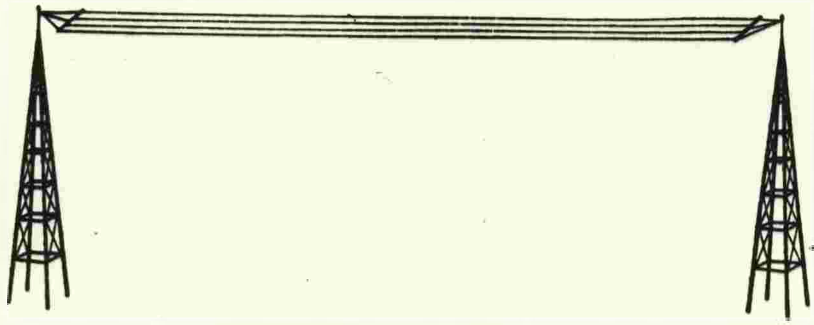

LESSON
11 R

# ANTENNA SYSTEMS

RADIO-TELEVISION TRAINING SCHOOL, INC.
LOS ANGELES
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# ANTENNA SYSTEMS

THE NATURE OF RADIO TRANSMISSION. In a standard broadcasting station, two fundamental operations take place - a continuous series of high frequency waves are generated, and these waves are moulded or modulated in intensity according to the intensity of the sounds that strike the microphone in the studio. If the broadcast station operates at a wavelength of 400 meters, then a radio frequency of 750,000 current waves is generated cycles per second. Let us consider a very simple case and assume that the note "A" which has a frequency of 435 cycles per second, is produced in front of the microphone. Instantly the high frequency current waves would be divided into groups or trains occurring at the rate of 435 cycles per second, and the waves would also be shaped or moulded according to this sound, whether it came from a piano or cornet. Each group of waves would then consist of 750 thousand divided by 435 or 1702 high frequency waves. The number of groups of waves per second would be 435 and the shape of the individual waves would depend upon the quality of the sound.

This process of moulding the radio frequency carrier wave in accordance with the audible sound that are to be transmitted, is called <u>amplitude modulation</u>. The two are developed independently, one the high frequency carrier and the other the audio frequency signal received from the microphone. The audio wave is impressed upon the radio wave and a single complex train of current waves are produced as explained above. These, when transmitted to the aerial, create the correspondingly modulated electro-magnetic waves that are radiated outward into space. As the waves move onward and are intercepted by a receiving antenna, they induce in it a current of the same nature as originally flowed in the transmitting aerial. This current is of a compound nature, consisting, as was explained, of the radio frequency carrier and the audio frequency signals. In order that this current can be rendered fit for audible reproduction in the speaker, it must be undone or demodulated.

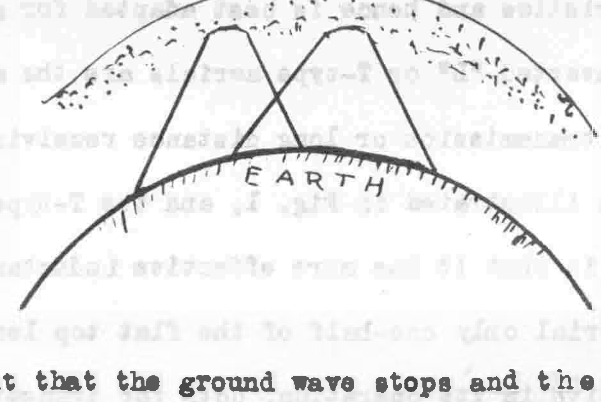
that is, the audio frequency voice current must be separated from the carrier current. It is the voice current only that is useful for reproduction. This demodulation process is commonly known as detection, and the stage of a receiving circuit in which it takes place is called the detector. Although it is generally said that the detector reduces the radio frequency oscillations to an audio frequency, in reality it separates the audio frequency voice current from the high frequency carrier waves.

