

Radio

I INTRODUCTION

Radio, system of communication employing electromagnetic waves propagated through space. Because of their varying characteristics, radio waves of different lengths are employed for different purposes and are usually identified by their frequency. The shortest waves have the highest frequency, or number of cycles per second; the longest waves have the lowest frequency, or fewest cycles per second. In honor of the German radio pioneer Heinrich Hertz, his name has been given to the cycle per second (hertz, Hz); 1 kilohertz (kHz) is 1000 cycles per sec, 1 megahertz (MHz) is 1 million cycles per sec, and 1 gigahertz (GHz) is 1 billion cycles per sec. Radio waves range from a few kilohertz to several gigahertz. Waves of visible light are much shorter. In a vacuum, all electromagnetic waves travel at a uniform speed of about 300,000 km (about 186,000 mi) per second. For electromagnetic waves other than radio, see Electromagnetic Radiation.

FREQUENCY	DESIGNATION	ABBR.	WAVELENGTH
3-30 kHz	Very low frequency	VLF	100,000-10,000 m
30-300 kHz	Low frequency	LF	10,000-1000 m
300-3000 kHz	Medium frequency	MF	1000-100 m
3-30 MHz	High frequency (Short wave)	HF	100-10 m
30-300 MHz	Very high frequency	VHF	10-1 m
300-3000 MHz	Ultrahigh frequency	UHF	1 m-10 cm
3-30 GHz	Superhigh frequency	SHF	10-1 cm
30-300 GHz	Extremely high frequency	EHF	1 cm-1mm

*kHz = kilohertz, or 1000 Hz; MHz = megahertz, or 1000 kHz;
GHz = gigahertz, or 1000 MHz.

© Microsoft Corporation. All Rights Reserved.

Radio Frequency and Wavelength Ranges

Radio waves have a wide range of applications, including communication during emergency rescues (transistor and shortwave radios), international broadcasts (satellites), and cooking food (microwaves). A radio wave is described by its wavelength, the distance from one crest to the next, or its frequency, the number of crests that move past a point in one second. Wavelengths of radio waves range from 100,000 m (270,000 ft) to 1 mm (.004 in). Frequencies range from 3 kilohertz to 300 gigahertz.

Radio waves are used not only in radio broadcasting but in wireless telegraphy, telephone transmission, television, radar, navigational systems, and space communication. In the atmosphere, the physical characteristics of the air cause slight variations in velocity, which are sources of error in such radio-communications systems as radar. Also, storms or electrical disturbances produce anomalous phenomena in the propagation of radio waves. See Wave Motion.

Because electromagnetic waves in a uniform atmosphere travel in straight lines and because the earth's surface is approximately spherical, long-distance radio communication is made possible by the reflection of radio waves from the ionosphere. Radio waves shorter than about 10 m (about 33 ft) in wavelength—designated as very high, ultrahigh, and superhigh frequencies (VHF, UHF, and SHF)—are usually not reflected by the ionosphere; thus, in normal practice, such very short waves are received only within line-of-sight distances. Wavelengths shorter than a few centimeters are absorbed by water droplets or clouds; those shorter than 1.5 cm (0.6 in) may be absorbed selectively by the water vapor present in a clear atmosphere.

A typical radio communication system has two main components, a transmitter and a receiver. The transmitter generates electrical oscillations at a radio frequency called the carrier frequency. Either the amplitude or the frequency itself may be modulated to vary the carrier wave. An amplitude-modulated signal consists of the carrier frequency plus two sidebands resulting from the modulation. Frequency modulation produces more than one pair of sidebands for each modulation frequency. These produce the complex variations that emerge as speech or other sound in radio broadcasting, and in the alterations of light and darkness in television broadcasting.

