AMATEUR RADIO
Encyclopedia

Stan Gibilisco, W1GV
EDITOR-IN-CHIEF

Amateur Radio Encyclopedia

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To Jack and Sherri

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How to use this book

This encyclopedia is intended as a permanent reference source for radio amateurs of all experience levels, as well as aspiring radio hams, shortwave listeners, and electronics hobbyists.

If you have a subject, device, or specialty in mind, look for it in the main body of articles, just as when using a dictionary. The cross references will provide a nearly unlimited source of reading when you start with a general subject. If your term is not an article title, consult the index. It contains far more terms than the main body of titles, and will guide you to one or more starting points in the book.

Suggestions for future editions are welcome. 73.

Stan Gibilisco, W1GV
Editor-in-Chief

Suggested additional reading

Numerous ham radio books are available. The best listings are in advertisements in ham-radio related magazines. The American Radio Relay League, Inc. has an excellent set of publications covering all aspects of ham radio. At the time of this writing, the major ham magazines are:

CQ, 76 N. Broadway, Hicksville, NY 11801
QST, 225 Main Street, Newington, CT 06111
73, Forest Road, Hancock, NH 03449

The two leading books for ham radio projects are:

American Radio Relay League, Inc., *The ARRL Handbook for Radio Amateurs* (published annually)
Orr, William, *Radio Handbook* (Howard W. Sams & Co., Inc.)

Foreword

Amateur radio, more familiarly known as ham radio, was the forerunner of our electronic age before we even knew we were in one! In an enthralling, hands-on manner, it has managed to keep its enthusiasts interested and abreast of communications technology, lured first by the novelty of talking across town, then across the nation, across the world, and ultimately with hams orbiting the earth in spacecraft.

Since the beginning of this century, radio hams have pioneered communications techniques and protocols, built antennas, learned to operate all kinds of equipment, and communicated with each other in endlessly diverse ways: morse code, voice, radioteletype, television, moonbounce, packet radio. It is an absorbing and fascinating hobby, often starting with shortwave listening, then leading many participants into careers undreamed of, and providing a way for those with physical challenges to reach the world.

Hams measure their operating skills against others in operating competitions and field events. They share experiences without any of the traditional limitations on geography, age, language, religion, ethnic background, or sex. Hams have a well-earned tradition of assisting their communities in times of disaster, when commercial communication is inoperative. It is a lifetime satisfying hobby that one can explore, enjoy, and grow with.

Living in today's technologically advanced world brings just about everyone in contact with the electronic age. For those beginning an association with ham radio, there are even more things to discover! But where does one start? Where do you look when you're not quite sure how much information you want on a given subject, nor how to go about finding it? That initial question in your mind needs a quick and easy-to-find answer. As your background grows, you'll have more questions needing answers. This is what this book is all about. It's an alphabetical, detailed database, starting you on the information track to a specific item—easy-to-find data, understandable and useful.

What an adventure awaits you if you're planning on entering the Amateur Radio service, and what a continuing and interesting challenge faces you as you explore the newer techniques melding computers with transmitters! The more than 500,000 hams in the U.S. alone, with millions more worldwide, bid you welcome with a heartfelt 73: best regards.

Ellen White, W1YL/4

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A

ABSORPTION

When any kind of energy or current is converted to some other form of energy, the transformation is referred to as *absorption* if it is dissipated and not used. Light is be converted to heat, for example, when it strikes a dark surface. Generally, absorption refers to an undesired conversion of energy.

Radio signals encountering the ionosphere undergo absorption as well as refraction. The amount of absorption depends on the wavelength, the layer of the ionosphere, the time of day, the time of year, and the level of sunspot activity. Sometimes most of the radio signal is converted to heat in the ionosphere; sometimes very little is absorbed and most of it is refracted or allowed to continue on into space. The amount of absorption in a given situation is called *absorptance*, and is expressed in *decibels* or *decibels per unit length*.

ABSORPTION WAVEMETER

An *absorption wavemeter* is a device for measuring radio frequencies. It consists of a tuned inductance-capacitance (LC) circuit, which is loosely coupled to the source to be measured. Knowing the resonant frequency of the tuned circuit for various capacitor or inductor settings (by means of a calibrated dial), the LC circuit is adjusted until maximum energy transfer occurs. This condition is indicated by a peaking of RF voltage, as shown by a meter.

When using an absorption wavemeter, it is extremely important that it not be too tightly coupled to the circuit under test. An RF probe, or short-wire pickup, should be connected to the LC circuit of the absorption wavemeter, and the probe brought near the source of RF energy. If too much coupling occurs, reactance can be introduced into the circuit under test, and this might in turn change its frequency, resulting in an inaccurate measurement.

A special kind of absorption wavemeter has its own oscillator built in. Known as a *grid-dip meter*, this device enables easy determination of the resonant frequency or frequencies of LC circuits and antenna systems.

ACCESS TIME

When accessing an electronic memory, such as in a microcomputer calculator, the data is not received instantaneously. Although the process might appear to be instantaneous, there is always a slight delay, called the *access time*. When storing information in an electronic memory, a delay occurs as well between the storage command and actual storage; this, too, is known as *access time*, or it might be called *storage time*. If the computer itself activates a memory circuit, the access time is the delay between arrival of the command pulse at the memory circuit and the arrival of the required information.

In small computers and calculators, access time is so brief that it can hardly be noticed. If much information must be stored or retrieved in a large computer, the access time might be much longer. This is especially likely if the computer time is simultaneously shared among many users. *See also* MEMORY.

ACCURACY

Physical quantities, such as time, distance, temperature, and voltage, can never be determined precisely; there is always some error. Standard instruments or objects are used as the basis for all measurements. The accuracy of a given instrument is expressed as a percentage difference between the reading of that instrument and the reading of a standard instrument. Mathematically, if a standard instrument reads x_s units and the device under test reads x_t units, then the accuracy, A in percent is:

$$A = 100\,|x_s - X_t|/X_s$$

For meters, accuracy is usually measured at several points on the meter scale, and the accuracy taken as the greatest percentage error. Sometimes only the full-scale reading is used, then the accuracy is stated as a percentage of full scale. For example, a meter might be specified as being accurate to within $\pm$ 10% (plus or minus 10 percent); this guarantees that the meter reading is within 10 percent of the actual value. If full scale is specified, then the only tested point is at full scale. These figures assume that the meter reading is sufficient to cause significant deflection of the needle.

