CHAPTER SIX

ANTENNAS

Types—Material—Insulators—Ground Connection—Protection Against Lightning—Transmitting Antennas—Counterpoise—Directional Properties—Coil Antennas—Circuits for Coil Antennas—Construction of Coil Antennas—Direction Finding—Summer Antennas—Plate Condenser Antennas.

Types.—The antenna is the device for radiating waves from the transmitting station and for receiving the radio waves from the air at the receiving station. Many types of antennas are in general use. The two general classes of antennas are, first, the ordinary elevated wire type, usually called simply an "antenna"; second, a "coil antenna" (sometimes called a "loop" or "frame aerial"), which is usually made by winding a number of turns of wire around a rectangular frame. When this latter type is to be used it is furnished by the maker as part of the receiving set. For most receiving sets an antenna of the first type is used. A good form is a single wire about 50 to 75 feet long with the far end supported 30 to 50 feet above the ground. The higher it is above the ground, the better. The natural wave length of such an antenna is about 200 meters, but the wave length to which the antenna circuit tunes is increased by inserting the inductance coil. The addition of more wires to such a single wire antenna is of but little advantage in securing louder signals. In case the antenna is necessarily shorter than about 75 feet, it is desirable to construct it of two wires placed parallel to one another and about 3 feet apart. The wires should be connected together at the distant end and also at the near end. From this latter, nearby end the "lead-in" wire is brought to the point marked "antenna" on the receiving set.

If necessary, the connection of the lead-in wire may be made to the center of the antenna wires instead of to the end. But this shortens the effective length of the antenna and makes it necessary to add to the series inductance in order to tune to a given wave length, thus somewhat decreasing the strength of the signals.

Figs. 1 to 7 show a number of suggested methods of installing simple antennas. The antenna wires may be strung inside the attic of a house, but care should be taken to locate them as free as possible from proximity to surrounding objects. It is especially desirable to keep the antenna wires some distance from wires used

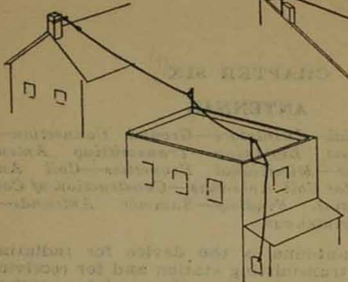

Fig. 1

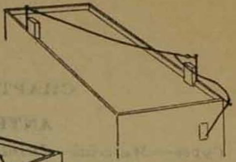

Fig. 2

Fig. 1—A single continuous wire antenna. Where wire passes over edge of roof it is prevented from coming in contact with the building by the insulators at the end of the wood poles.

Fig. 2—A single-wire antenna with lead-in held away from edge of building by insulator on end of pole.

for electric light and power purposes. Antennas should not be run either under or over electric power lines.

For receiving purposes alone it is sometimes satisfactory to use a wire laid near or along the ground, though in this case, as in the case of the coil antenna, which is described in more detail below, it is necessary to have very sensitive amplifiers in order to receive loud signals from a distant station.

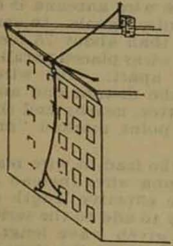

Fig. 3

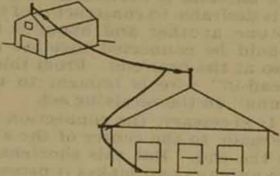

Fig. 4

Fig. 3—A single-wire antenna showing how advantage can be taken of the height of a building to get the necessary length. The horizontal length is very short compared to the vertical. The wire is held away from the building by running it through insulators on the end of poles.

Fig. 4—A single-wire antenna with lead-in held away from edge of roof

Material.—The usual material for constructing antennas is 7-strand No. 22 hard drawn copper or phosphor-bronze wire, though No. 14 or larger bare, hard drawn copper is also quite satisfactory. If the antenna is used mainly for receiving signals from long-wave stations it is desirable to make it considerably longer than the 75 feet previously mentioned.