Radio communication is divided into three general fields, short wave, medium wave and long wave communication. The designations refer to the lengths of the radio waves that are used to convey the messages. Broadly speaking, these three groups of wave lengths are used for the following classes of service. Long-wave transmission (5000 to 20,000 meters) is used for long distance communication such as transoceanic, medium-wave transmission (1000 to 5000 meters) is used for government stations and by industrial concerns, and short-wave transmission (below 1000 meters) for ships, broadcasting stations and amateur use.

## WAVE PROPAGATION

The waves that are emitted from a broadcast antenna are divided equally into two parts. They are of electromagnetic wave and electrostatic waves. The electrostatic wave and their corresponding electromagnetic waves are always at right angles to each other. These two waves set up a cross sectional area of lines of force. These lines of force set up what is known as a wave front. The direction of the wave is always perpendicular to the wave front. The polarization of the antenna is the same as that of the wave leaving it. The radiated wave is caused to travel by two paths to the receiving set. For broadcast reception the most important wave is the ground wave. This wave follows the contour of the earth, very close to the ground. The other wave is called the sky wave used for long distance communications. The sky wave can be refracted or bent back to earth. This is accomplished by the fact that there is a layer of ionized air which extends up into the upper atmosphere. This ionized layer is caused by ultra-violet rays which are emitted from the sun which causes clouds of electrons to be present in the upper strata of air. These electrons cause the waves to be bent back to earth depending upon how many free electrons there are in this upper layer of air and depending upon the frequency of the wave, we can get more or less refraction. In the lower frequency we will get more refraction than in the higher frequencies. The distance that the ground wave travels in the lower frequency is about 50 to 100 miles and frequency up to about 10,000,000 cycles per second as the ground acts as a good conductor. Frequencies above 10,000,000 cycles do not travel as far because at that high frequency, the earth loses some of its conductivity. In other words, as the frequencies go up, the distance that the ground wave will travel decreases.

Depending upon the angle that the wave enters the ionized layer, it will be bent back to the earth at that same angle.




Between the point that the ground wave stops and the sky wave is bent down to earth again, there will be a dead spot - that is, no radio reception will be heard. This distance is called a skip distance. The skip distance will vary depending upon atmospheric conditions, the time of day and the season of the year. Skip distances will also differ at different frequencies. The effect of the ionized layer will also be different if the broadcast is coming from east to west or from west to east because of the different times of the day and the different position of the sun. These dead spots have been taken care of by intermediate or relay stations which pick up the signals and amplify them and send them out again.

## TYPES OF RECEIVING ANTENNAS

The antenna, in its common form, consists of a network of wires suspended in space; and in a receiving station it is used to intercept the radio ether waves as they move through space, and to absorb part of their energy for operating the receiving apparatus. In a transmitting station this same network of wires serves a different purpose - here it is the source from which the radio waves are radiated or flung out into space. For a transmitting station it is desirable to have the antenna of special design and construction in accordance with the wave length and power of the station; but for a receiving antenna the actual dimensions are not quite as important, for here the available space and the installation cost are generally given more consideration.

Several types of antennas have been devised and are now in use, but each has its own special characteristics and hence is best adapted for a certain class of service. The flat top inverted "L" or T-type aerials are the most common forms of aerials used for amateur transmission or long distance receiving stations. The inverted L-type aerial is illustrated in Fig. 1, and the T-type in Fig. 2. The L-type has the advantage in that it has more effective inductance, and in considering the length of a T-type aerial only one-half of the flat top length can be used. The L-type is somewhat directive in its operation, both for transmitting and receiving. For receiving a long-distance station the free end of the L-type aerial should point in a direction away from the station to be heard. However, although it acts best for one direction, it serves almost as well for receiving stations from all directions, for the variations with different directions produce only a small appreciable effect.

