CHAPTER 18

Antenna Systems

General Terms.—The term "**Aerial**" generally is applied to that portion of the antenna which is elevated or the flat top portion and the term "**lead in**" applies to the connection between the aerial and the receiver. The antenna constitutes the combination of the *aerial* and the *lead in*.

By definition an aerial is a conductor or a system of conductors suspended in the air and insulated at the ends for receiving or transmitting radio waves.

Aerials may be classified: 1. According to the number of wires as single or multi-wires, and 2, according to their geometrical design or shape as:

a. Inverted L type.
b. Tee (T)
c. Cage.
d. Fan.
e. Umbrella.
f. Loop (Solenoid spiral, pancake).
g. Doublet.
h. V-doublet.
i. Spider-web.

etc.

Broadcast Band Receiving Antennas.—The simplest type of aerial for general broadcast reception especially in rural districts where man-made static is negligible, is the inverted L type shown in figs. 1 and 2.

Ordinarily the antenna will be erected either on the roof of a building or suspended between that roof and a pole, as shown in fig. 2, which consists of a single wire inverted L antenna suspended from the house proper to the garage roof, by means of a pole. The purpose of the pole being to elevate the aerial wire.

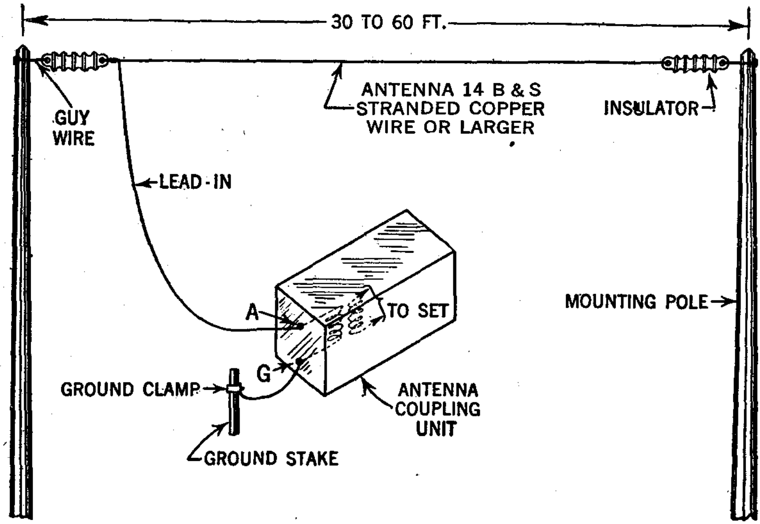


FIG. 1—Outside inverted L-type antenna, with connected lead-in wire.

When erecting an antenna it is of the utmost importance that the horizontal part be removed as far as possible from such objects as trees, walls, chimneys, gutters, telephone and power wires, both to avoid induction from them which may make objectionable noises in the receiving telephone as well as the receiver, and to *avoid injury.*

There has occurred many serious accidents due to ignorance and carelessness in erecting radio antennas too close to high voltage power lines.

How an Antenna Works.—Before a discussion of the relative merits of each type of aerial, it is necessary to have a clear conception of how the various aerials receive the radio frequency currents emitted from the broadcasting stations.

In order that an aerial may receive maximum energy from the space in which it is suspended, it is necessary that the aerial be tuned to the broadcasting station, i.e. be resonant at the same frequency.

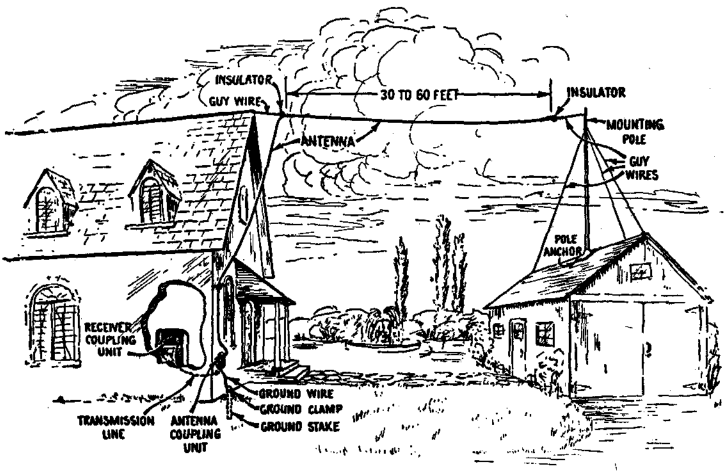


FIG. 2—Typical single-wire antenna installation. (Courtesy R.C.A. Mfg. Co.)