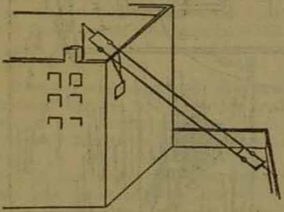

Fig. 5

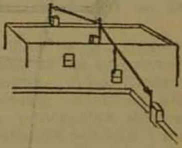

Fig. 6

Fig. 5—A two-wire antenna. The pole on the roof must be sufficiently high or so located that the antenna is held well away from the edge of the roof. This type is not as efficient as one where the entire antenna is above the building.

Fig. 6—A single-wire antenna with lead-in taken from the center.

Insulators.—Each end of the antenna should be insulated from its support by means of an insulator. Almost any insulator of glazed porcelain, glass, impregnated wood, or other material which will not absorb moisture and which has a length of several inches will be satisfactory for receiving antennas. Sometimes two or three porcelain cleats are used in series, the farther one being connected to a rope or heavy cord which is run through a pulley for convenience in raising or lowering the antenna. The lead-in wire should be held away from the building and should enter the room where the receiving apparatus is located through a lead-in bushing or insulator. A small hole may be made in a window pane or the wire may be mounted in any way which will insure its not becoming grounded during wet weather. Inside of the house the wiring should be as short and direct as possible and should not run close to the other wires or water pipes except where the ground connection is made. The receiving apparatus should be located as close as convenient to the entrance of the wire into the room.

Ground Connection.—A good ground connection is usually secured by connection to a water pipe or any thoroughly grounded metal structure. Sometimes

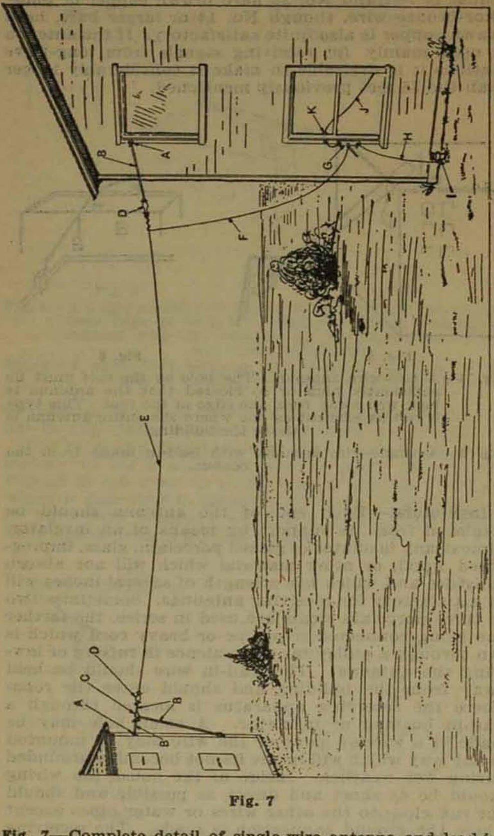

Fig. 7

Fig. 7—Complete detail of single-wire antenna and lead-in: A—screw eye, B—rope, C—pulley, D—insulator, E—antenna, F—lead-in wire, G—lightning switch, H—ground wire, I—ground pipe, J—lead to receiving set, K—insulating tube used where lead-in passes through window frame.

louder signals may be secured by using several different ground connections together. If, however, one of the ground connections is poor and has a long connecting wire it may reduce the audibility of signals below that obtained with a single connection. It is usually not as satisfactory to use a rod or pipe driven into the ground, since the soil surrounding the pipe may become dry and fail to make good connection. To insure good electrical contact with the grounding system, both the pipe and wire connecting to it should be well scraped and the connection made with an approved connecting clamp or else thoroughly soldered. It should be as short as possible.