II TRANSMITTER

Essential components of a radio transmitter include an oscillation generator for converting commercial electric power into oscillations of a predetermined radio frequency; amplifiers for increasing the intensity of these oscillations while retaining the desired frequency; and a transducer for converting the information to be transmitted into a varying electrical voltage proportional to each successive instantaneous intensity. For sound transmission a microphone is the transducer; for picture transmission the transducer is a photoelectric device. See Facsimile Transmission; Television.

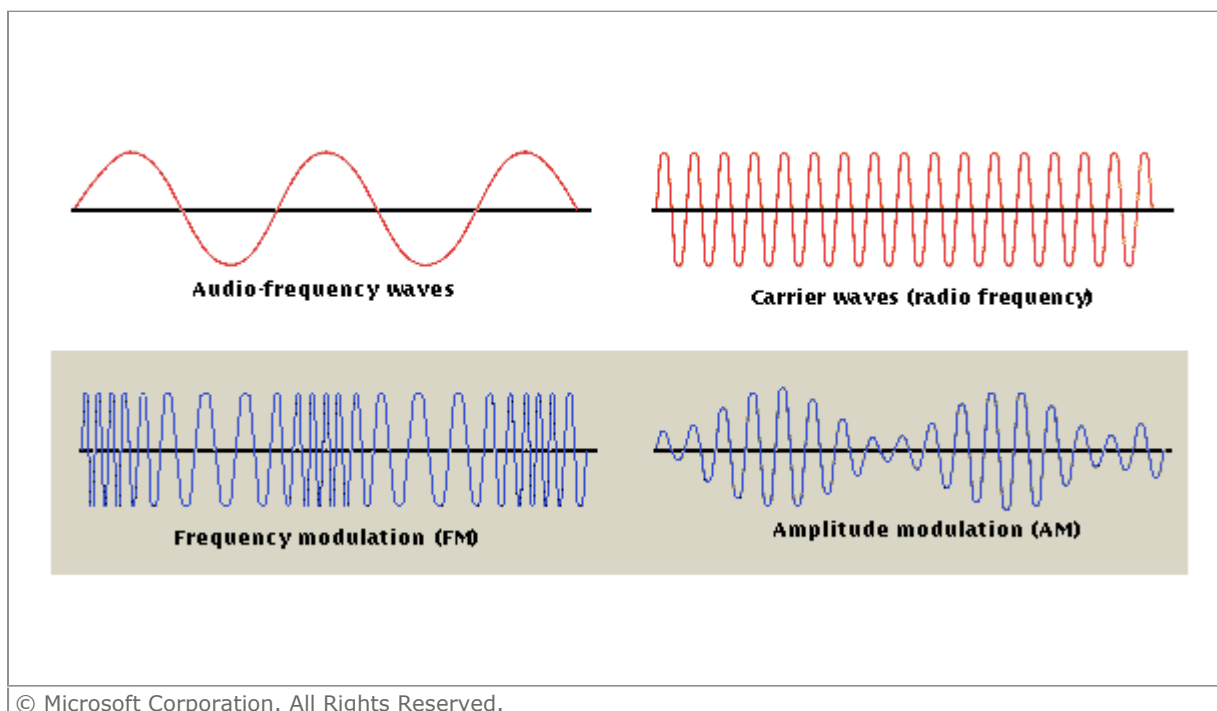
Other important components of the radio transmitter are the modulator, which uses these proportionate voltages to control the variations in the oscillation intensity or the instantaneous frequency of the carrier, and the antenna, which radiates a similarly modulated carrier wave. Every antenna has some directional properties, that is, it radiates more energy in some directions than in others, but the antenna can be modified so that the radiation pattern varies from a comparatively narrow beam to a comparatively even distribution in all directions; the latter type of radiation is employed in broadcasting.