The fan type or vertical aerial, which is not used very extensively, consists of a series of vertical wires arranged like the ribs of a fan between two vertical supports or other convenient structures of sufficient height. These wires are all connected electrically at the bottom to the lead-in wire which enters the station. Although this type of aerial is an excellent radiator, it is very costly in construction, and nearly as good results can be obtained from a flat top aerial. The umbrella type aerial is little used commercially and we will not go into a discussion on this type of antenna.

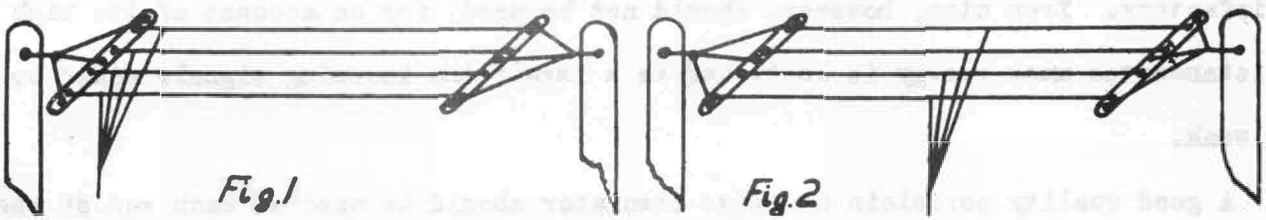


Fig.1 Fig.2

THE BEST RECEIVING ANTENNA SYSTEM

Since the antenna of a receiving station serves to intercept the radio waves and to absorb some of their energy, the more efficient it is the more energy will be absorbed and the louder will be the signals produced by the receiving set. The question then arises, what is the most efficient receiving antenna.

Extensive experimental work has proven that the best form of antenna to use is a single wire from seventy-five to one hundred feet in length and stretched in a straight line between two rigid supports. It is important that the antenna be mounted so that it cannot sway in the wind, for swaying in space produces undesirable noises in the receiver.

Only pure copper wire, either solid or stranded, should be used. Since copper corrodes easily, it is advisable frequently to brighten the surface of the wire by going over it with sandpaper. It would be better to use a copper enameled wire, for the enamel protects the wire and therefore lengthens its useful life. An excellent antenna wire is gold-plated copper. The gold does not corrode; and since it is a good electrical conductor, it forms an almost ideal antenna. The cost is not prohibitive, and excellent results are secured with it.

Aluminum wire is used to some extent, but it tears easily when in a long span; and it is also difficult to make good soldered joints with it. Another form of wire which recently came into considerable use, is copper-clad steel wire, which consists of an inner core of steel surrounded with a shell of copper. The steel core gives the wire great tensile strength; and since high-frequency currents travel only through the outer layers of a conductor, this form of wire is very satisfactory. Iron wire, however, should not be used, for on account of its high resistance too much energy is lost, and as a result the incoming signals would be too weak.

A good quality porcelain or glass insulator should be used at each end of the antenna. Moulded or composition insulators should be avoided, for they have a tendency to absorb moisture and thus allow some of the received energy to leak off into the ground to no useful purpose.

The longer the antenna, the greater will be the amount of energy received; but the disadvantage of a long antenna is that it renders the set much broader in tuning. Therefore, in a congested district where good selectivity is essential, a shorter antenna will be superior, for even though some volume may be sacrificed, much sharper tuning is possible with it. In rural districts, on the other hand, a long antenna gives better service. Another advantage of a short, single-wire aerial is that static has less chance to cause trouble. Static always tends to accumulate on the aerial, and the greater the network of wires that comprise the aerial, the greater will be the amount of static that collects on it. Static always renders radio reception noisy, and therefore a shorter aerial will always produce cleaner signals in the loud speaker.

