

ANNEX 3

ELEMENTS IN AN HF RADIO SYSTEM

A3-1 Introduction

Now that you have an overview of how radio waves propagate, let's take a look at how they are generated. The primary components in an HF radio system fall into three groups: transmitters, receivers, and antennas. In many modern radio sets, the transmitter and receiver are contained in a single unit called a *transceiver*. In large, fixed systems, transmitting stations and receiving stations are customarily at separate locations, often controlled from a remote third site.

A3-2 Transmitter group

Although transmitters may vary widely in their configuration, they all consist of an *exciter* and *power amplifier*. A simplified diagram of a typical HF transmitter is shown in Figure A3-1.

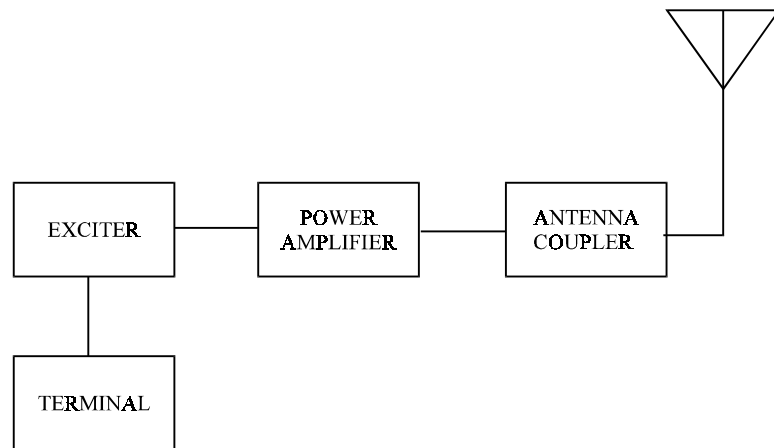


FIGURE A3-1
Simplified diagram of a typical HF transmitter

The exciter synthesizes a carrier, which has one of its properties — modified (modulated) by a lower frequency signal derived from a source of information such as a microphone. The resulting signal is converted to the frequency that is to be transmitted. The power amplifier boosts the output power of the signal to the desired wattage for transmission before sending it through a cable to the transmitting antenna.

The transmitter may also contain filters that are used to “clean up” its output. A *bandpass filter* removes noise, spurious signals, and harmonics generated in the exciter, or output frequency harmonics coming from the power amplifier. This process reduces interference with adjacent communications channels.

A3-3 Receiver group

All modern HF receiving systems include an rf input filter/amplifier, a series of frequency converters and intermediate frequency (IF) amplifiers, a demodulator, and a local oscillator frequency synthesizer (see Figure A3-2). To function, the receiver selects a desired signal, amplifies it to a suitable level, and recovers the information through the process of *demodulation*, in which the original modulating signal is recovered from a modulating carrier. With contemporary radio equipment, many of these functions are performed digitally.

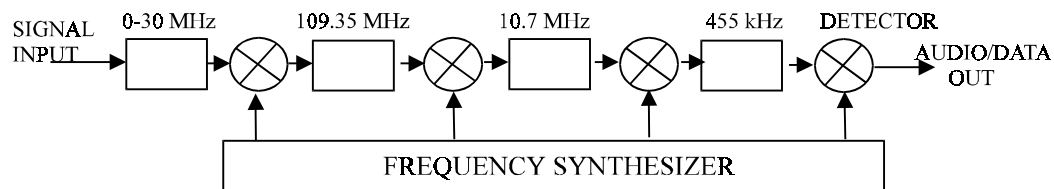


FIGURE A3-2
Simplified diagram of an HF receiver

In order to filter out noise and undesired signals, the rf input stages sometimes incorporate a tunable preselector (a bandpass filter). The filtered signal is then amplified and converted to another frequency for further processing.

But the filtering process does not end here. Typically, the received signal is filtered and amplified again at several different intermediate frequencies. The amplification provided in these stages is a variable that depends on the strength of the received signal.

In order to output voice or data, for example, the demodulator produces an audio-frequency (*baseband*) signal that interfaces with additional equipment. Also, because the strength of the input signal may not be constant, the demodulator stage produces a voltage proportional to the level of the rf input signal. To compensate for changes in the signal, the voltage is fed back to the rf and IF amplifiers for automatic gain control (AGC), to maintain a constant input to the demodulator.