The particular method of designing and arranging the various components depends on the effects desired. The principal criteria of a radio in a commercial or military airplane, for example, are light weight and intelligibility; cost is a secondary consideration, and fidelity of reproduction is entirely unimportant. In a commercial broadcasting station, on the other hand, size and weight are of comparatively little importance; cost is of some importance; and fidelity is of the utmost importance, particularly for FM stations (see Frequency Modulation); rigid control of frequency is an absolute necessity. In the U.S., for example, a typical commercial station broadcasting on 1000 kHz is assigned a bandwidth of 10 kHz by the Federal Communications Commission, but this width may be used only for modulation; the carrier frequency itself must be kept precisely at 1000 kHz, for a deviation of one-hundredth of 1 percent would cause serious interference with even distant stations on the same frequency.

A Oscillators

In a typical commercial broadcasting station the carrier frequency is generated by a carefully controlled quartz-crystal oscillator. The fundamental method of controlling frequencies in most radio work is by means of tank circuits, or tuned circuits, that have specific values of inductance and capacitance, and that therefore favor the production of alternating currents of a particular frequency and discourage the flow of currents of other frequencies (see Electric Circuit; Resonance). In cases where the frequency must be extremely stable, however, a quartz crystal with a definite natural frequency of electrical oscillation is used to stabilize the oscillations (see Crystal). The oscillations are actually generated at low power by an electron tube and are amplified in a series of power amplifiers that act as buffers to prevent interaction of the oscillator with the other components of the transmitter, because such interaction would alter the frequency. The crystal is shaped accurately to the dimensions required to give the desired frequency, which may then be modified slightly by adding a condenser to the circuit to give the exact frequency desired. In a well-designed circuit, such an oscillator does not vary by more than one-hundredth of 1 percent in frequency. Mounting the crystal in a vacuum at constant temperature and stabilizing the supply voltages may produce a frequency stability approaching one-millionth of 1 percent. Crystal oscillators are most useful in the ranges termed very low frequency, low frequency, and medium frequency (VLF, LF, and MF). When frequencies higher than about 10 MHz must be generated, the master oscillator is designed to generate a medium frequency, which is then doubled as often as necessary in special electronic circuits. In cases where rigid frequency control is not required, tuned circuits may be used with conventional electron tubes to generate oscillations up to about 1000 MHz, and reflex klystrons are used to generate the higher frequencies up to 30,000 MHz. Magnetrons are substituted for klystrons when even larger amounts of power must be generated. See Electronics.

B Modulation



Radio Modulation

Audio-frequency waves must be combined with carrier waves in order to be transmitted over the radio. Either the frequency (rate of oscillation) or the amplitude (height) of the waves may be modified in a process called modulation. This accounts for the option on the radio dial for AM or FM stations; the signals are very different, so both kinds may not be received simultaneously.

Modulation of the carrier wave so that it may carry impulses is performed either at low level or high level. In the former case the audio-frequency signal from the microphone, with little or no amplification, is used to modulate the output of the oscillator, and the modulated carrier frequency is then amplified before it is passed to the antenna; in the latter case the radio-frequency oscillations and the audio-frequency signal are independently amplified, and modulation takes place immediately before the oscillations are passed to the antenna. The signal may be impressed on the carrier either by frequency modulation (FM) or amplitude modulation (AM).

The simplest form of modulation is keying, interrupting the carrier wave at intervals with a key or switch used to form the dots and dashes in continuous-wave radiotelegraphy.

The carrier wave may also be modulated by varying the amplitude, or strength, of the wave in accordance with the variations of frequency and intensity of a sound signal, such as a musical note. This form of modulation, AM, is used in many radiotelephony services including standard radiobroadcasts. AM is also employed for carrier current telephony, in which the modulated carrier is transmitted by wire, and in the transmission of still pictures by wire or radio. See Broadcasting, Radio and Television.

In FM the frequency of the carrier wave is varied within a fixed range at a rate corresponding to the frequency of a sound signal. This form of modulation, perfected in the 1930s, has the advantage of yielding signals relatively free from noise and interference arising from such sources as automobile-ignition systems and thunderstorms, which seriously affect AM signals. As a result, FM broadcasting is done on high-frequency bands (88 to 108 MHz), which are suitable for broad signals but have a limited reception range.