Theory of Tuning.—In an aerial circuit the high frequency potential developed by the incoming waves from the transmitting station causes an *a.c. current* to flow in the aerial.

The frequency of such a current is the same as that in the transmitting aerial. The magnitude of the current (I_a) through the aerial depends upon the value of the induced voltage (E_a)

and the effective aerial impedance (Z_a), the relations of which according to Ohm's law may be written $I_a = \frac{E_a}{Z_a}$ ampere.

By varying the impedance (Z_a) of the aerial circuit until it becomes in resonance with the frequency of the induced voltage a comparatively large current may be obtained.

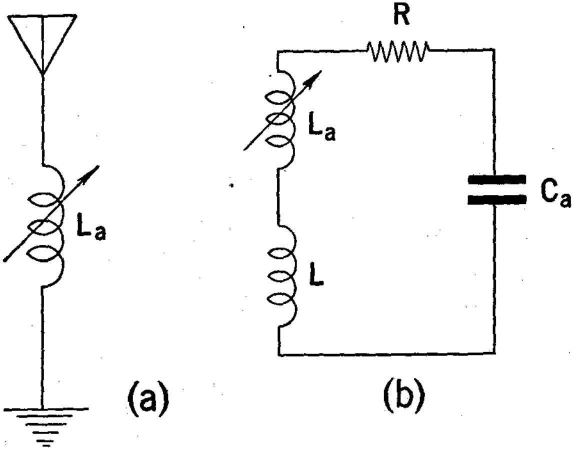


FIG. 3—(*a*) indicates variometer tuned aerial circuit; (*b*) indicates equivalent closed aerial circuit.

When the circuit is in resonance the inductive and capacitive reactance will be equal and the impedance of the aerial becomes equal to the effective resistance (R).

Natural Frequency and Wave-length of Aerials.—The wave-length to which an aerial may be tuned is called its *natural wave-length* or *frequency*. The frequency corresponding to the *natural frequency* (f) of an aerial may be derived by remembering that the conditions for resonance is that the inductive reactance ($2\pi fLa$) must equal the capacitive reactance $\frac{1}{2\pi fCa}$ or

$2\pi fLa = \frac{1}{2\pi fCa}$ from which

$$f = \frac{1}{2\pi\sqrt{La \times Ca}} \text{ cycles per second.....(1)}$$

In the above equation La and Ca are given in henries and farads respectively.

In a similar manner if (La) represent the inductance and (Ca) the capacity in micro-henries and microfarads respectively, then the natural wave-length

$$\lambda = 1{,}885\sqrt{La \times Ca} \text{ meters.............(2)}$$

It is obvious that both the inductance and the capacity depends upon the length and shape of the aerial.

For the inverted "*L*" type shown on page 377 each of those quantities are more or less proportional to the total length of the aerial wire as measured from the remote end to the ground connection.

That this is true must be self-evident as it has previously been shown that the natural wave-length is proportional to $\sqrt{La \times Ca}$. Now then, in order to be able to tune a receiving aerial circuit over a fairly wide range of wave-lengths, a tuning arrangement for vaying this product of inductance and capacity is all that is necessary.

How the Wave-Length of an Aerial May Be Increased.—It has been found convenient to include an inductance in the down lead wire to the receiver for the purpose of passing the received signal voltage to the set. Sometimes this added inductance coil is connected directly to the set and at other times it is coupled magnetically to the tuned circuit.

When in the closed circuit type, a coil of inductance L micro-henries is connected in the down-lead of an aerial whose inductance is La micro-henries, the new wave-length is being given by

$\lambda = 1{,}885\sqrt{(L+La)\ Ca}$ meters, that is assuming that the coil itself has no capacity. Again the corresponding frequency to which the aerial circuit is now tuned is given by

$$f = \frac{1}{2\pi\sqrt{(L+L_a)C_a}} \text{ cycles per second.}$$

The units in this case being henries and farads.

Aerial Wire (Size and Material).—In order that the resistance of the antenna be as low as possible No 14 or 12 B & S stranded copper wire is most generally used.

This wire has a high factor of conductivity, is mechanically strong and can easily be soldered. Antenna wire of this type, of suitable length, is nowadays carried as standard, and can be obtained at any hardware store.