Electronic components, such as resistors and capacitors, are given tolerance factors in percentages, which are an expression of the accuracy of their values. Typical tolerances are 5, 10, and 20 percent. However, certain components are available with much lower tolerances (and therefore greater accuracy).

All units in the United States, and in the engineering world in general, are based on the meter-kilogram-second (MKS) system. The National Bureau of Standards is the ultimate basis in the U.S. for all determinations of accuracy. *See also* CALIBRATION, NATIONAL BUREAU OF STANDARDS, TOLERANCE.

AC GENERATOR

Mechanical energy is converted to electric current, with the aid of a magnetic field, in a device called an *electric generator*. Alternating current is produced by an ac generator.

The ac generator is essentially the same device as an ac motor, except that the conversion of energy occurs in reverse. By rotating the magnet inside the coil of wire, an alternating magnetic field is produced. This change in magnetic flux causes the electrons in the wire to be accelerated, first in one direction and then in the other. The frequency of alternation depends on the speed of rotation of the magnet.

Some ac generators use a rotating coil inside a magnet. The magnet can be operated from electricity itself. Ac generators might provide only a few milliwatts of power, or they might supply many thousands of watts, as is the case with commercial ac power generators.

Any radio-frequency transmitter or audio oscillator is, theoretically, an ac generator because it puts out alternating current. *See also* AUDIO FREQUENCY, and RADIO FREQUENCY.

AC NETWORK

An *alternating-current network* is a circuit that contains resistance and reactance. It differs from a direct-current network, where there is only simple resistance. Resistances are provided by all electrical conductors, resistors, coils, lamps, and the like; when a current passes through a resistance, heat is generated. Pure reactances, though, do not convert electrical current into heat. Instead, they store the energy and release it later. In storing energy, a reactance offers opposition to the flow of alternating current. Inductors and capacitors are the most elementary examples of reactances. Reactance is always either positive (inductive) or negative (capacitive). Certain specialized semiconductor circuits can be made to act like coils or capacitors by showing reactance at a particular ac frequency. Shorted or open lengths of transmission line also behave like reactances at some frequencies.

Although simple resistance is a one-dimensional quantity, and reactance is also one-dimensional (though it might be positive or negative), their combination in an ac network is two-dimensional. Resistance ranges from zero to unlimited values; reactance ranges from zero to unlimited positive or negative values. Their combination in an alternating-current circuit is called *impedance*. Any ac network has a net impedance at a given frequency. The impedance generally changes as the frequency changes, unless it is a pure resistance. Reactance is multiplied by the imaginary number *j*, called the *j factor*, for mathematical convenience. This quantity is defined as the square root of −1, also sometimes denoted by *i*. *See also* IMPEDANCE, *J* OPERATOR, and REACTANCE.

ACOUSTIC FEEDBACK

Positive feedback in a circuit, if it reaches sufficient proportions, will cause oscillation of an amplifier. In a public-address system, feedback might occur not only electrically, between the input and output component wiring, but between the speaker(s) and microphone. The result is a loud audible rumble, tone, or squeal. It might take almost any frequency, and totally disables the public-address system for its intended use. This kind of feedback might also occur between a radio receiver and transmitter, if both are voice modulated and operated in close proximity. This is called *acoustic feedback*.

Another form of acoustic feedback occurs in voice-operated communications systems (*see* VOX). While receiving signals through a speaker, the sound might reach sufficient amplitude to actuate the transmitter switching circuits. This results in intermittent unintended transmissions, and makes reception impossible. Compensating circuits in some radio transceivers equipped with VOX reduce the tendency toward this kind of acoustic feedback.

To prevent acoustic feedback in a public-address system, a directional microphone should be used, and all speakers should be located well outside the microphone-response field. The gain (volume) should be kept as low as possible consistent with the intended operation. The room or environment in which the system is located should have sound-absorbing qualities, if at all possible, to minimize acoustic reflection.

AC RELAY

An *alternating-current (ac) relay* is a device designed for the purpose of power switching from remote points (*see* RELAY). The ac relay differs from the dc relay in that it utilizes alternating current rather than direct current in its electromagnet. This offers convenience because no special power supply is required if the electromagnet is designed to operate from ordinary 117-Vac house outlets.

Ac relays are less likely than dc units to get permanently magnetized. This occurs when the core of the electromagnet becomes a magnet itself. In an ac relay, the magnetic field is reversed every time the direction of current flow changes so that one polarity is not favored over the other. Ac relays must be damped to a certain extent for 60-Hz operation, or the armature will attempt to follow the current alternations and the relay will buzz. The armature and magnetic pole-pieces in ac relays are specially designed to reduce this tendency to buzz.

AC RIPPLE

Alternating-current ripple, usually referred to simply as *ripple*, is the presence of undesired modulation on a signal or power source. The most common form of ripple is 60- or 120-Hz ripple that originates from ac-operated power supplies.

In theory, the output of any power supply will contain some ripple when the supply delivers current. This ripple can, and should, be minimized in practice because it will cause undesirable performance of equipment if not kept under control. Sufficient filtering, if used, will ensure that the ripple will not appear in the output of the circuit.

Ac ripple is virtually eliminated by using large inductors in series with the output of a power supply, and by connecting large capacitors in parallel with the supply output. The more current the supply is required to deliver, the more inductance and capacitance will be required in the filter stage. *See also* POWER SUPPLY.

ACTIVE COMPONENT

In any electronic circuit, certain components are directly responsible for producing gain, oscillation, switching action, or rectification. If such components draw power from an external source, such as a battery or power supply, then they are called *active components*. Active components include integrated circuits, transistors, vacuum tubes, and some diodes. An active component always requires a source of power to perform its function.

A passive component, by contrast, does its job with no outside source of power. Passive components include resistors, capacitors, inductors, and some diodes.

Some devices might act as either passive or active components, depending on the way they are used. One example is the varactor diode (*see* VARACTOR DIODE). When an audio-frequency voltage is applied across this type of diode, its junction capacitance fluctuates without any source of external power, and thus frequency modulation might be produced in an oscillator circuit. A dc voltage from a power supply, however, might be applied across the same diode, in the same circuit, for the purpose of adjusting the carrier frequency of the oscillator. In the first case, the varactor might be considered a passive component because it requires no battery power to produce FM from an audio signal. But in the second case, dc from an external source is necessary, and the varactor becomes an active component.