Carrier waves can also be modulated by varying the phase of the carrier in accordance with the amplitude of the signal. Phase modulation, however, has generally been limited to special equipment.

The development of the technique of transmitting continuous waves in short bursts or pulses of extremely high power (see Radar) introduced the possibility of yet another form of modulation, pulse-time modulation, in which the spacing of the pulses is varied in accordance with the signal.

The information carried by a modulated wave is restored to its original form by a reverse process called demodulation or detection. Radio waves broadcast at low and medium frequencies are amplitude modulated. At higher frequencies both AM and FM are in use; in present-day commercial television, for example, the sound may be carried by FM, while the picture is carried by AM. In the superhigh-frequency range (above the ultrahigh-frequency range), in which broader bandwidths are available, the picture also may be carried by FM. Experiments have also been conducted in which sound as well as pictures are transmitted digitally at these high frequencies. Such transmissions may

some day replace current analog broadcasting techniques.

C Antennas

The antenna of a transmitter need not be close to the transmitter itself. Commercial broadcasting at medium frequencies generally requires a very large antenna, which is best located at an isolated point far from cities, whereas the broadcasting studio is usually in the heart of the city. FM, television, and other very-high-frequency broadcasts must have very high antennas if appreciably long range is to be achieved, and it may not be convenient to locate such a high antenna near the broadcasting studio. In all such cases, the signals may be transmitted by wires. Ordinary telephone lines are satisfactory for most commercial radio broadcasts; if high fidelity or very high frequencies are required, coaxial cables are used (see Cable, Electric).

III RECEIVERS



Dorling Kindersley

Components in a Transistor Radio

This circuit board illustrates the complexity of the modern radio receiver. The six black rectangular components are the Integrated Circuits (ICs) which contain hundreds of transistors. The remaining components are resistors (small, flat, round objects), capacitors (tall, black cylinders), and inductors (coils of wire). Newer circuits have fewer parts, often only one IC and a few resistors. These improvements are due to the development of more advanced ICs and the shift from LC (inductor-capacitor) tuning to PLL (phase-locked loop) tuning. The latter, in addition to providing a digital display of the frequency, requires no discrete components.

The essential components of a radio receiver are an antenna for receiving the electromagnetic waves and converting them into electrical oscillations; amplifiers for increasing the intensity of these oscillations; detection equipment for demodulating; a speaker for converting the impulses into sound

waves audible by the human ear (and in television a picture tube for converting the signal into visible light waves); and, in most radio receivers, oscillators to generate radio-frequency waves that can be “mixed” with the incoming waves.

The incoming signal from the antenna, consisting of a radio-frequency carrier oscillation modulated by an audio-frequency or video-frequency signal containing the impulses, is generally very weak. The sensitivity of some modern radio receivers is so great that if the antenna signal can produce an alternating current involving the motion of only a few hundred electrons, this signal can be detected and amplified to produce an intelligible sound from the speaker. Most radio receivers can operate quite well with an input from the antenna of a few millionths of a volt. The dominant consideration in receiver design, however, is that very weak desired signals cannot be made useful by amplifying indiscriminately both the desired signal and undesired radio noise (see Noise below). Thus, the main task of the designer is to assure preferential reception of the desired signal.

Most modern radio receivers are of the superheterodyne type in which an oscillator generates a radio-frequency wave that is mixed with the incoming wave, thereby producing a radio-frequency wave of lower frequency; the latter is called intermediate frequency. To tune the receiver to different frequencies, the frequency of the oscillations is changed, but the intermediate frequency always remains the same (at 455 kHz for most AM receivers and at 10.7 MHz for most FM receivers). The oscillator is tuned by altering the capacity of the capacitor in its tank circuit; the antenna circuit is similarly tuned by a capacitor in its circuit. One or more stages of intermediate-frequency amplification are included in all receivers; in addition, one or more stages of radio-frequency amplification may be included. Auxiliary circuits such as automatic volume control (which operates by rectifying part of the output of one amplification circuit and feeding it back to the control element of the same circuit or of an earlier one) are usually included in the intermediate-frequency stage. The detector, often called the second detector, the mixer being called the first detector, is usually simply a diode acting as a rectifier, and produces an audio-frequency signal. FM waves are demodulated or detected by circuits known as discriminators or radio-detectors that translate the varying frequencies into varying signal amplitudes.