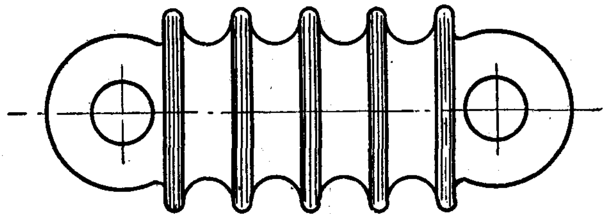
The Importance of Insulators.—One important factor when erecting an antenna is to obtain good insulators and use a sufficient number of them.

Approved wire insulators are usually made of Pyrex glass, porcelain, etc. and are made with a hole or eye at each end to facilitate the fastening of the wires.

Fig. 4 shows a ribbed constructed insulator, the purpose of the ribbons being to increase the leakage path and to increase the insulating property of the insulator.

If small insulators are employed, it is necessary to connect two or more in series with short pieces of wire to increase their insulating property. It is obvious that insulators should *not* be inserted in the aerial at random, and should not be used for example, to connect several pieces of aerial wire to obtain the required length of aerial.

As pointed out in the beginning of this chapter, an aerial has only one insulator at each end, except in case of doublet aerials (which actually consist of two separate aerials) in which case three or four insulators are used. See fig. 5.



STRAIN INSULATOR

FIG. 4—The ribbed construction serves to mitigate leakage of the weak signal energy received by the antenna. This leakage may assume considerable proportions especially during wet weather, hence the necessity of providing good antenna insulators.

Lead-In Conductors.—Lead-in conductors should be kept away from the house and should not approach the side of the house closer than six inches.

This is accomplished by insulator supports as shown in fig. 6. The insulator support should be properly fastened by means of wooden screws or brackets. Lead-in conductors should be of stranded copper wire, not smaller than No. 14 B & S gauge.

As in the case of the aerial the lead-in conductors should be kept away from obstructions such as trees, walls, chimneys, gutters, telephone and power wiring. It should also be noted that the lead-in conductor should be of one continuous piece with the aerial.

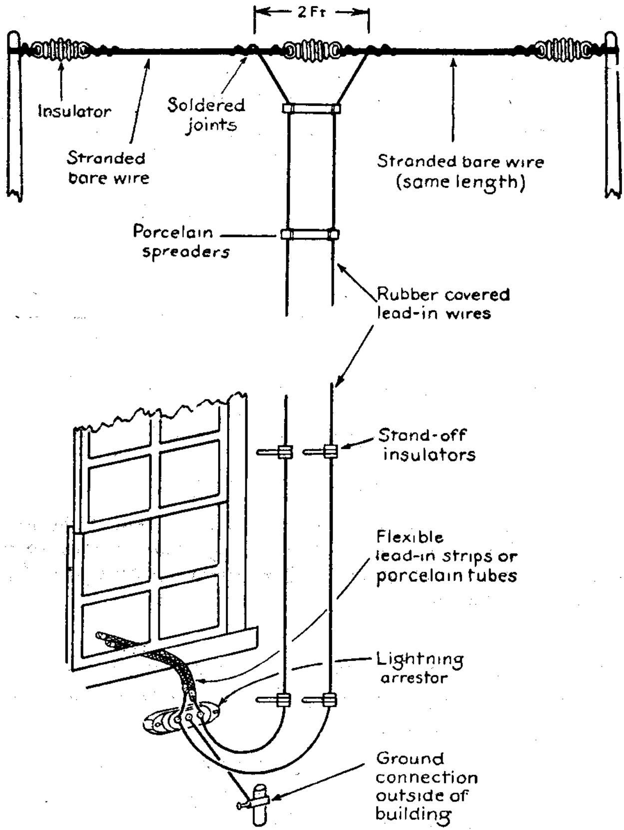


FIG. 5—Double antenna may be of the tuned or untuned type. The tuned type have definite aerial lengths (the horizontal portions) for respective wave-lengths or frequencies, and the untuned have not; the untuned are, therefore, suitable for a wide range of short-wave frequencies. The lead-in wires, or transmission lines, pick up more noise or interference on short waves than they do on long waves; therefore transposed or closely parallel lead-in wires are used. The drawing shows a typical short wave reception antenna.

In entering the building two methods are commonly employed. 1, Entering the conductor through the lower part of a window adjacent to the receiver by means of flat flexible insulated strips, or 2, entering the conductor through a special condulet or porcelain lead-in insulator very similar to that employed in electrical wiring.