LOOP ANTENNAS

The loop antenna is a form of indoor antenna suitable only for receiving purposes and not for transmission. Under favorable conditions the loop antenna is inferior to the outdoor antenna as far as distance reception and loudness of the signal received is concerned, but a loop antenna is smaller than the outside regular antenna and will not pick up man made noises or static as much as the other type of antenna. The loop antenna is used extensively today in small table models and portable sets, and although the signal strength coming in from a loop antenna may be weak, the modern radio sets have the ability to give such high amplification that this will compensate for any weak signal. Loop antennas consist of a number of turns of wire wound to a diameter of one to three feet. The two ends of the loop are connected to a variable condenser which is in series with the grid of the radio frequency tube which forms a circuit that will tune in the frequency of the incoming signal.

## COUNTERPOISE ANTENNA

A counterpoise is a system or group of wires mounted a few feet above the ground or roof directly below the antenna, and is used as a ground connection in places where the ground is very dry or where it is difficult to establish a good ground contact. A good form of counterpoise consists of a fan-shaped network of wires extending radially (like the spokes of a wheel) from a point below the end of the aerial from which the lead-in is taken. It is very important that the counterpoise be well insulated from the earth or any surrounding objects, for otherwise its effectiveness is greatly diminished. If a T-type antenna is used, the counterpoise should preferably be circular and extend well beyond the antenna in all directions.

## THE ANTENNA LEAD-IN

The lead-in is that conductor or wire by means of which the energy absorbed by the antenna system is conducted to the receiving set. In most respects this lead-in is just as important as the antenna itself, for if there are weak links in it, of what value really is a highly efficient antenna if some of the energy is allowed to escape or leak off in the lead-in. An ideal arrangement would be to have the antenna and lead-in one continuous wire leading directly to the receiving set. But this is not always possible, and the next best step is to solder the lead-in securely to the antenna wire. A well soldered joint is practically as efficient as though the antenna wire were continuous.

In order that the lead-in wire will not offer excessive electrical resistance, and that it will be of sufficient mechanical strength, the conductor should be of copper, or approved copper-clad steel, or other low-resistance metal that will not corrode readily. In no case is it advisable to use wire smaller than No. 16, except bronze or copper-clad steel which may be No. 17.

To prevent the lead-in from coming in accidental contact with the other wires on the outside of the building, it should not come nearer than six inches to electric light and power wires. Whether bare or insulated wire be used, the lead-in should always be held secure by means of porcelain or glass insulators. This will prevent leakage even though some of the insulation on the conductor should be destroyed. Where the lead-in enters the building, it should pass through an insulating bushing or tube of non-absorptive material, such as glazed porcelain. This bushing or tube should slant upward toward the inside so that rain or snow cannot enter the building. The bushing serves to prevent the lead-in from coming in contact with any other electric light, power or signal and telephone wires that may be within the wall.

Two important general rules to observe are the following. Never run the antenna or lead-in very near any metallic object that is grounded, such as metal roofs, fire-escapes, vent pipes, etc., for these all have a tendency to absorb some of the intercepted energy and conduct it down into the ground. In the second place, never run the antenna or lead-in parallel with an electric light, power or telephone wire, for by induction, currents will be set up that cause unpleasant noises in the receiving set. If the antenna must be erected near trolley wires or high-power electric lines, it should always run at right angles to these, for then the inductive interference is reduced to a minimum.

## THE ANTENNA CIRCUIT

The antenna system in a receiving station as was heretofore explained, serves to intercept the radio waves as they pass through space and to absorb some of their energy. By induction an electric current is caused to flow in the antenna which is of the same nature and frequency as that which originally flowed in the transmitting aerial. The effectiveness of this induced current is dependent largely upon the dimensions of the antenna system.

Essentially the antenna circuit consists of the antenna itself, the lead-in wire, the primary inductance of the receiver, and the ground connection. These are illustrated in Fig. 3. Since every wire possesses a certain amount of inductance, the inductance of the entire antenna circuit can be considered as made up of two components, the distributed inductance of the antenna and lead-in proper, and the lumped inductance of the primary coil. The term, distributed, is used because it is the accumulation of the inductance effects along the entire antenna and lead-in. There is, however, also a certain amount of capacity effect present in the circuit, for the antenna acts like one plate of a condenser, the ground forming the other plate and the air the dielectric. This capacity effect acts like a condenser in parallel with the inductance of the circuit, as is illustrated by the dotted lines in Fig. 4.