A3-4 The antenna group

The antenna is one of the most critical elements in a radio circuit. Here, we will look at typical antenna types and their applications.

A3-4.1 Antenna characteristics and parameters

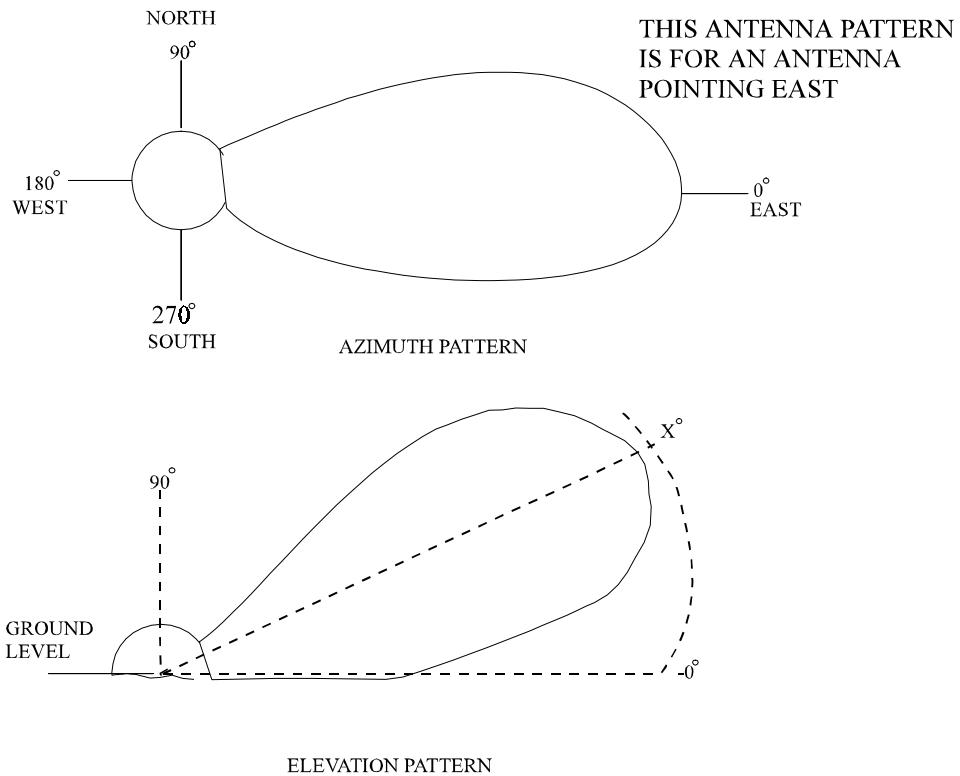
Some of the most commonly used terms to describe antennas are *impedance*, *gain*, *radiation pattern*, *take-off angle*, and *polarization*.

Every antenna has an input impedance, which represents the load to be applied to the transmitter. This impedance depends upon many factors, such as antenna design, frequency of operation, and location of the antenna with respect to surrounding objects.

The basic challenge in radio communications is finding ways to get the most power possible, where and when you need it, to generate and transmit signals. Most transmitters are designed to provide maximum output power and efficiency into a 50-ohm load. (*Ohm* is a unit of measurement of resistance. Its symbol is Ω .) Some antennas, such as log periodic antennas, can provide a 50-ohm load to the transmitter over a wide range of frequencies. These antennas can generally be connected directly to the transmitter. Other antennas, such as dipoles, whips, and long-wire antennas, have impedances that vary widely with frequency and the surrounding environment. In these cases, an *antenna tuner* or *coupler* is used. This device is inserted between the transmitter and antenna to modify the characteristics of the load presented to the transmitter so that maximum power may be transferred from the transmitter to the antenna.

The *gain* of an antenna is a measure of its directivity — its ability to focus the energy it radiates in a particular direction. The gain may be determined by comparing the level of signal received from it against the level that would be received from an isotropic antenna, which radiates equally in all directions. Gain can be expressed in dBi; the higher this number, the greater the directivity of the antenna. Transmitting antenna gain directly affects transmitter power requirements. If, for example, an omnidirectional antenna were replaced by a directional antenna with a gain of 10 dBi, a 100-watt transmitter would produce the same effective radiated power as a 1 – kW transmitter and omnidirectional antenna.

