dipoles. Bidirectional antennas are usually used for point-to-point circuits and in situations where the antenna nulls can be positioned to reduce or block out interfering signals when receiving. They can also be used when many antennas are closely located, by placing other antennas in the nulls of bidirectional antennas, interference and interaction between the antennas can be reduced. A drawback of bidirectional antennas is that they must be oriented correctly to radiate in the desired direction.



DIRECTIONAL PATTERN:

Directional antennas are much like a bidirectional antenna with one of its lobes cut off. In fact, several bidirectional antennas (long wire, sloping Vee) are made directional by the addition of a termination that absorbs the second main lobe. A termination is a resistor that matches the antenna and is capable of absorbing one-half the power output of the connected transmitter.



A directional antennas concentrates almost all the radio signal in one specific direction; therefore, it must be carefully oriented. Depending on the antenna design, the main lobe of a directional antenna can cover 60% or more, or be a narrow pencil beam. Directional antennas are usually used on long-range point-to-point circuits where the concentrated radio energy is needed for circuit reliability.

It is important to realize that the azimuthal pattern of an antenna does not determine the take-off angle of the antenna. Depending on design, an omnidirectional antenna may have a low take-off angle or a high take-off angle. Vertical patterns must be examined to determine the take-off angles of antennas in the HF range.

CONCLUSION:

This information will be discussed in greater detail in both the Radio Wave Propagation and Antenna Theory classes, while introducing advanced material and mathematical equations to allow students to craft antennas for their field exercises. Understanding these basic concepts will allow you to be better prepared for the communication aspect of the training and return to your unit as a qualified reconnaissance leader and subject matter expert on HF Communication.