ACTIVE COMMUNICATIONS SATELLITE

Much of today's communications is done by means of relaying via satellites. This is true in amateur radio, as it is in commercial systems, such as telephone and television.

All modern satellites are of the *active type*. This means that they receive and retransmit the information. The earliest communications satellites, placed in orbit in the 1960s and known as *Echo satellites*, were *passive reflectors* of radio signals. The signals they returned were extremely weak, and they had to be physically large in order to function.

Early Amateur Satellites Active communications satellites can be placed in low, circular orbits. Then they pass close by overhead, and they do not need much transmitter power to be heard on the surface. But the range is limited to whatever horizon exists from the vantage point of the satellite. This will be only a small, and constantly changing, part of the earth if the orbit is low.

The first amateur satellites, called *OSCAR* for Orbiting Satellite Carrying Amateur Radio, were placed in low, nearly circular orbits. Contacts had to be carried out within a few minutes via these satellites. It was necessary to keep changing the azimuth and elevation bearings of the antenna in order to keep it pointed at the satellite, or else to use low-gain, omnidirectional, "turnstile" antennas at the surface. It was also necessary to keep constant track of orbital decay effects, because any satellite in low earth orbit is subject to atmospheric drag. Eventually, it will fall into the atmosphere and burn up.

Later Amateur Satellites Later OSCAR satellites have been placed in elliptical orbits. This causes them to swing out far away from the earth, and during this time, they move much more slowly than a satellite in low orbit. It is possible to access the satellite for periods of hours, instead of just minutes, when the satellite is at apogee. Also, a directional antenna can be left alone for some time, not needing constant readjustment. The effective range of the satellite is much greater, because it "sees" a larger part of the earth's surface from its higher altitude, but more gain is generally required for antennas at the surface. This means such antennas must be more complex and more expensive.

Future Amateur Satellites In the future, some amateur satellites will probably be placed in geostationary orbits. This allows for a constant azimuth/elevation setting for surface-station antennas. An antenna can be mounted in a fixed position, aimed at the satellite, and then left alone without the need for tracking, or for azimuth/elevation rotators. The satellite altitude is about 22,300 miles. Such satellites must orbit over the equator. This excludes regions at the very high latitudes, in the Arctic and Antarctic, from coverage. But three geostationary satellites, each spaced equally around the world at angles of 120 degrees, with respect to each other, provide for communications between almost all points in the civilized world. This is the case for most commercial satellite networks today.

Future amateur satellites can also be expected to operate over larger bandwidths, and probably also on higher frequency bands, than current amateur satellites. It will probably be possible to communicate using two satellites, if necessary. In this way, almost every amateur station in the world will have immediate, continuous access to almost every other amateur station, 24 hours a day, every day. The problems (and challenges) associated with ionospheric and tropospheric propagation will be gone. It will be, in essence, a world ham-radio telephone network.

Principles of Operation An amateur satellite *transponder* is actually a sophisticated form of repeater. There are some important differences, however, between a simple repeater, such as the kind you work through on 2-meter FM, and a satellite transponder.

The transponder converts signals from one band to signals in another band. It is, in this way, like a transmitting converter. The bands are portions of the amateur 10-meter, 2-meter, 70-centimeter and 13-centimeter bands. The figure is a simplified block diagram of an amateur active communications satellite, showing the antennas and the main components of the transponder.

The input band and output band are of the same width, but the output is often "upside-down," relative to the input, because of the conversion process. Therefore, if you increase the frequency of your transmitter signal, the output frequency from the satellite might go down, rather than up. In this case, upper-sideband uplink signals will be lower-sideband in the downlink, and vice-versa. In radioteletype, if this mode is allowed through the satellite, the mark and space signals will be reversed when the transponder is of the inverting type. There is no effect on CW signals.

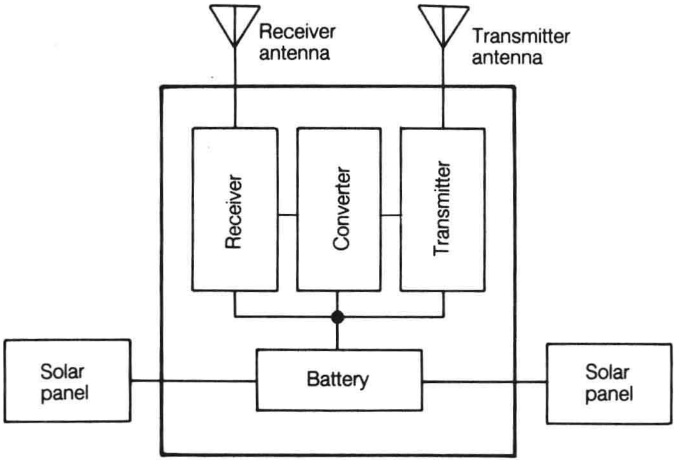
The transponder can handle numerous signals all at once. This makes full duplex operation possible; your QSO can interrupt you while you talk to him/her. You can even listen to yourself. The satellite transponder might use batteries alone, or batteries with solar panels to charge them.

Satellite Use It is a fundamental rule in amateur satellite work that you never use more power than you need. This is a good rule (and actually a law) for all amateur communications, but with satellites, there is an added importance to it. If a single station uses far more power than necessary to access, or to communicate through, the satellite, the transponder will pay a disproportionate amount of attention to that one station. The result will be that the other stations' signals are greatly attenuated while the strong station is transmitting.

Normally, only about 4 watts maximum power is needed for low-orbiting satellites, and about 30 watts with high-altitude satellites. If significantly more power is used than this, the station might "hog" transponder power.

Signals in the downlink are sometimes inverted, relative to those in the uplink. The whole band thus comes out "upside down." In other cases, the band comes out "right-side up." The advantage of inverting transponders is that the Doppler effect is minimized, so that signals in the downlink do not change frequency as rapidly. In future geostationary satellites, Doppler shift will not be a factor.