In addition to gain, radio users must understand the radiation pattern of an antenna for optimal signal transmission. Radiation pattern is determined by an antenna's design and is strongly influenced by its location with respect to the ground. It may also be affected by its proximity to nearby objects such as buildings and trees. In most antennas, the pattern is not uniform, but is characterized by plots in the vertical and horizontal planes (Figure A3-3), which show antenna gain as a function of elevation angle (vertical pattern) and azimuth angle (horizontal plot). The radiation patterns and frequency dependent, so plots at different frequencies are required to fully characterize the radiation pattern of an antenna.



Antenna radiation patterns

In determining communications range, it is important to factor in the *take-off angle*, which is the angle between the *main lobe* of an antenna pattern and the horizontal plane of the transmitting antenna. Low take-off angles are generally used for long-haul communications; high take-off angles are used for shorter-range communications.

The orientation of an antenna with respect to the ground determines its *polarization*. Most HF antennas are either vertically or horizontally polarized. A vertically polarized antenna produces low take-off angles and is therefore suitable for ground waves and for long-haul sky wave links. The main drawback of vertical antennas is their sensitivity to ground conductivity and locally generated noise. It is necessary to use a grounding screen to get the best results.

A horizontally polarized antenna radiates the higher take-off angles and is suitable for shorter range communications, out to about 400 miles. By adjusting the height of the antenna above ground, it is possible to increase gain at lower take-off angles for longer-range sky wave performance. Horizontally polarized antennas are largely independent of ground conductivity, and are less affected by local noise than vertical antennas.

For ground wave propagation, the transmitting and receiving antennas should have the same polarization for best results. For sky wave propagation, the polarization of the antennas need not be the same, since the polarization of the signal will change during ionospheric refraction.

A3-4.2 Types of antennas

There is a countless variety of antennas used in HF communication. We'll focus here on just some of the more common types.

The *vertical whip* antenna is usually adequate for ground wave circuits, since it is *omnidirectional*, has low take-off angles, and is vertically polarized. A typical vertical whip radiation pattern is shown in Figure A3-4. A reflector, consisting of a second vertical whip, can add directivity to the radiation pattern of a whip.

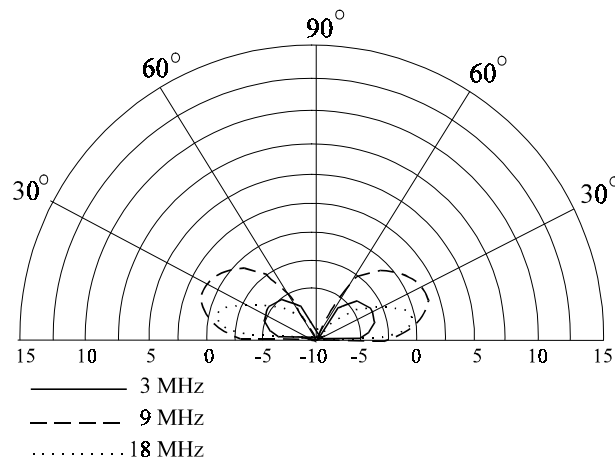


FIGURE A3-4
A typical vertical whip radiation pattern

One of the most versatile types of HF antenna is the half-wave *dipole*, which is basically a length of wire equal to one-half the transmitting wavelength. The dipole can be oriented to provide either horizontal or vertical (center-fed) polarization. Figure A3-5 shows a center-fed horizontal dipole antenna. The radiation pattern can change dramatically as a function of its distance above the ground Figure A3-6 shows the vertical radiation pattern of a horizontal dipole for several values of its height (in terms of transmitting wavelength) above the ground.

A vertical dipole can often be used effectively on ships or vehicles. An inverted vee (sometimes called a “drooping dipole”) produces a combination of horizontal and vertical radiation with omnidirectional coverage. See Figure A3-7.