Protection Against Lightning.—The Fire Underwriters' Rules require the installation of an approved device for protection against lightning. The Underwriters' Rules regarding radio receiving antennas are given in Chapter 7, page 4. The protective device should be connected between the antenna lead-in wire and the ground wire at some point very close to the entrance of the antenna to the building. (See diagram.) The protective device may be mounted on the receiving set itself if this is located close to the point where the antenna lead-in wire enters the building. While it is not required, it is desirable in receiving sets to employ in addition a single-pole double-throw knife switch to disconnect the antenna from the receiving set and connect the antenna directly to the ground. This does not obviate the requirement for the protective device, which must then be connected so that it will be short-circuited by the antenna switch as shown in Fig. 10. It is important that the wires used for the antenna lead-in and for the ground connection be large enough to withstand any danger of mechanical breakage to which they may be subject, while the lead-in wire should be kept from coming in contact with any conducting objects up to the point where it is connected to the receiving set. It is not necessary to insulate the ground wire unless it is an extremely long one. Protective devices, grounding clamps and antenna switches may be purchased from any dealer in radio receiving sets or parts.

Transmitting Antennas.—The most common form of antenna at a radio transmitting station consists of several long, parallel horizontal wires with a "lead-in" wire attached to the center or to one end of the horizontal portion. They are called "flat-top" antennas, of the "T" or the "inverted L" type. The "fan" or "harp" antenna consists of a number of wires extending upward and spreading somewhat from a common point. A good antenna where tall, supporting structures are available is the "cage" antenna, which consists of a number of parallel wires held in a vertical position and separated from one another by spreaders

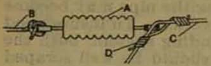

Fig. 8

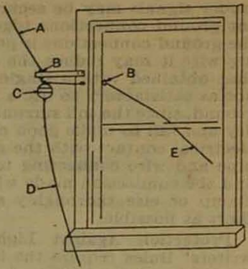

Fig. 9

Fig. 8—Detail at insulator, showing how antenna wire may be passed through the eye of the insulator and be secured by a tie wire. A—insulator, B—rope for raising and lowering the antenna, C—antenna wire, D—tie wire. This arrangement allows the use of a continuous wire forming both antenna and lead-in, thus eliminating the necessity for soldered joints.

Fig. 9—Detail showing arrangement of lightning arrester. A—lead-in from antenna, B—insulating tube through board used to hold lead-in away from building and where lead-in passes through window frame, C—lightning arrester, D—ground wire, E—wire to receiving instruments. Care must be taken that no appreciable strain is placed on the binding posts of the lightning arrester.

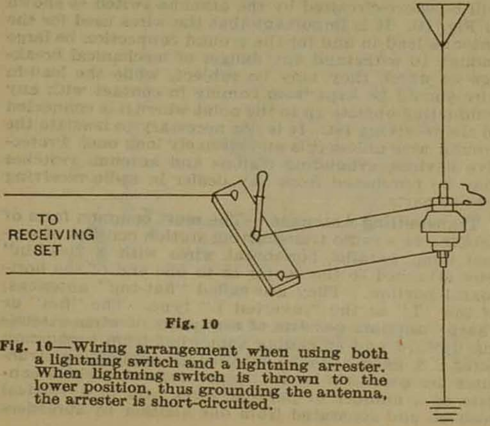

Fig. 10

Fig. 10—Wiring arrangement when using both a lightning switch and a lightning arrester. When lightning switch is thrown to the lower position, thus grounding the antenna, the arrester is short-circuited.

or a barrel hoop. This type can also be used horizontally. None of these forms are superior to the single wire for receiving.

The requirements as to the insulation of antennas used at transmitting stations are more severe on account of the high voltages which are created in the antenna by a transmitting set. The antenna and lead-in wire must be supported at least five inches away from the building wall. The protective device referred to above is not required on transmitting sets, but instead it is necessary to install a grounding switch which will carry a current of 60 amperes and which has a spacing of at least 5 inches between the central contact and either end connection. The wire leading to the ground from this switch need not be insulated, but must, as in the case of receiving installations, be thoroughly strong mechanically.