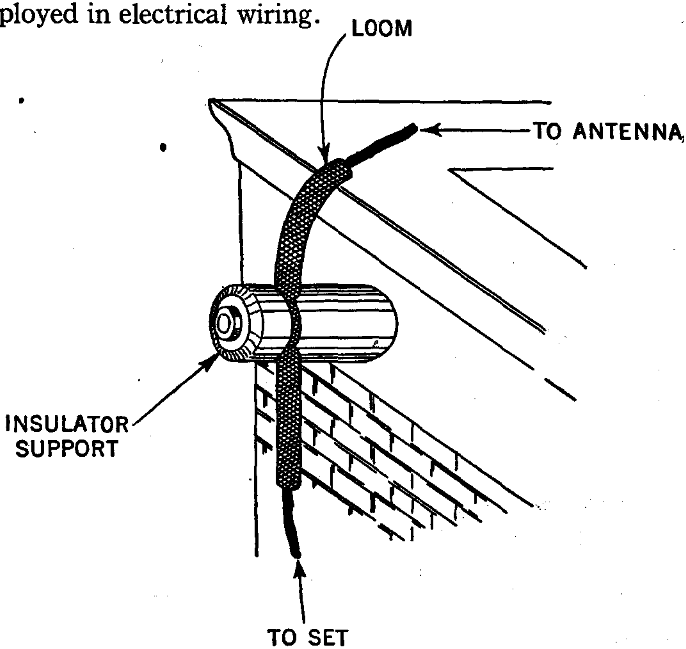


FIG. 6—Demonstrating how a short section of loom is inserted to protect the aerial at the point where the line is supported by a nail-on knob. The loom eliminates swinging and forcing of too sharp a bend in the wire.

When installing the condulet, precautions should be taken that the conductor is sloped outward as shown in fig. 8, this to prevent rain or moisture following the lead-in conductor to enter the building.

Lightning Arresters.—The function of the lightning arrester is to prevent sudden voltage surges originating in the aerial (as during a thunderstorm) entering the receiver. Essentially the lightning arrester is a device which provides a very small air gap between the aerial and the ground and through which sudden voltage gradients may escape to ground. See fig. 9.

The rules of the Board of Fire Underwriters require an approved form of lightning arrester. The lightning arrester

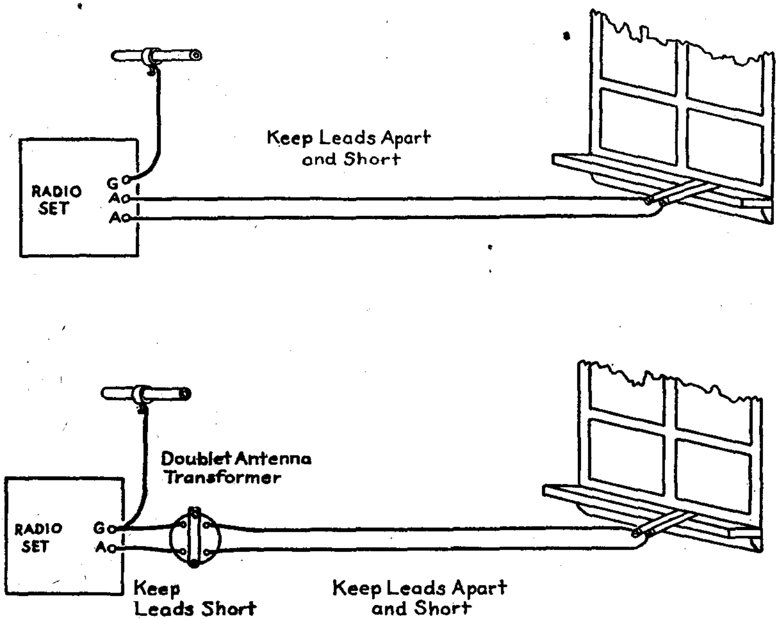


FIG. 7—Showing method of carrying antenna leads through the windows—using either porcelain tubes or flexible lead-in strips. Upper figure shows connections where antenna transformer is embodied in the radio receiver, and the lower, where it is connected outside. Transmission lines must be well insulated and stand off from the walls, as well as kept away from wires, drain pipes and other metallic surfaces and conductors.