For additional information, refer to the following terms: APOGEE, ASCENDING NODE, ASCENDING PASS, DESCENDING NODE, DESCENDING PASS, DOWNLINK, GEOSTATIONARY ORBIT, OSCAR, OSCARLOCATOR, PERIGEE, PHASE I SATELLITE, PHASE II SATELLITE, PHASE III SATELLITE, REPEATER, SATELLITE TRANSPONDER MODES, TRANSPONDER, and UPLINK.



ACTIVE COMMUNICATIONS SATELLITE: Block diagram of the major components of an amateur active communications satellite.

ACTIVE FILTER

An *active filter* is a filter that uses active components to provide selectivity. Generally, active filters are used in the audio range.

Active filters might be designed to have predetermined selective characteristics, and are lightweight and small. Control is easily accomplished by switches and potentiometers. Such filters, being active devices, require a source of dc power, but because the filters consume very little current, a miniature 9-V transistor-radio type battery is usually sufficient to maintain operation for several weeks. Most audio filters use operational amplifiers or "op amps." Active filters are not often seen at radio frequencies.

ACTIVE REGION

In a bipolar transistor, class-A or class-AB amplification occurs when the collector voltage, as measured relative to ground in a common-emitter circuit, is larger than the base voltage. This is called the *active region* of the transistor. This region is between *cutoff* and *saturation*.

Power amplification is possible in the region at or beyond cutoff if there is sufficient drive. No amplification is possible when a transistor is in saturation. *See also* CLASS-A AMPLIFIER, CLASS-AB AMPLIFIER, CLASS-B AMPLIFIER, CLASS-C AMPLIFIER, and CUTOFF.

AC VOLTAGE

There are several different ways of defining voltage in an alternating-current circuit. They are called the *peak, peak-to-peak,* and *root-mean-square (RMS) methods.*

An ac waveform does not necessarily look like a simple sine wave. It might be square, sawtoothed, or irregular in shape. But whatever the shape of an ac waveform, the peak voltage is definable as the largest instantaneous value the waveform reaches. The *peak-to-peak voltage* is the difference between the largest instantaneous values the waveform reaches to either side of zero. Usually, the peak-to-peak voltage is exactly twice the peak voltage. However, if the waveform is not symmetrical, the peak value might be different in the negative direction than in the positive direction, and the peak-to-peak voltage might not be twice the positive peak or negative peak voltage.

The RMS voltage is the most commonly mentioned property of ac voltage. RMS voltage is defined as the dc voltage needed to cause the same amount of heat dissipation, in a simple, nonreactive resistor, as a given alternating-current voltage. For symmetrical, sinusoidal waveforms, the RMS voltage is 0.707 times the peak voltage and 0.354 times the peak-to-peak voltage. *See also* ROOT MEAN SQUARE.

ADAPTOR

Any device that makes two incompatible things work together is an *adaptor*. In electronics, adaptors are most frequently seen in cable connectors because there are so many different kinds of connectors. Such cable adaptors are sometimes called *tweenies* in the popular jargon.

Adaptors should be used as sparingly as possible, especially at radio frequencies, because they sometimes produce impedance irregularities along a section of feed line or cable. However, adaptors are invaluable in engineering and test situations as a convenience. Every test or service shop should have a good supply. *See also* CONNECTOR.

ADDER

In digital electronics, an adder is a circuit that forms the sum of two numbers. An adder is also a circuit that combines two binary digits and produces a carry output. Such a combination is simple in binary arithmetic.

In color television receivers, the circuit that combines the red, green, and blue signals from the receiver is called an adder. *See also* COLOR TELEVISION.

ADDRESS

Computer memory is stored in discrete packages for easy access. Each memory location bears a designator, usually a number, called the *address*. By selecting a particular address by number, the corresponding set of memory data is made available for use.

A calculator or small computer might have several different memory channels for storing numbers. Each channel is itself designated by a number, for example, 1 through 8. By actuating a memory-address function control, followed by the memory address number, the contents of the memory channel are called for use. Some radio receivers and transceivers make use of a memory-address function for convenience in calling, or switching among, frequently used frequencies. The memory-address status is shown by a panel indicator, such as an LCD display. *See also* MEMORY.

ADJACENT-CHANNEL INTERFERENCE

When a receiver is tuned to a particular frequency and interference is received from a signal on a nearby frequency, the effect is referred to as *adjacent-channel interference.*

To a certain extent, adjacent-channel interference is unavoidable. When receiving an extremely weak signal near an extremely strong one, interference is likely—especially if the stronger signal is voice modulated. No transmitter has absolutely clean modulation, and a small amount of off-frequency emission occurs with voice modulation—especially AM and SSB types. *See* AMPLITUDE MODULATION, SINGLE SIDEBAND, and SPLATTER.

Adjacent-channel interference might be reduced by using proper engineering techniques in transmitters and receivers. Transmitter audio amplifiers, modulators, and RF amplifiers should produce as little distortion as the state of the art will permit. Receivers should use selective filters of the proper bandwidth for the signals to be received and the adjacent-channel response should be as low as possible. A flat response in the passband (*see* PASSBAND), and a steep drop-off in sensitivity outside the passband, are characteristics of good receiver design. Modern technology has made great advancements in the area of receiver-passband selectivity.

ADMITTANCE

In some electronic circuit calculations, it is convenient to use a quantity called *admittance*. This is the reciprocal of impedance.

Admittance is a complex quantity, just as is impedance. The components of admittance are *conductance* (the reciprocal of resistance) and *susceptance* (the reciprocal of reactance). Symbolically, the abbreviations for the various quantities are:

Resistance	$= R$
Reactance	$= X$
Impedance	$= Z$
Conductance	$= G$
Susceptance	$= B$
Admittance	$= Y$

Total admittance is the reciprocal of total impedance. That is, in simplified terms, $Y = 1/Z$. Also, $G = 1/R$ and $B = 1/X$.

Knowing the total resistance and reactance in a circuit, the conductance and susceptance can be found by the formulas:

$$G = R/(R^2 + X^2)$$
$$B = -X/(R^2 + X^2)$$

Knowing the total conductance and the total susceptance, the resistance and reactance can be found by the formulas:

$$R = G/(G^2 + B^2)$$
$$X = -B/(G^2 + B^2)$$

Total admittance is defined in terms of total conductance and total susceptance, according to the formula:

$$Y = (G^2 + B^2)^{1/2}$$

Admittance is especially useful when determining the impedance of a network of resistances, capacitances and/or inductances in parallel. This is because admittances add in parallel, just as impedances add in series. Once the total admittance has been found, impedance Z can be determined simply by the reciprocal: $Z = 1/Y$. *See also* CONDUCTANCE, IMPEDANCE, *J* OPERATOR, and REACTANCE.