A Amplifiers

Radio-frequency and intermediate-frequency amplifiers are voltage amplifiers, increasing the voltage of the signal. Radio receivers may also have one or more stages of audio-frequency voltage amplification. In addition, the last stage before the speaker must be a stage of power amplification. A high-fidelity receiver contains both the tuner and amplifier circuits of a radio. Alternatively, a high-fidelity radio may consist of a separate audio amplifier and a separate radio tuner.

The principal characteristics of a good radio receiver are high sensitivity, selectivity, fidelity, and low noise. Sensitivity is primarily achieved by having numerous stages of amplification and high amplification factors, but high amplification is useless unless reasonable fidelity and low noise can be obtained. The most sensitive receivers have one stage of tuned radio-frequency amplification. Selectivity is the ability of the receiver to obtain signals from one station and reject signals from another station operating on a nearby frequency. Excessive selectivity is not desirable, because a bandwidth of many kilohertz is necessary in order to receive the high-frequency components of the

audio-frequency signals. A good broadcast-band receiver tuned to one station has a zero response to a station 20 kHz away. The selectivity depends principally on the circuits in the intermediate-frequency stage.

B High-Fidelity Systems

Fidelity is the equality of response of the receiver to various audio-frequency signals modulated on the carrier. Extremely high fidelity, which means a flat frequency response (equal amplification of all audio frequencies) over the entire audible range from about 20 Hz to 20 kHz, is extremely difficult to obtain. A high-fidelity system is no stronger than its weakest link, and the links include not only all the circuits in the receiver, but also the speaker, the acoustic properties (see Acoustics) of the room in which the speaker is located, and the transmitter to which the receiver is tuned. Most AM radio stations do not reproduce faithfully sounds below 100 Hz or above 5 kHz; FM stations generally have a frequency range of 50 Hz to 15 kHz, the upper limit being set by Federal Communications Commission regulations.

C Distortion

A form of amplitude distortion is often introduced to a radio transmission by increasing the relative intensity of the higher audio frequencies. At the receiver, a corresponding amount of high-frequency attenuation is applied. The net effect of these two forms of distortion is a net reduction in high-frequency background noise or static at the receiver. Many receivers are also equipped with user-adjustable tone controls so that the amplification of high and low frequencies may be adjusted to suit the listener's taste. Another source of distortion is cross modulation, the transfer of signals from one circuit to another through improper shielding. Harmonic distortion caused by nonlinear transfer of signals through amplification stages can often be significantly reduced by the use of negative-feedback circuitry that tends to cancel most of the distortion generated in such amplification stages.

D Noise

Noise is a serious problem in all radio receivers. Several different types of noise, each characterized by a particular type of sound and by a particular cause, have been given names. Among these are hum, a steady low-frequency note (about two octaves below middle C) commonly produced by the frequency of the alternating-current power supply (usually 60 Hz) becoming impressed onto the signal because of improper filtering or shielding; hiss, a steady high-frequency note; and whistle, a pure high-frequency note produced by unintentional audio-frequency oscillation, or by beats. These noises can be eliminated by proper design and construction. Certain types of noise, however, cannot be eliminated. The most important of these in ordinary AM low-frequency and medium-frequency sets is static, caused by electrical disturbances in the atmosphere. Static may be due to the operation of nearby electrical equipment (such as automobile and airplane engines), but is most often caused by lightning. Radio waves produced by such atmospheric disturbances can travel thousands of kilometers with comparatively little attenuation, and inasmuch as a thunderstorm is almost always occurring somewhere within a few thousand kilometers of any radio receiver, static is almost always present.