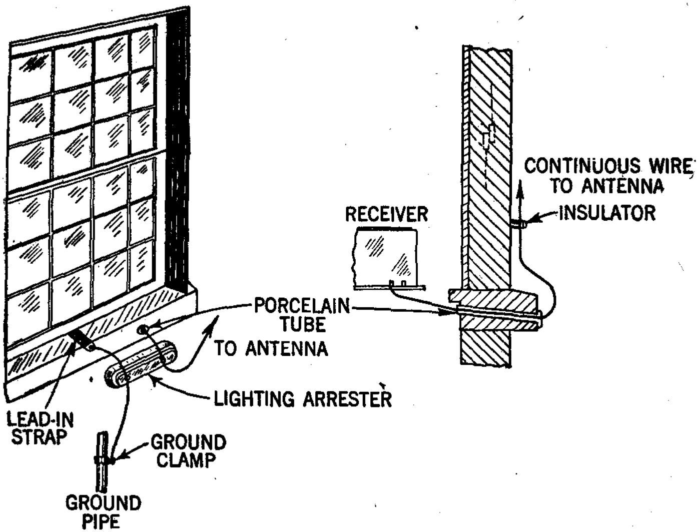


FIG. 8—Conventional method of installing inverted L-antenna lead-ins.

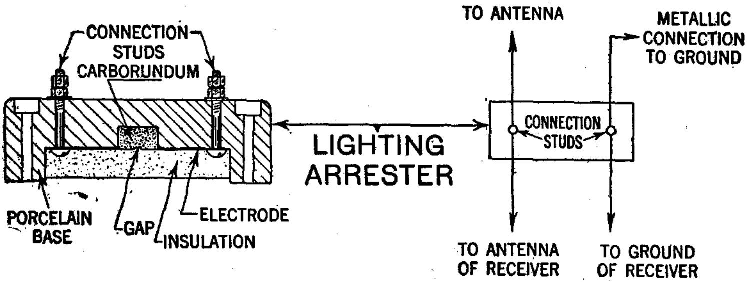
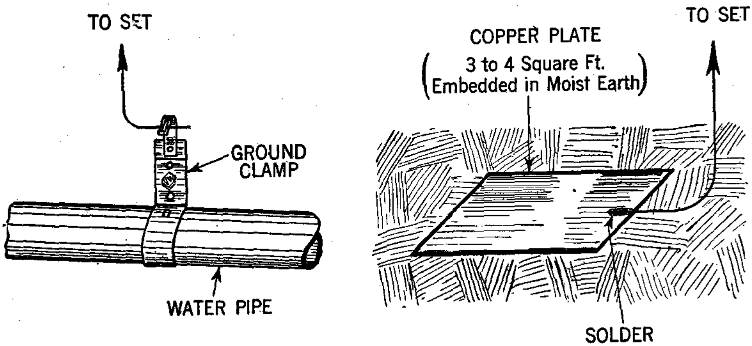


FIG. 9—Lightning arrester detail and diagram of connection.

should be designed to operate at a voltage of 500 volts or less, and should be properly connected and located either inside the building at some point between the entrance and the set which is convenient to ground, or outside the building as near as possible the point of entrance.

Particular precaution should be taken that the lightning arrester be not placed in the proximity of easily ignitable material, or where exposed to inflammable gases or dust, or flying of combustible substances.

Grounding Conductor.—Since it is necessary that the grounding conductor be of low resistance, it should be of the same size as the lead-in conductor and should in no case be smaller than No. 14 B & S gauge.



FIGS. 10 and 11—Two methods of ground connection.

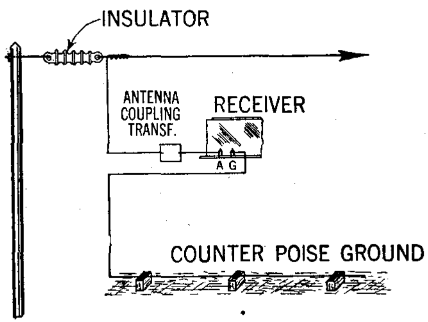
Care should be taken to make this connection as short and straight as possible to the nearest water pipe where a good metallic connection should be made. A suitable metal ground clamp designed especially for this purpose can be obtained in any hardware store.

Where a water pipe is not convenient for use as a ground connection, other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building.

When an artificial ground connection has to be made, a large copper plate or a bucket buried in a well or in moist earth may be employed. Under no condition should *gas pipes* be used for ground connection.

In case of exposure to mechanical injury, the ground conductor should be adequately protected.

Counterpoise Ground.—In locations where a satisfactory ground cannot readily be secured because of dry soil, a *counterpoise* is used. This consists essentially of a second aerial suspended on supports preferably one foot above the ground and insulated from the latter. See figs. 12 and 13.