AFC

See AUTOMATIC FREQUENCY CONTROL.

AGC

See AUTOMATIC GAIN CONTROL.

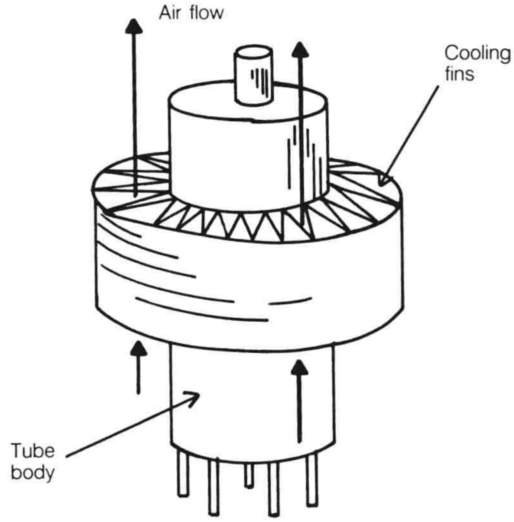
AIR COOLING

Components that generate great amounts of heat, such as vacuum tubes, transistor power amplifiers, and some resistors, must be provided with some means for cooling or damage might result. Such components might be air cooled or conduction cooled (*see* CONDUCTION COOLING). Air cooling might occur as heat radiation, or as convection.

In high-powered vacuum-tube transmitters, a fan is usually provided to force air over the tubes or through special cooling fins (see the illustration). By using such fans, greater heat dissipation is possible than would be the case without them, and this allows higher input and output power levels.

Low-powered transistor amplifiers use small heatsinks to conduct heat away from the body of the transistor (*see* HEATSINK). The heatsink might then radiate the heat into the atmosphere as infrared energy, or the heat might be dissipated into a large, massive object, such as a block of metal. Ultimately, however, some of the heat from conduction-cooled equipment is dissipated in the air as radiant heat.

With the increasing use of solid-state amplifiers in radio and electronic equipment, conduction cooling is becoming more common, replacing the air blowers that are so often seen in tube-type amplifiers. Conduction cooling is quieter and requires no external source of power.

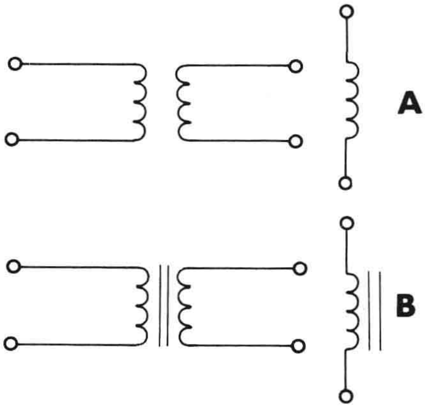


AIR COOLING: The air passes through fins to carry heat away by convection.

AIR CORE

The term *air core* is usually applied in reference to inductors or transformers. At higher radio frequencies, air-core coils are used because the required inductances are small. Powdered-iron and ferrite cores greatly increase the inductance of a coil, as compared to an air core (*see* FERRITE CORE). This occurs because such materials cause a concentration of magnetic flux within the coil. The magnitude of this concentration is referred to as permeability (*see* PERMEABILITY); air is given, by convention, a permeability of 1 at sea level.

Air-core inductors and transformers might be identified in schematic diagrams by the absence of lines near the turns. In a ferrite or powdered-iron core, two parallel straight lines indicate the presence of a permeability-increasing substance in the core (see A and B). Coils are sometimes wound on forms made of dielectric material, such as glass or bakelite. Because these substances have essentially the same permeability as air (with minor differences), they are considered air-core inductors in schematic representations.



AIR CORE: At A, schematic symbols for air core transformer and inductor. At B, symbols for transformer and coil with ferromagnetic core.

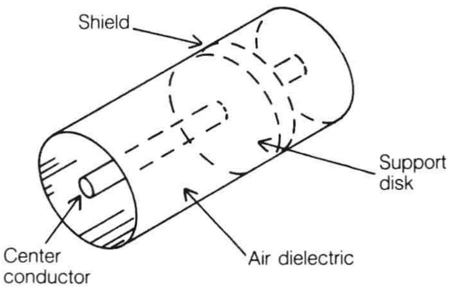
AIR-SPACED COAXIAL CABLE

A coaxial cable might have several kinds of dielectric material. Polyethylene is probably the most common. If loss is to be minimized, air-dielectric coaxial cable is the best.

The principal difficulty in designing air-spaced coaxial cable is the maintenance of proper spacing between the inner conductor and the shield. Usually, disk-shaped pieces of polyethylene or other solid dielectric material are positioned at intervals inside the cable (see illustration). Although sharp bends in an air-dielectric coaxial cable cannot be made without upsetting the spacing and possibly causing a short circuit, the disks keep the center conductor properly positioned while affecting very little the low-loss characteristics of the air dielectric. Each disk is kept in place by adhesive material or bumps or notches in the center conductor.

It is important that moisture be kept from the interior of an air-spaced coaxial cable. If water gets into such a cable, the low-loss properties and characteristic impedance are upset (*see* CHARACTERISTIC IMPEDANCE).

A solid, rigid, coaxial cable, which might have either air or solid dielectric, is called a *hard line* (*see* HARD LINE).



AIR-SPACED COAXIAL CABLE: Supporting disks or beads keep the center conductor spaced away from the shield.