Counterpoise.—Sometimes it is convenient, instead of making a connection through the receiving set to the ground to replace the ground connection by a wire running to a set of wires, which approximately duplicates the antenna. Such an antenna system is, in reality, a two-plate condenser, the overhead wires forming one plate and the counterpoise the other. This set of wires is called a counterpoise. This is more commonly used at transmitting stations than at receiving stations. It is often convenient to run the counterpoise wires out in several directions from the radio set, supported a foot or so above the ground and insulated from it. The wires should cover an area at least as large as that covered by the antenna and should be placed below the antenna. Under some conditions of the surroundings of a radio station it is found to be an advantage to connect the transmitting set to both the ground and a counterpoise. When a counterpoise is used, both the antenna and counterpoise wires must be connected to the ground through the approved protective device as a protection against lightning. A counterpoise is especially useful where the ground is very dry or where the receiving set is located in one of the upper floors of a tall building where the distance to the ground is especially great.

Directional Properties.—A long, low antenna is somewhat directional in its action, that is, it will receive signals slightly better when the long, open end (the end opposite the lead-in connection) is pointed in a direction away from the transmitting station which it is desired to hear. For short antennas, however, this effect is not very noticeable and it makes little difference in which direction the antenna is strung. For further information regarding the directional and other properties of antennas, as well as suggestions for the construction of antennas and counterpoises of different

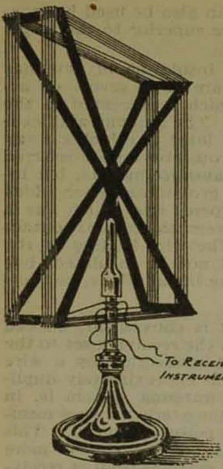

Fig. 11

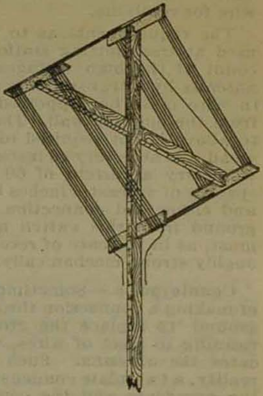

Fig. 12

Fig. 11—Coil antenna mounted on pedestal and arranged to allow revolving coil around its vertical axis.

Fig. 12—Coil antenna on wood frame fitted with end pieces of sheet insulation, such as bakelite or hard rubber. To be mounted so that coil can be revolved. The two ends of the coil shown hanging at side of support are to be connected to the receiving instruments.

types, the reader is referred to the book, "The Principles Underlying Radio Communication."*

Coil Antennas.—A compact and sometimes very satisfactory type of antenna is the coil antenna, which consists of a few turns of wire wound on a wooden frame about four feet square. No ground connection is required on an antenna of this type. Arrangements of such an antenna are shown in Figs. 11, 12 and 13. On account of the small size of this antenna it cannot be used satisfactorily for receiving very distant stations unless sensitive amplifiers are employed with it. However, for nearby stations or where good amplification is available, the coil antenna has many advan-

*The "Principles Underlying Radio Communication" is published as Signal Corps Radio Communication Pamphlet No. 40, prepared by the U. S. Bureau of Standards. It may be purchased from the Supt. of Documents, Government Printing Office, Washington, D. C., for $1.00.

tages. One of the most important of these is its directional characteristic. When the coil is turned so that its plane is in the line of direction toward the transmitting station, the loudest signals are received. When the coil is turned at right angles to this direction, either no signals or only weak signals are received. This makes it possible to receive messages from some stations while avoiding the reception of messages from others, even though the stations are transmitting on the same wave length.