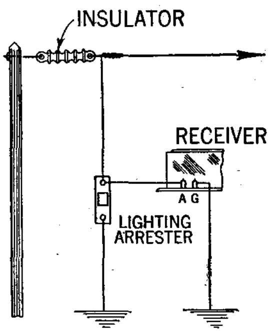


FIG. 12—Counterpoise and connection. Theoretically the counterpoise forms one plate of a condenser of which the main aerial is the other plate.

FIG. 13—Method of connecting lightning arrester to the aerial.

The counterpoise should run parallel with and preferably underneath the main aerial, though if necessary it may be offset to one side.

The action of the counterpoise over the ground is exactly as that of a condenser; in fact it is a *large condenser* conforming to all of the laws pertaining to condensers. In the case of aircraft or automobiles, the body (being metallically bonded together) to which the grounding conductor is connected, acts as a counterpoise.

Various Types of Antennas.—Among the various types of antennas enumerated in the beginning of this chapter, it should be observed that each geometrical form has particular characteristics desirable for the particular operating conditions as shown in figs. 14 to 19.

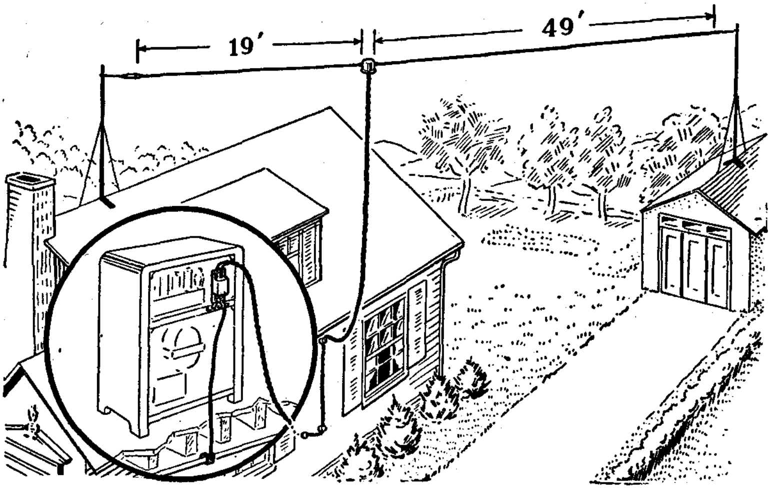


FIG. 14—Illustrating how a doublet receiving antenna may be erected. This antenna consists of a special doublet, a transposed transmission line, and antenna junction box and a receiver coupling unit. An antenna of this type is an efficient pick-up medium giving high signal strength over a wide frequency range.

The doublet antenna shown in fig. 14 has been found to be highly efficient for short wave reception, and should for best results, have a length of ¼ of the desired wave-length. A close approximation of the total length for the two dipoles of the doublet may be obtained by dividing 492,000 by the desired frequency in kilocycles. The lead-in conductors (or transmission line) are

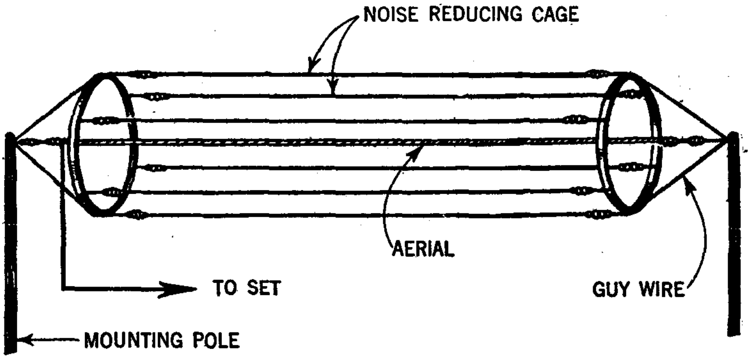


FIG. 15—Cage antenna. A type frequently used at transmitting stations.

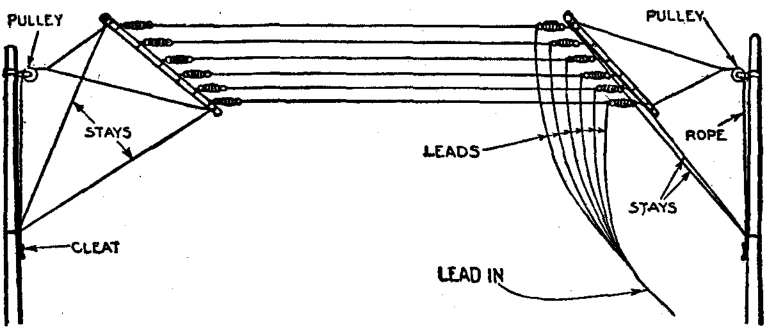


FIG. 16—Multi-wire inverted L (flat top) outside aerial. Where the distance between supports is limited, the necessary length of aerial may be obtained by running two or more lengths of wire parallel as shown.

transposed at intervals as shown in fig. 14. This method is employed in order to eliminate the pick up of man-made static or local interference.