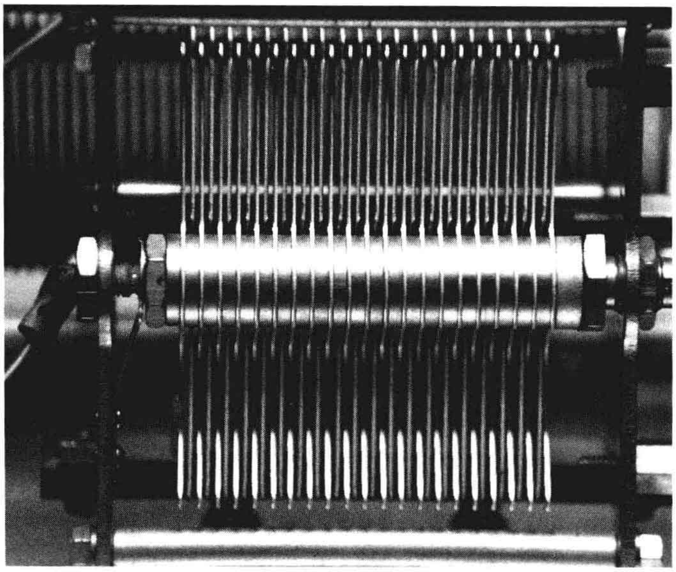
AIR-VARIABLE CAPACITOR

An *air-variable capacitor* is a device whose capacitance is adjustable, usually by means of a rotating shaft. One rotating and one fixed set of metal plates are positioned in meshed fashion with rigidly controlled spacing. Air forms the dielectric material for such capacitors. The capacitance is set to the desired value by rotating one set of plates, called the *rotor plates*, to achieve a certain amount of overlap with a fixed set of plates, called the *stator plates*. The rotor plates are usually connected electrically to the metal shaft and frame of the unit. The photo shows a common type of air-variable capacitor.

Air-variable capacitors come in many physical sizes and shapes. For receiving, and low-power RF transmitting applications, the plate spacing might be as small as a fraction of a millimeter. At high levels of RF power, the plates might be spaced an inch or more apart. The capacitance range of an air variable has a minimum of a few picofarads (abbreviated pF and equal to 10^{-12} farad or 10^{-6} microfarad) and a maximum that might range from about 10 to 1000 pF. The maximum capacitance depends on the size and number of plates used, and on their spacing.

Because the dielectric material in an air-variable capacitor is air, which has a small amount of loss, air variables are efficient capacitors, as long as they are not subjected to excessive voltages that result in flashover. A special kind of variable capacitor is the *vacuum-variable*, a variable capacitor that is placed in an evacuated enclosure. Such capacitors are even more efficient than air variables.

Air-variable capacitors are frequently found in tuned circuits, RF power-amplifier output networks, and antenna matching systems. *See also* ANTENNA MATCHING, and TRANSMATCH.



AIR-VARIABLE CAPACITOR: A tuning capacitor in a transmatch.

ALC

See AUTOMATIC LEVEL CONTROL.

ALEXANDERSON ANTENNA

An antenna for use at low or very low frequencies, the *Alexanderson antenna* consists of several base-loaded vertical radiators that are connected together at the top and fed at the bottom of one radiator.

At low frequencies, the principal problem with transmitting antenna design is the fact that any radiator of practical height has an exceedingly low radiation resistance (*see* RADIATION RESISTANCE) because the wavelength is so large. This results in severe loss—especially in the earth near the antenna system. By arranging several short, inductively loaded antennas in parallel, and coupling the feed line to only one of the radiators, the effective radiation resistance is greatly increased. This improves the efficiency of the antenna, because more of the energy from the transmitter appears across the larger radiation resistance.

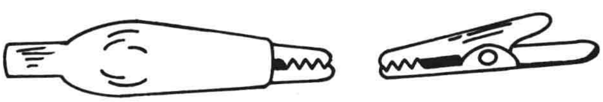
The Alexanderson antenna has not been extensively used at frequencies above the standard AM broadcast band. But where available ground space limits the practical height of an antenna and prohibits the installation of a large system of ground radials, the Alexanderson antenna could be a good choice at frequencies as high as perhaps 5 MHz. The Alexanderson antenna requires a far-less elaborate system of ground radials than a single-radiator vertical antenna worked against ground. The radiation resistance of an Alexanderson array, as compared to a single radiator of a given height, increases according to the square of the number of elements. *See also* INDUCTIVE LOADING.

ALLIGATOR CLIP

For electronic testing and experimentation, where temporary connections are needed, alligator clips (also known as *clip leads*, although there are other kinds of clip leads) are often used. They are easy to use and require no modification to the circuit under test.

Alligator clips come in a variety of sizes, ranging from less than ½ inch long to several inches long. They are clamped to a terminal or a piece of bare wire. Although such clips are convenient for temporary use, they are not good for long-term installations because of their limited current-carrying capacity and the tendency toward corrosion, especially outdoors.

See the drawing, which shows common alligator clips. They derive their somewhat humorous name from their visible resemblance to the mouth of an alligator! *See also* CLIP LEAD.



ALLIGATOR CLIP: These are useful for temporary connections.

ALLOY-DIFFUSED SEMICONDUCTOR

Some semiconductor junctions are formed by a process called *alloy diffusion*. A semiconductor wafer of p-type or n-type material forms the heart of the device. An impurity metal is heated to its melting point and placed onto the semiconductor wafer. As the impurity metal cools, it combines with the semiconductor material to form a region of the opposite type from the semiconductor wafer.

A transistor might be formed in this manner by starting with a wafer of n-type semiconductor. A small amount of metal, such as indium, is melted on each side of this wafer, and the melting process is continued so that the indium diffuses into the n-type wafer. This gives the effect of *doping* (creating an alloy with) the n-type material next to the indium. (*See* DOPING.) Indium is an acceptor impurity (*see* IMPURITY), and thus two p-type regions are formed on either side of the n-type material. The result is a pnp transistor.

Alloy-diffused semiconductor transistors can be made to have extremely thin base regions. This makes it possible to use the transistor at very high frequencies.

ALL-PASS FILTER

An *all-pass filter* is a device or network that is designed to have constant attenuation at all frequencies of alternating current. However, a phase shift might be introduced, and this phase shift is also constant for all alternating-current frequencies. In practice, the attenuation is usually as small as possible (*see* ATTENUATION).

All-pass filters are generally constructed using noninverting operational amplifiers. The amount of phase delay is determined by the values of resistor *R* and capacitors *C*. The amount of attenuation is regulated by the values of the other resistors.

ALPHA

In a transistor, the ratio between a change in collector current and a change in emitter current is known as the *alpha* for that particular transistor. Alpha is represented by the first letter of the Greek alphabet, lowercase (α). Alpha is determined in the grounded-base arrangement.