Circuits for Coil Antenna.—For receiving from near-by stations on a coil antenna it is desirable to have an electron-tube detector and two stages of audio-frequency amplification. For receiving from stations 50 or 100 miles away it is advisable to employ five or six stages of amplification. The above statements refer chiefly to the reception from transmitting stations, such as are ordinarily used for radio-telephone broadcasting.

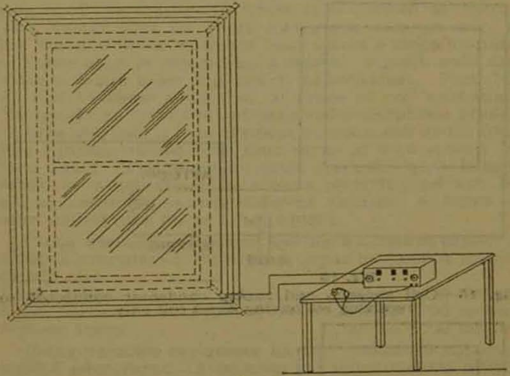

Fig. 13

Fig. 13—A coil antenna made by wrapping a length of wire around a window. The wire is held in place by being forced into saw kerfs in pieces of sheet insulation placed at each corner as shown. This type is of course fixed in position, and full advantage of the directional quality of coils cannot be obtained.

However, if coils are wound with a large number of turns of wire they can be used even with only moderate amplification to receive signals from European stations. A coil antenna may be connected to an ordinary receiving set. The actual connection which is used depends upon the wiring of the inside of the receiving set. If the receiving set or tuner has a series condenser, the coil antenna may simply have its two terminal wires

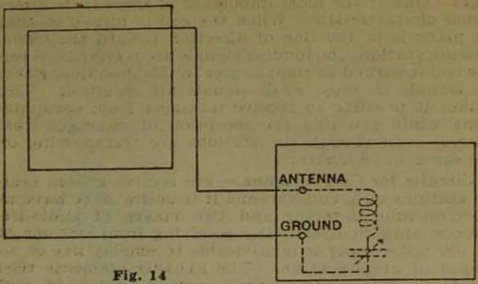

Fig. 14

Fig. 14—Coil antenna connected to receiving set having series coil and condenser.

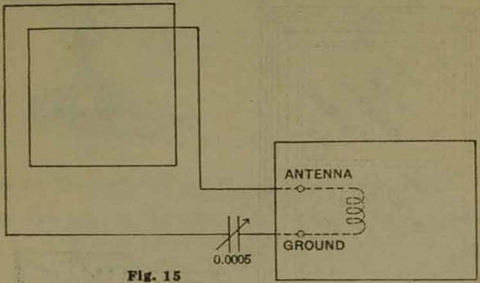

Fig. 15

Fig. 15—Coil antenna and tuning condenser connected to receiving set having series coil only.

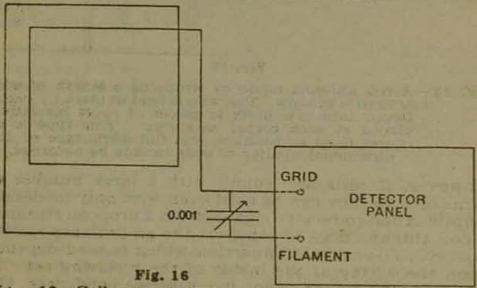

Fig. 16

Fig. 16—Coil antenna and variable condenser connected to detector panel

connected to the antenna and ground binding posts of the receiving set, as shown in Fig. 14. If the receiving set or tuner does not have a series condenser it is necessary to connect a variable condenser in series with one side of the coil antenna, between it and the ground terminal of the tuner. The other terminal of the coil is connected to the antenna binding post of the tuner. This connection is shown in Fig. 15. It is very simple to use the coil antenna and an extra variable air condenser in place of the regular tuner. In this case the condenser is connected across the terminals of the coil, and these two terminals are also connected to the grid and filament terminals of the detector or radio-frequency amplifier which is used. This circuit is very simple, as may be seen by reference to Fig. 16.