Static affects FM receivers to a much smaller degree, because the amplitude of the intermediate waves is limited in special circuits before discrimination, and this limiting removes effects of static, which influences the signal only by superimposing a random amplitude modulation on the wave.

Another basic source of noise is thermal agitation of electrons. In any conductor at a temperature higher than absolute zero, electrons are moving about in a random manner. Because any motion of electrons constitutes an electric current, this thermal motion gives rise to noise when amplification is carried too far. Such noise can be avoided if the signal received from the antenna is considerably stronger than the current caused by thermal agitation; in any case, such noise can be minimized by suitable design. A theoretically perfect receiver at ordinary temperatures can receive speech intelligibly when the signal power in the antenna is only 4×10^{-18} W (40 attowatts); in ordinary radio receivers, however, considerably greater signal strength is required.

E Power Supply

A radio has no moving parts except the speaker cone, which vibrates within a range of a few thousandths of a centimeter, and so the only power required to operate the radio is electrical power to force electrons through the various circuits. When radios first came into general use in the 1920s, most were operated by batteries. Although batteries are used widely in portable sets today, a power supply from a power line has advantages, because it permits the designer more freedom in selecting circuit components. If the alternating-current (AC) power supply is 120 V, this current can be led directly to the primary coil of a transformer, and power with the desired voltage can be drawn off as desired from the secondary coils. This secondary current must be rectified and filtered before it can be used because transistors require direct current (DC) for proper operation. Electron tubes require DC for plate current; filaments may be heated either by DC or AC, but in the latter case hum may be created. Transistorized radios do not require as high an operating DC voltage as did tube radios of the past, but power supplies are still needed to convert the AC voltage distributed by utility companies to DC, and to step up or step down the voltage to the required value, using transformers. Airplane and automobile radio sets that operate on 12 to 24 volts DC often contain circuits that convert the available DC voltage to AC, after which the voltage is stepped up or down to the required voltage level and again converted to DC by a rectifier (see Rectification). Airplane and automobile radio sets that operate on 6 to 24 volts DC always contain some such device for raising the voltage. The advent of transistors, integrated circuits, and other solid-state electronic devices, which are much smaller in size and require very little power, has today greatly reduced the use of vacuum tubes in radio, television, and other types of communications equipment and devices (see Integrated Circuit; Transistor; Vacuum Tubes).

IV HISTORY

Although many discoveries in the field of electricity were necessary to the development of radio, the history of radio really began in 1873, with the publication by the British physicist James Clerk Maxwell of his theory of electromagnetic waves.

A Late 19th Century



Culver Pictures

Guglielmo Marconi

Inventor of the radio-signaling system, Italian electrical engineer Guglielmo Marconi was the first to send wireless signals across the ocean. Prior to his invention, there was no way to communicate over long distances without telegraph wires to carry electric signals. His equipment played a vital role in rescuing survivors of sea disasters such as the sinking of the *Titanic*. He won the Nobel Prize in physics in 1909 for his work in wireless telegraphy.

Maxwell's theory applied primarily to light waves. About 15 years later the German physicist Heinrich Hertz actually generated such waves electrically. He supplied an electric charge to a capacitor, and then short-circuited the capacitor through a spark gap. In the resulting electric discharge the current surged past the neutral point, building up an opposite charge on the capacitor, and then continued to surge back and forth, creating an oscillating electric discharge in the form of a spark. Some of the energy of this oscillation was radiated from the spark gap in the form of electromagnetic waves. Hertz measured several of the properties of these so-called Hertzian waves, including their wavelength and velocity.