The collector current in a transistor is always smaller than the emitter current. This is because the base draws some current from the emitter-collector path when the transistor is forward biased. Generally, the alpha of a transistor is given as a percentage:

$$\alpha = 100\ (I_c/I_e),$$

where I_c is the collector current and I_e is the emitter current.

Transistors typically have alpha values from 95 to 99 percent. Alpha must be measured, of course, with the transistor biased for normal operation.

ALPHA-CUTOFF FREQUENCY

As the frequency through a transistor amplifier is increased, the amplification factor of the transistor decreases. The current gain, or beta (*see* BETA) of a transistor is measured at a frequency of 1 kHz with a pure sine-wave input for reference when determining the alpha-cutoff frequency. Then, a test generator must be used, which has a constant output amplitude over a wide range of frequencies. The frequency to the amplifier input is increased until the current gain in the common-base arrangement decreases by 3 dB, with respect to its value at 1 kHz. A decrease in current gain of 3 dB represents a drop to 0.707 of its previous magnitude. The frequency at which the beta is 3 dB below the beta at 1 kHz is called the *alpha-cutoff frequency* for the transistor.

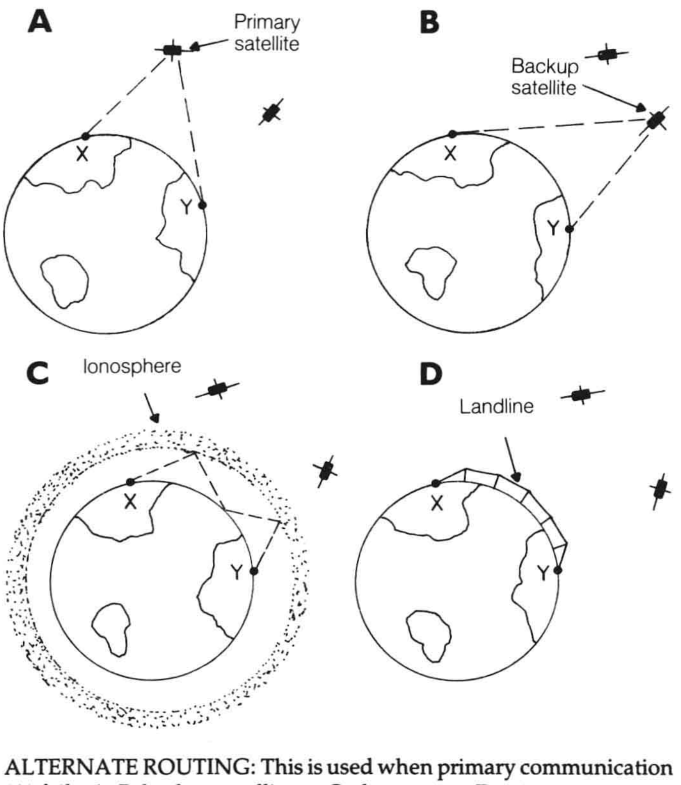
Depending on the type of transistor involved, the alpha-cutoff frequency might be only a few MHz, or perhaps hundreds of MHz. The alpha-cutoff frequency is an important specification in the design of an amplifier. An alpha-cutoff frequency that is too low for a given amplifier requirement will result in poor gain characteristics. If the alpha-cutoff frequency is unnecessarily high, expense becomes a factor; and under such conditions there is a greater tendency toward unwanted VHF parasitic oscillation (*see* PARASITIC OSCILLATION).

As the input frequency is increased past the alpha-cutoff frequency, the gain of the transistor continues to decrease until it reaches unity (zero dB). At still higher frequencies, the gain becomes smaller than unity. *See also* DECIBEL, and GAIN.

ALTERNATE ROUTING

When the primary system for communications between two points breaks down, a backup system must be used to maintain the circuit. Such a system, and its deployment, is called *alternate routing*. Alternate routing might also be used in power transmission, in case of interruption of a major power line, to prevent prolonged and widespread blackouts. Power from other plants is routed to cities that are affected by the failure of one particular generating plant or transmission line.

As an example, the primary communications link for a particular system might be via a geostationary satellite (as shown in A). If the satellite fails, another satellite can be used in its place if one is available (B). This is alternate routing. If the second satellite ceases to function or is not available, further backup systems might be used, such as an HF shortwave link (C) or telephone connection (D). Alternate routing systems should be set up and planned in advance, before the primary system goes down, so that communications might be maintained with a minimum of delay.



ALTERNATE ROUTING: This is used when primary communication (A) fails. At B, backup satellite; at C, sky wave; at D, wire communication.

ALTERNATOR

See AC GENERATOR.

ALUMINUM

Aluminum is a dull, light, somewhat brittle metal, atomic number 13, atomic weight 27, commonly used as a conductor for electricity. Although it does break rather easily, aluminum is very strong in proportion to its weight, and has replaced much heavier metals, such as steel and copper, in many applications.

Aluminum, like other metallic elements, is found in the earth's crust. It occurs in a rock called *bauxite*. Recent advances in mining and refining of bauxite have made aluminum one of the most widely used, and inexpensive, industrial metals.

Aluminum is fairly resistant to corrosion, and is an excellent choice in the construction of communications antenna systems. Hard aluminum tubing is available in many sizes and thicknesses. The do-it-yourself electronics hobbyist can build quite sophisticated antennas from aluminum tubing purchased at a hardware store. Most commercially manufactured antennas use aluminum tubing.

Soft aluminum wire is used for grounding systems in communications and utility service. Large-size aluminum wire often proves the best economic choice for such applications. Some municipalities, however, require copper wire for grounding. *See also* LIGHTNING PROTECTION.

AMATEUR RADIO EMERGENCY SERVICE

The American Radio Relay League (ARRL) has numerous public-service organizations. One of these is the *Amateur Radio Emergency Service (ARES)*.

The ARES is organized for each ARRL section. The Section Manager, an elected ARRL official, is in charge of ARES communications for each section. Within sections, local branches operate.

Membership in ARRL is not required for participation in ARES. The primary purpose is to give public assistance; this is an essential aspect of ham radio, and helps to justify the existence of the hobby. Detailed information about ARES can be obtained by writing to the Communications Manager, ARRL Headquarters, Newington, CT 06111. *See also* AMERICAN RADIO RELAY LEAGUE.