Construction of Coil Antennas.—In constructing a coil antenna for receiving, it is desirable to use as many turns of wire as possible without exceeding the wave length of the station to which it is desired to listen. This means that for short waves one can use only a few turns of wire, while for long waves a large number of turns may be wound on a frame. Square coils are usually found most convenient to construct. Figs. 14, 15 and 16 show a number of types of coil antennas. For receiving from the ordinary radio-telephone broadcasting stations it is convenient to use a coil about four feet square, wound with four turns of wire spaced ½ inch apart. The following table gives the wave-length range to which the coil antenna receiving set can be tuned, assuming several different numbers of turns of wire wound on a frame 5 feet square.

Using variable condenser having maximum capacity 0.00065 microfarad. Minimum capacity 0.00004 microfarad:

Four turns	200 to 400 meters
Eight turns	350 to 700 meters
Sixteen turns	500 to 1000 meters

Using variable condenser having maximum capacity 0.0014 microfarad. Minimum capacity 0.00004 microfarad:

Four turns	375 to 650 meters
Eight turns	400 to 950 meters
Sixteen turns	675 to 2300 meters

Direction Finding.—In chapter 2 it was explained that a coil antenna is directional; that is, it receives signals from stations which are in line with its plane and receives practically no signals from stations which are in a direction at right angles. This property of coil antennas is being used to an increasing extent as a method of eliminating the interference which is caused by the working of a number of broadcasting stations on practically the same wave lengths. In order to accomplish this, the coil should be turned

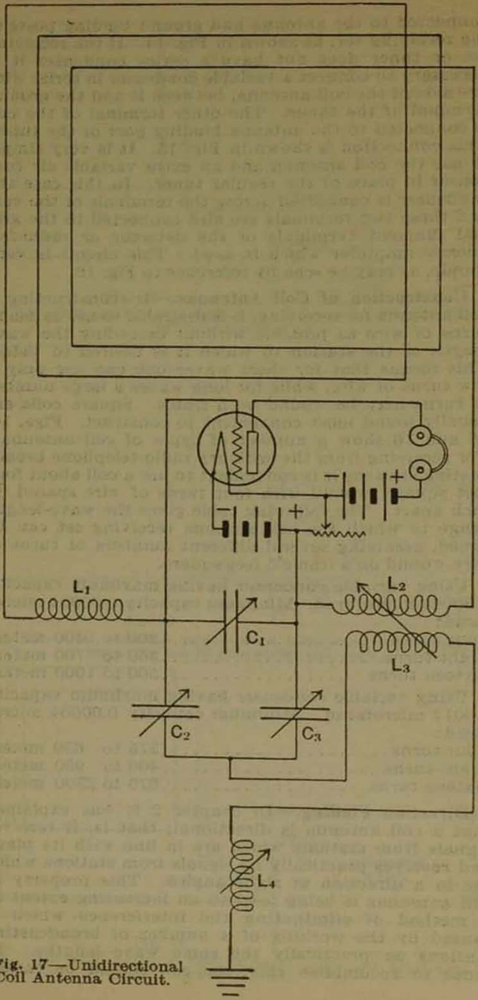

Fig. 17—Unidirectional Coil Antenna Circuit.

about a vertical axis until its plane is at right angles to the station whose signals it is desired to eliminate. It will then be possible to hear stations which are in any direction within 30 or 40 degrees of the direction in which the plane of the coil lies, but nothing will be received from stations in a direction of 90°.

The coil antenna receives equally well from two opposite directions. Recent studies have indicated that it is possible to arrange a circuit which will receive from one direction to the exclusion of signals from the opposite direction. Fig. 17 shows a circuit which may be used for this purpose. Other methods are possible, and it is to be expected that further experiments with combined coils and elevated antennas will greatly improve this unidirectional reception.