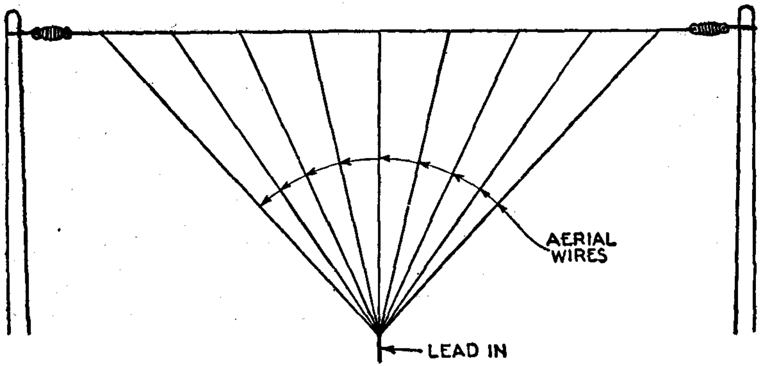


FIG. 17—Fan aerial.

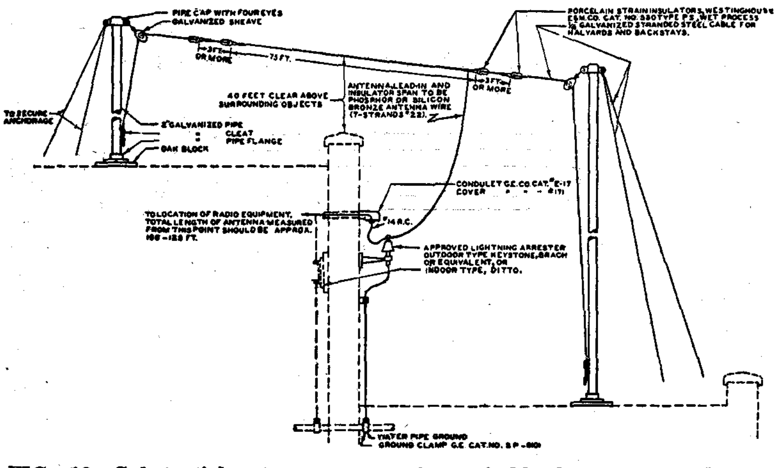


FIG. 18—Substantial antenna construction suitable for apartment house, school or hotel.