The concept of using electromagnetic waves for the transmission of messages from one point to another was not new; the heliograph, for example, successfully transmitted messages via a beam of light rays, which could be modulated by means of a shutter to carry signals in the form of the dots and dashes of the Morse code (see Morse Code, International). Radio has many advantages over light for this purpose, but these advantages were not immediately apparent. Radio waves, for example, can travel enormous distances; but microwaves (which Hertz used) cannot. Radio waves can be enormously attenuated and still be received, amplified, and detected; but good amplifiers were not available until the development of electron tubes. Although considerable progress was made in radiotelegraphy (for example, transatlantic communication was established in 1901), radiotelephony might never have become practical without the development of electronics. Historically, developments in radio and in electronics have been interdependent.

To detect the presence of electromagnetic radiation, Hertz used a loop of wire somewhat similar to a wire antenna. At about the same time the Anglo-American inventor David Edward Hughes discovered that a loose contact between a steel point and a carbon block would not conduct current, but that if electromagnetic waves were passed through the junction point, it conducted well. In 1879 Hughes demonstrated the reception of radio signals from a spark transmitter located some hundreds of meters

away. In these experiments he conducted a current from a voltaic cell through a glass tube filled loosely with zinc and silver filings, which cohered when radio waves impinged on it. The principle was used by the British physicist Sir Oliver Joseph Lodge, in a device called the coherer, to detect the presence of radio waves. The coherer, after becoming conductive, could again be made resistant by tapping it, causing the metal particles to separate. Although far more sensitive than a wire loop in the absence of an amplifier, the coherer gave only a single response to sufficiently strong radio waves of varying intensities, and could thus be used for telegraphy but not for telephony.

The Italian electrical engineer and inventor Guglielmo Marconi is generally credited with being the inventor of radio. Starting in 1895 he developed an improved coherer and connected it to a rudimentary form of antenna, with its lower end grounded. He also developed improved spark oscillators, connected to crude antennas. The transmitter was modulated with an ordinary telegraph key. The coherer at the receiver actuated a telegraphic instrument through a relay, which functioned as a crude amplifier. In 1896 he transmitted signals for a distance exceeding 1.6 km (more than 1 mi), and applied for his first British patent. In 1897 he transmitted signals from shore to a ship at sea 29 km (18 mi) away. In 1899 he established commercial communication between England and France that operated in all types of weather; early in 1901 he sent signals 322 km (200 mi), and later in the same year succeeded in sending a single letter across the Atlantic Ocean. In 1902 messages were regularly sent across the Atlantic, and by 1905 many ships were using radio for communications with shore stations. For his pioneer work in the field of wireless telegraphy, Marconi shared the 1909 Nobel Prize in physics with the German physicist Karl Ferdinand Braun.

During this time various technical improvements were being made. Tank circuits, containing inductance and capacitance, were used for tuning. Antennas were improved, and their directional properties were discovered and used. Transformers were used to increase the voltage sent to the antenna. Other detectors were developed to supplement the coherer with its clumsy tapper; among these were a magnetic detector that depended on the ability of radio waves to demagnetize steel wires; a bolometer that measured the rise in temperature of a fine wire when radio waves are passed through the wire; and the so-called Fleming valve, the forerunner of the thermionic tube, or vacuum tube.

B 20th Century

The modern vacuum tube traces its development to the discovery made by the American inventor Thomas Alva Edison that a current will flow between the hot filament of an incandescent lamp and another electrode placed in the same lamp, and that this current will flow in only one direction. The Fleming valve was not essentially different from Edison's tube. It was developed by the British physicist and electrical engineer Sir John Ambrose Fleming in 1904 and was the first of the diodes, or two-element tubes, used in radios. This tube was then used as a detector, rectifier, and limiter. A revolutionary advance, which made possible the science of electronics, occurred in 1906 when the American inventor Lee De Forest mounted a third element, the grid, between the filament and cathode of a vacuum tube. De Forest's tube, which he called an audion but which is now called a triode (three-element tube), was first used only as a detector, but its potentialities as an amplifier and oscillator were soon developed, and by 1915 wireless telephony had developed to such a point that communication was established between Virginia and Hawaii and between Virginia and Paris.