Sometimes it will be found that the minimum indication of a direction finder is not very sharp, but that weak signals can be heard, no matter in what position the coil is turned. One cause for this may be a lack of symmetry in the capacity of the two ends of the coil to ground or to the nearby metallic base. Remedies are being developed for such troubles. One remedy is to connect a "balancing condenser," as shown in Fig. 17. This is simply a variable condenser with two sets of fixed plates and one set of moving plates, the moving set of plates being connected to the ground or to one side of the filament ("A") battery. Sometimes even the adjustment of this condenser will not secure a sharp minimum. It is then likely that the waves in the immediate vicinity of the receiving station are bent from their normal position by the proximity of electric power wires, telephone wires, or metal structures. It is an interesting experiment to take a small coil antenna and rotate it in an effort to find the position in which it receives loud or weak signals.

The coil antenna shown in Fig. 17 and the tuning condenser C_1 are of ordinary design and construction, as described above. For example, the coil may consist of 6 turns of wire on a frame 5 feet square, and the condenser may be a variable air condenser having a maximum capacity of 0.001 microfarad. The three upper coils, L_1, L_2 and L_3, may have an inductance of the order of 100 to 1000 microhenries. The entire circuit, with the exception of the coupling of L_2 and L_3, should be arranged symmetrically. The lower coil, L_4, should have the proper inductance to tune the antenna to ground circuit to the wave length of the signals which it is desired to receive. An inductance of several millihenries is likely to be required, since the capacity to ground of the wire forming the coil antenna is ordinarily quite small. Instead of using the specially constructed balancing condenser, two variable air condensers may be used, as shown at C_2 and C_3. These may each have a maximum capacity of about 0.0002 microfarad.

Summer Antennas.—The principal difficulty with radio reception during the summer time is that caused by atmospheric disturbances or strays. If extremely sensitive receiving apparatus is used, the noises produced in the telephone receivers by the strays may be much louder than the signals which it is desired to hear. As the first principle in summer radio reception it may be stated that one should be content with weaker signals; that is, the receiving set and antenna used should not be as sensitive or susceptible to atmospheric interference. This means also that the signals received will not be as loud as might otherwise be secured. It is therefore desirable to use as small antennas as possible while still receiving the desired signals. Another principle to follow is that by increasing the sharpness of resonance or selectivity of the receiving set it can be made less susceptible to the kinds of waves which the atmospheric disturbances produce.

In order to increase the sharpness of tuning or selectivity of a receiving set, coupled circuits should be used. The use of radio-frequency amplifiers will also greatly assist in minimizing the effect of atmospheric disturbances.

Where the transmitting station is nearby, the antenna may be simply a single insulated wire laid along the ground. In case it is desired to tune the antenna circuit as in the case of ordinary elevated antennas, this ground wire should not be longer than 100 feet. There are some circuits, such as the Reinartz circuit, which employ untuned antennas. Even with the ordinary coupled-circuit receiving set it is possible to use an untuned antenna if one is fairly close to the broadcasting station. In this case the length of the antenna need not be as short as that required when tuning is used. A much longer antenna (several hundred feet) may be used, with a probability that the signal strength will be somewhat increased. Long, low antennas of this sort should be placed in such a direction as to point from the receiving set away from the broadcasting station.

When fairly sensitive receiving sets are employed, that is, with one or more electron tubes, indoor antennas are sometimes found as satisfactory as outdoor antennas. An indoor antenna can be made by hanging a wire 50 to 100 feet long onto a picture moulding or other convenient support.

A coil antenna can be wound on blocks fastened to a door. The directional property of the coil can be utilized by swinging the door open and shut.

An antenna can be constructed on an automobile in the form of a skeleton-like cap of wires over the top, a long piece of insulated wire being wound around the machine above the fenders and running boards as a counterpoise.