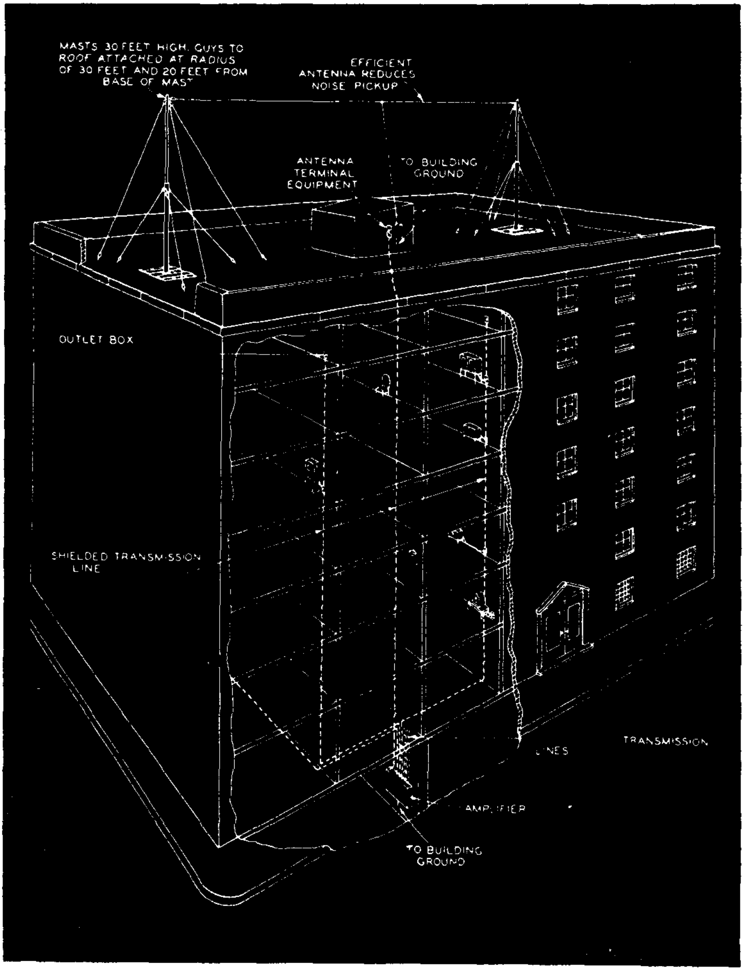


FIG. 19—Antenna installation for apartment house or hotel. To avoid duplicate and inefficient antenna installations where many radio sets are located in one building, a single, properly installed antenna is most suitable.

Example.—*What is the natural wave-length of an aerial the inductance of which is* 10 *microhenries and the capacity* 0.00025 *microfarads? If a tuning inductance of* 150 *microhenries be placed in series with it, what is the resonant wave-length?*

Solution.—The formula for the natural wave-length of a series resonant circuit is $\lambda = 1{,}885\sqrt{LC}$ in which λ is in meters, L and C are the inductance and capacity of the circuit expressed in microhenries and microfarads respectively. In the present example

$$\lambda = 1{,}885\sqrt{10 \times 0.00025} = 1{,}885 \times 0.05 \text{ or } 94 \text{ meters}$$

approximately.

With the addition of the tuning inductance of 150 microhenries the total inductance becomes 160 microhenries. The resonant wave-length is now $\lambda = 1{,}885\sqrt{160 \times 0.00025} = 1{,}885 \times 0.2 = 377$ meters.

Example.—*Assuming that the total inductance of the aerial circuit in the preceding problem is concentrated in the tuning coil, what parallel capacity is required to tune to* 500 *meters?*

Solution.—Let C represent the extra capacity required since this is placed across the tuning inductance, it may be considered to be in parallel with the existing natural capacity of the aerial, so that the total capacity across the tuning circuit is $(C+0.00025)$ Mfd. The required wave-length is given as 500 meters. Applying the same formula as before, the following is obtained:

$1{,}885\sqrt{160(C+0.00025)} = 500$, that is

$3.77\sqrt{160(C+0.00025)} = 1$; squaring both sides of the equation,

$14.2129 \times 160(C+0.00025) = 1$

therefore $C+0.00025 = 0.00044$

and $C = 0.00019$ mfd.

Example.—*Assume in an aerial with the constant as given, that it is required to tune it over a band of wave-lengths varying from 250 meters and upward by means of a coil and a parallel condenser of the variable type, having a maximum capacity of 0.0005 microfarads and a minimum capacity of 0.00003 microfarad, what value of coil induction should be used?*

Solution.—In substituting the known values in equation (2) the following is obtained:

$$250 = 1{,}885\sqrt{(L+10)\ (0.00003+0.0002)}$$

from which $L = 66.4$ micro-henries.

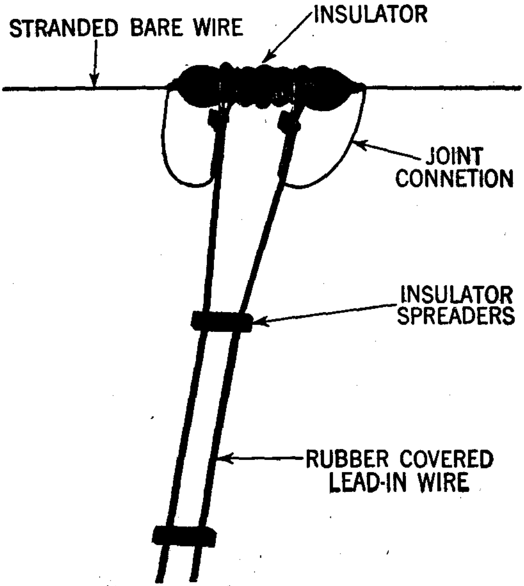


FIG. 20—Illustrating good spacing arrangement for doublet type antenna.

Using a coil with this value of inductance the aerial circuit tunes to 250 meters with the condenser set to its minimum value.

If now the condenser be set to its maximum value of 0.0005 *M.f.* the maximum wave-length of the tuning range is obtained by equation

$$\lambda = 1{,}885\sqrt{(66.4+10)\ (0.0005+0.0002)} = 436 \text{ meters.}$$