The rectifying properties of crystals were discovered in 1912 by the American electrical engineer and inventor Greenleaf Whittier Pickard, who pointed out that crystals can be used as detectors. This discovery gave rise to the so-called crystal sets popular about 1920. In 1912 the American electrical engineer Edwin Howard Armstrong discovered the regenerative circuit, by which part of the output of a tube is fed back to the same tube. This and certain other discoveries by Armstrong form the basis of many circuits in modern radio sets.

In 1902 the American electrical engineer Arthur Edwin Kennelly and the British physicist and electrician Oliver Heaviside, independently and almost simultaneously, announced the probable existence of a layer of ionized gas high in the atmosphere that affects the propagation of radio waves. This layer, formerly called the Heaviside or Kennelly-Heaviside layer, is one of several layers in the ionosphere. Although the ionosphere is transparent to the shortest radio wavelengths, it bends or reflects the longer waves. Because of this reflection, radio waves can be propagated far beyond the horizon. Propagation of radio waves in the ionosphere is strongly affected by time of day, season, and sunspot activity. Slight variations in the nature and altitude of the ionosphere, which can occur rapidly, can affect the quality of long-distance reception. The ionosphere is also responsible for skip, the reception at a considerable distance of a signal that cannot be received at a closer point. This phenomenon occurs when the ground ray has been absorbed by the intervening ground and the ionospherically propagated ray is not reflected at an angle sufficiently steep to be received at short distances from the antenna.

C Short-wave Radio



Early Radio

Radio receivers of the 1930s and 1940s were big and heavy in comparison to more compact, modern devices. This was because the less streamlined individual components were wired individually and ran off large, powerful batteries. This view looks through the back of an early radio, showing

components such as valves, coils, and the tuning condenser.

Although parts of the various radio bands—short-wave, long-wave, medium-wave, very-high frequency, and ultrahigh frequency—are allocated for a variety of purposes, the term *short-wave radio* generally refers to radiobroadcasts in the high-frequency range (3 to 30 MHz) beamed for long distances, especially in international communication. Microwave communication via satellite, however, provides signals with superior reliability and freedom from error.

Amateur, or “ham,” radio is also commonly thought of as short-wave, although amateur operators have been allotted frequencies in the medium-wave band, the very-high-frequency band, and the ultrahigh-frequency band as well as the short-wave band. Certain of these frequencies have restrictions designed to make them available to maximum numbers of users.

During the rapid development of radio after World War I, amateur operators executed such spectacular feats as the first transatlantic radio contact (1921). They have also provided valuable voluntary assistance during emergencies when normal communications are disrupted. Amateur radio organizations have launched a number of satellites piggyback with regular launches by the United States, the former Soviet Union, and the European Space Agency. These satellites are usually called Oscar, for Orbiting Satellites Carrying Amateur Radio. The first, *Oscar 1*, orbited in 1961, was also the first nongovernmental satellite; the fourth, in 1965, provided the first direct-satellite communications between the U.S. and the Soviet Union. More than 1.5 million people worldwide were licensed amateur radio operators in the early 1980s. See *also* Citizens Band Radio.

D Radio Today

Immense developments in radio communication technology after World War II helped make possible space exploration, most dramatically in the Apollo moon-landing missions (1969-72). Sophisticated transmitting and receiving equipment was part of the compact, very-high-frequency, communication system on board the command modules and the lunar modules. The system performed voice and ranging functions simultaneously, calculating the distance between the two vehicles by measuring the time lapse between the transmission of tones and the reception of the returns. The voice signals of the astronauts were also transmitted simultaneously around the world by a communications network. See *also* Cellular Radio.

Contributed By:

[Leonard Feldman](#)

[Sir Robert Alexander Watson-Watt](#)

[Vladimir Kosma Zworykin](#)

Microsoft ® Encarta ® 2006. © 1993-2005 Microsoft Corporation. All rights reserved.