Electrically, then, the antenna circuit c an be represented as is illustrated in Fig. 5, where L-1 represents the distributed inductance and C-1 the distributed capacity and L-2 the lumped primary inductance. Current set up in such a circuit, it will be remembered, will oscillate (flow back and forth) at a definite frequency depending upon the values of inductance and capacity. Hence, any antenna circuit is most responsive to current waves of a definite frequency. This frequency to which an antenna circuit is inherently tuned by virtue of its inductance and capacity, is commonly known as the fundamental or natural frequency.

The distributed inductance and capacity values are dependent both upon the length and height of the antenna. Therefore, the physical dimensions of an antenna system will determine to a great extent its operating characteristics and efficiency over any wave length range.

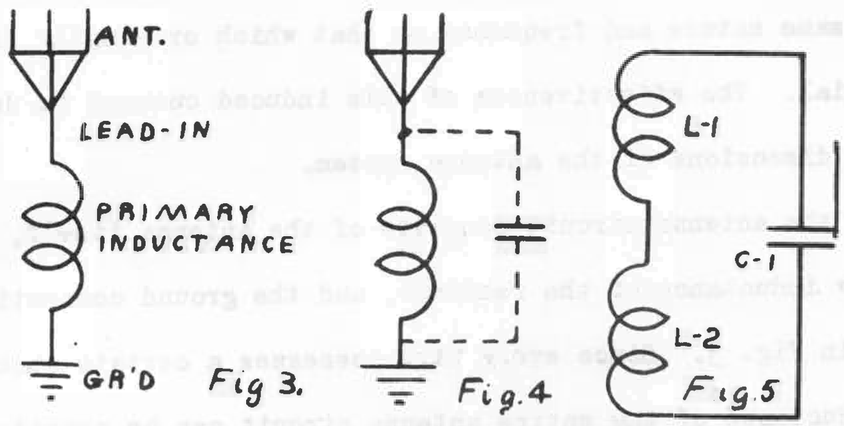



Fig 3. Fig.4 Fig.5

## LENGTH AND HEIGHT OF AN ANTENNA

The length and height of an antenna installation depend upon the available space and the conditions under which the receiving set is to operate. If the installation is to be in a place where no outdoor antenna space is to be had, such as in a hotel or large apartment house, some form of indoor aerial must be used. But if suitable space is available, an outdoor aerial always is preferable.

As to what length to make the antenna, this depends upon the location and type of set with which it is to be used. The longer the aerial, the greater the signal strength produced in it. Hence, if the receiver is located at a great distance fromany broadcasting stations, or if it is desired to tune in rather distant stations, a longer aerial is necessary. For local reception, however, a shorter aerial will be quite satisfactory. Also, the design and construction of the receiving set must be considered. The modern, high-powered sets have a high sensitivity and are able to respond to very weak signal impulses. They are thus able to operate effectively on very short aerials. Other sets that do not possess such high sensitivity need a longer aerial to produce equally good results.

Another factor to consider is the effect of the antenna length on the tuning of the receiver. As was stated in a previous paragraph, greater tuning selectivity is had with a short aerial than with a longer one, although a longer aerial is needed for the reception of more distant stations. Here, again, the relative location of the receiving set with respect to the transmitting stations to be received is the determining factor. Stronger signals are obtained from a longer aerial, more noise interference is also experienced; however, the desired signal usually increases more than the noise signal and, as a result, better reception is obtained. For local reception, a very short aerial is generally satisfactory.

## EFFECTIVE HEIGHT OF AN ANTENNA

The height of an antenna above the ground also affects the quality of the reception. In general, the higher the antenna, the easier it is to receive distant stations and, at the same time, more static noises are received. However, the relationship between the desired signal and static remains essentially the same. An antenna from fifteen to twenty-five feet in height will be satisfactory for the average radio receiver.