AMERICAN RADIO RELAY LEAGUE

Electromagnetic communication has been in existence only since about 1900. Before the Twentieth Century, physics labs were the only places in which such phenomena were even observed, much less put to use. But within just a few years after the discovery of electromagnetic propagation, communicators began to compete for space in the electromagnetic spectrum.

In modern societies, commercial and government interests tend to prevail over amateur interests, because of economic and political factors. One radio amateur, Hiram Percy Maxim, saw the need for an organization to consolidate the power of radio hams, lest amateur privileges eventually be lost. In 1914, the American Radio Relay League (ARRL) was founded by Maxim and some close friends near Hartford, Connecticut. The ARRL is often called simply "the League."

Today, ARRL is a worldwide organization headquartered in Newington, Connecticut. The ARRL works closely with the Federal Communications Commission (FCC), federal legislators, and the International Telecommunication Union (ITU) to ensure that amateur radio continues to exist. The worldwide equivalent of ARRL is the International Amateur Radio Union (IARU). Some other countries have their own "leagues," such as England (Radio Society of Great Britain, RSGB) and Japan (Japan Amateur Radio League, JARL).

The ARRL has done far more than merely keep hostile interests from taking away all radio hams' privileges. Numerous publications are available to help new hams learn about the multiple facets of this hobby. The ARRL maintains a code-practice and bulletin station, bearing Hiram Percy Maxim's original call letters, W1AW. Many other services and activities are carried on by this organization. More than 150,000 American hams belong.

Membership is open to anyone. Even nonhams can be associate members. But to be a full member of ARRL, it is necessary to have at least a novice-class ham license.

For information about ARRL, write to ARRL Headquarters, 225 Main Street, Newington, CT 06111. *See also* INTERNATIONAL AMATEUR RADIO UNION, and W1AW.

AMATEUR RADIO SATELLITE CORPORATION

See RADIO AMATEUR SATELLITE CORPORATION.

AMERICAN MORSE CODE

The *American Morse Code* is a system of dot and dash symbols, first used by Samuel Morse in telegraph communications. The American Morse Code is not widely used today. It has been largely replaced by the International Morse Code. Some telegraph operators still use American Morse.

The American Morse Code differs from the International Morse Code. The American Morse symbols are sometimes called "Railroad Morse." Some letters contain internal spaces. This causes confusion for operators who are familiar with International Morse Code. Some letters are also entirely different between the two codes. *See also* INTERNATIONAL MORSE CODE.

AMATEUR TELEVISION

The term *amateur television (ATV)* refers to either fast-scan or slow-scan television communications by radio hams, with or without accompanying audio. Fast-scan ATV is generally used at UHF and microwave frequencies, because the signals require several megahertz of bandwidth. In fact, ATV signals are just like broadcast signals, except that the power levels are much lower. The signals can be either black-and-white or color. *See* COLOR TELEVISION, and TELEVISION.

Slow-scan TV, abbreviated SSTV, can be used on any ham band. The signals take up only about 3 kHz of spectrum space, the same as a single-sideband (SSB) voice transmission. The pictures can be either black-and-white or in color. *See* COLOR SLOW-SCAN TELEVISION, and SLOW-SCAN TELEVISION.

AMERICAN WIRE GAUGE

Metal wire is available in many different sizes or diameters. Wire is classified according to diameter by giving it a number. The designator for a given wire is known as the *American Wire Gauge (AWG)*. In England, a slightly different system is used (*see* BRITISH STANDARD WIRE GAUGE). The numbers in the American Wire Gauge system range from 1 to 40, although larger and smaller gauges exist. The higher the AWG number, the thinner the wire.

The table shows the diameter vs AWG designator for AWG 1 through 40. The larger the AWG number for a given conductor metal, the smaller the current-carrying capacity becomes. The AWG designator does not include any coatings on the wire such as enamel, rubber, or plastic insulation. Only the metal part of the wire is taken into account.

AMERICAN WIRE GAUGE: AMERICAN WIRE GAUGE EQUIVALENTS IN MILLIMETERS.

AWG	Dia., mm	AWG	Dia., mm
1	7.35	21	0.723
2	6.54	22	0.644
3	5.83	23	0.573
4	5.19	24	0.511
5	4.62	25	0.455
6	4.12	26	0.405
7	3.67	27	0.361
8	3.26	28	0.321
9	2.91	29	0.286
10	2.59	30	0.255
11	2.31	31	0.227
12	2.05	32	0.202
13	1.83	33	0.180
14	1.63	34	0.160
15	1.45	35	0.143
16	1.29	36	0.127
17	1.15	37	0.113
18	1.02	38	0.101
19	0.912	39	0.090
20	0.812	40	0.080

AMMETER

An *ammeter* is a device for measuring electric current. The current passes through a set of coils, which causes rotation of a central armature. An indicator needle attached to this armature shows the amount of deflection against a graduated scale. Ammeters might be designed to have a full-scale deflection as small as a few microamperes (*see also* AMPERE), up to several amperes.

To extend the range of an ammeter, allowing it to register very large currents, a resistor of precisely determined value is placed in parallel with the meter coils. This resistor diverts much, or most, of the current so that the meter actually reads only a fraction of the current.

Ammeters might be used as voltmeters by placing a resistor in series with the meter coils. Then, even a very high voltage will cause a small deflection of the needle (*see* VOLTMETER). The greatest accuracy is obtained when a sensitive ammeter is used with a large-value resistor. This minimizes the current drawn from the circuit. Ammeters should never be connected across a source of voltage without a series resistor because damage to the meter mechanism might result.

Ammeters are available for measuring both ac and dc. Some ammeters register RF current. The devices must be specially designed for each of these applications.

AMPERE

The *ampere* is the unit of electric current. A flow of one coulomb per second, or 6.28×10^{18} electrons per second, past a given fixed point in an electrical conductor, is a current of one ampere.

Various units smaller than the ampere are often used to measure electric current. A milliampere (mA) is one thousandth of an ampere, or a flow of 6.28×10^{15} electrons per second past a given fixed point. A microampere (μA) is one millionth of an ampere, or a flow of 6.28×10^{12} electrons per second. A nanoampere (nA) is a billionth of an ampere; it is the smallest unit of electric current you are likely to use. It represents a flow of 6.28×10^{9} electrons per second past a given fixed point.