Directional antennas range from simple single-wire configuration like the inverted vee to elaborate multi-wire arrays, including horizontal and vertical log periodic systems; see Figure A3-8. Directional antennas are often used in point-to-point links. In systems requiring point-to-point communications to widely dispersed stations, rotatable directional antennas may be used.

Skywave communications between relatively closely spaced stations may require antennas specially designed for this purpose. These near vertical incidences sky wave (NVIS) antennas have a very high take-off angle, radiating rf energy nearly straight up. The radio waves refract downward to the earth in a circular pattern. NVIS antennas provide omnidirectional coverage out to about 600 km.

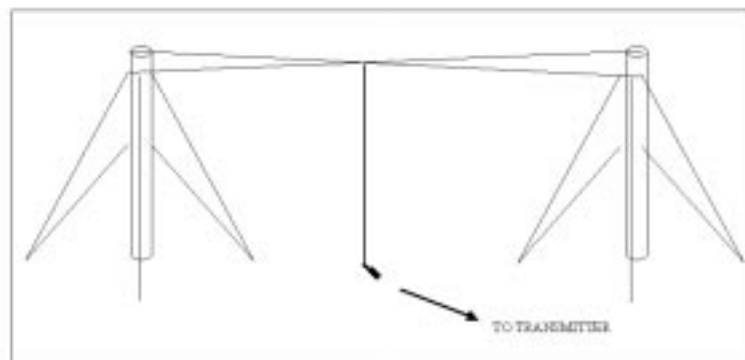


Figure 3-5. Center-Fed Horizontal Dipole Antenna

FIGURE A3-7
Center-fed horizontal dipole antenna

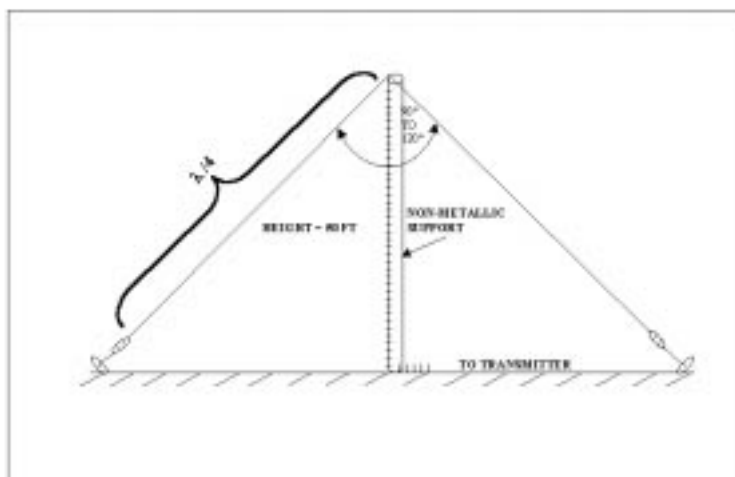


Figure 3-7. Inverted Vee Antenna

FIGURE A3-7
Inverted Vee antenna

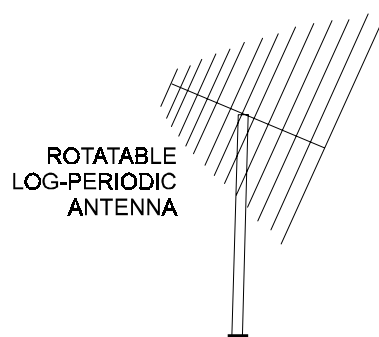


FIGURE A3-8
Horizontal log-periodic antenna

A3-5 Summary

- A radio system consists of a transmitter, receiver, and antenna group.
- The transmitter group consists of an exciter and power amplifier. The exciter includes a modulator, carrier generator, and frequency translator.
- The receiver group consists of an RF input filter/amplifier, frequency converters/IF amplifiers, demodulator, and local oscillator.
- Antenna selection is critical to successful HF communications. Antenna types include vertical whip, dipole, and directional.
- An antenna coupler matches the impedance of the antenna to that of the transmitter, transferring maximum power to the antenna.
- The gain of an antenna is a measure of its directivity — its ability to focus the energy it radiates in a particular direction.
- Antenna radiation patterns are characterized by nulls (areas of weak radiation) and lobes (areas of strong radiation).
- Low antenna take-off angles are generally used for long-haul communications; high take-off angles are used for shorter-range communications.