But the actual height of an antenna above the ground is not always its electrical or its effective height. The antenna forms one plate of a large condenser and the ground forms the other. As long as the intervening space is perfectly clear, the effective height of the antenna will be the vertical distance between the horizontal antenna wire and ground.

If the antenna is mounted on the roof of a house and metal gutters are used, or the roof covering is of metal, or there are a number of iron pipes or conduits in the ceiling, and all these metallic objects are grounded as is generally the case, then the effective or electrical height of the antenna is not the vertical distance to the ground below, but it is the vertical distance between the antenna wire and the nearest one of these grounded metallic objects. For example, if an antenna is mounted ten feet high on the roof of a house which is thirty feet above the ground, and a network of grounded pipes and conduits is in the ceiling, then the effective height of the antenna is only ten feet even though the wire is actually forty feet above the ground.

If there is a tree under an antenna wire, the effective height will be reduced to the distance between the wire and the nearest branch, for the branches are filled with sap and are grounded, and they consequently raise the ground level to their height and thus reduce the effective height of the antenna itself. The same effect is produced by any other grounded and conducting objects under an antenna.

## CALCULATING ANTENNA WAVE LENGTHS

It is a general rule that an antenna system will function at maximum efficiency when its fundamental frequency is approximately equal to the frequency of the signals that are to be transmitted or received, for the introduction of series condensers and coils has a tendency to waste some of the energy. With a transmitter this is rather important, because the greater the amount of energy that is radiated the greater distances will be covered.

In a receiving station, however, it is not always possible,for the available space often will not permit the erection of an antenna of just the right lengths. Furthermore, with the large amount of power that is now being employed by the broadcasting stations, very good reception will be obtained with the use of comparatively short antennas. The tendency of the antenna circuit to oscillate at its own natural frequency is readily overcome by the received signals having such strength that they easily force their own oscillation frequency upon the circuit.

The process of calculating the fundamental frequency or wave length of an antenna of certain height above the ground, is a rather complex process and will be postponed for a later lesson. However, a simple rule has been worked out that gives results sufficiently accurate for all practical purposes. This rule states that the fundamental wave length of a single wire antenna can be calculated by adding the length of the horizontal part of the antenna and of the lead-in and ground wire and then multiplying the result by 1-1/4. For example, suppose we have an antenna that is 100 feet long and the length of the lead-in is 40 feet, the total length thus being 140 feet. This number, 140, multiplied by 1-1/4 gives 175, which is the natural wave length measured in meters.

## NOISE LEVEL OR SIGNAL-STATIC RATIO

Not only does a receiving antenna intercept the various signal waves that are passing through space, but it also comes in contact with practically every other electrical disturbance in the atmosphere. As a result there are induced in the antenna wire not only the desired signal voltage, but also other stray voltages that manifest themselves as interfering noises in the reproducer. These electrical disturbances may be forms of atmospheric electricity commonly called static, or they may be electric waves sent out by defective electrical appliances, etc. In the latter case they are generally referred to as man-made static.

Radio reception is always at its best when the signal voltage is strong compared to the stray noise voltages. The relation between the strength of the signal voltage and the stray noise voltage, is commonly referred to as the signal-static ratio. As a practical illustration, suppose that on a warm summer evening the strength of an incoming signal could be represented by the number 8, and the noise level or strength has a comparative value of 4. The signal-static ratio would then have a value of 2 to 1. Under these conditions the noise would be very prominent in the background and reception would not be very pleasant. In other words, the signal-static ratio must be such that the noise voltages are very small compared to the desired signal voltages.

With a long and high antenna, the signal-static ratio will be higher and reception will be more pleasant than if a short or low antenna is used. Therefore, when deciding upon an antenna installation, these facts should be taken into account.

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Examination Questions on following page.