Plate Condenser Antennas.—A "condenser antenna" is the same thing as an "open antenna," namely, an antenna consisting of two capacity areas. Such a definition is necessary to distinguish from the coil antenna or loop antenna, which is quite a different thing. The more common types of condenser antennas are the usual antennas having elevated wires for the upper capacity area and either a counterpoise or the ground for the lower capacity area. A special type, in which both capacity areas consist of wires or metal plates, both elevated well away from the ground, is sometimes meant when the term "condenser antenna" is used. This "plate condenser antenna" will be dealt with below after some general qualities of condenser antennas are mentioned.

A condenser antenna is primarily a condenser. It is simply the condenser of a radio circuit made large enough to have an appreciable power interchange with the ether, so that it either radiates or absorbs radio wave power. Any 2-plate condenser of large physical dimensions will do; this statement is quite important. In the first place, it must be large; hence the ordinary antenna wire is strung high above the ground. In the second place, it must be a 2-plate and not a multiple-plate condenser. The reason for this may readily be seen from the diagram. In the 2-plate condenser, the

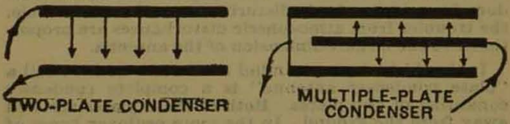

Fig. 18

instantaneous "displacement" current in the space between the plates has a certain direction. In a 3-plate condenser, as shown, the displacement current in one space is opposite in direction to that in the other space between plates. The effects at a distance neutralize each other. This is true, wholly or in part, for any condenser of more than two plates.

At least one of the two plates must be more or less parallel to the ground, or their principal effect will be to transmit the wave into the ground, or, in reception, to be unaffected by the incoming wave. The antenna's effectiveness in either transmitting or receiving depends on the vertical separation of the two plates. An effort is therefore made to raise the upper condenser plate to a considerable height. For reception, however, this is not so important, because a low and relatively ineffective antenna can be compensated by amplification. For this reason small antennas can be used for reception. The use of a wire hung up in the ordinary room is familiar, the lower condenser plate in that case being a mass of metal, such as the house piping.

A genuine "plate condenser antenna" has some advantages in those circumstances where a low or small antenna is possible. It may consist of two horizontal spreads of one or more square yards of galvanized or copper screening, netting, or sheet, with a vertical separation of 6 inches to 6 feet. Another form is simply two horizontal copper wires about 20 feet long, with a vertical separation of a few feet. No object should be allowed to be closer to the edges of the plate condenser antenna than the distance between the two "plates." One of the great advantages of such an antenna lies in this elimination of all objects from the space between the plates. Other forms of open antennas have a great variety of objects instead of merely the ideal (air) between the plates, and such objects are the cause of power loss that diminishes the signal strength. When used outdoors, the lower plate of the plate condenser antenna should have considerably more spread than the upper plate, so that the effect is confined to the air between the plates instead of spreading around the edges and possibly to ground.

An advantage of small antennas, such as the plate condenser antennas here described is the relative freedom from atmospheric disturbances. As a rough rule, the troubles from atmospheric disturbances are proportional to the largest dimension of the antenna.

It should be borne in mind that what we here call a "plate condenser antenna" is a complete condenser consisting of two plates. Both of these plates are well away from the ground. In the more ordinary types of open antennas, the lower plate (counterpoise) may be close to or on the ground, or may even be the ground. As to the question how high above the ground a plate condenser should be placed, it is desirable to have the lower plate at a height above the ground greater than the distance between the plates. When used indoors, it is desirable to maintain the upper plate also at a distance from the ceiling or other objects greater than the distance between the plates.

As to the signal intensity obtainable with a small plate condenser antenna as described, for the broadcasting frequencies the received signals are of about the same loudness as with a coil antenna of the same general dimensions. It is better than the coil antenna for the higher broadcasting and the amateur frequencies. It is usually not as good as a well installed antenna of the single-wire type.