RADIO-CANADA SHORTWAVE CLUB

ANTENNA HANDBOOK

INDEX

SHORTWAVE TRANSMISSION AND THE IONOSPHERE

Radio Waves

When a transmitter feeds a radio frequency signal into an antenna it sets up an oscillating electric charge in the antenna. This oscillating electric charge sets up a changing electric strain in the medium around the antenna. This changing electric strain results in a changing magnetic strain, which in its turn, results in another changing electric strain. Therefore we have changing electric and magnetic strains being created progressively further and further away from the antenna. We can therefore say that a radio wave or electro-magnetic wave is travelling away from the antenna. The type of medium through which the radio wave is travelling will control the speed at which the wave travels. But it can never be greater than the speed of light which is 300, 000 kilometers per second.

Types of Radio Waves

Radio waves are emitted from an antenna in all directions. However, we split them into two main groups, ground waves and sky-waves. Figure 1 shows a simple theoretical type of antenna. All those radio waves leaving the antenna above the line AB would become sky-waves and all those leaving below the line would become ground-waves. It is in the sky-wave that the SWL is normally interested as it is by this means that all international shortwave broadcasting is performed.

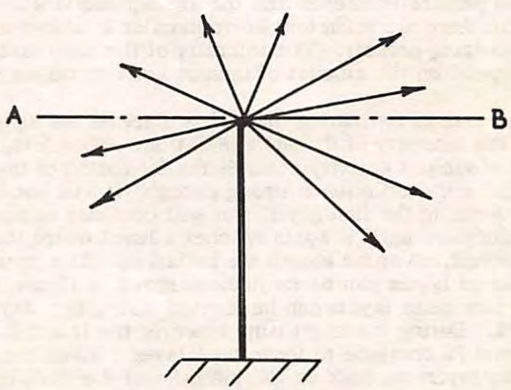

FIG 1

Sky-Wave Propagation

When the sky-wave leaves the antenna, it would travel upwards through the atmosphere, and escape into outer space if it were not for a series of layers of ionized gases, called the ionosphere. These ionospheric layers cause the radio wave to bend and change its direction of travel so that it finally returns back to earth. Each of these layers of gas since they are ionized has an abundance of free electrons. And it is the interaction between these electrons and the energy in the radio wave which causes it to change its direction of travel.

Formation of Ionospheric Layers

The various layers of the ionosphere are formed by the action of the sun's radiation upon the earth's atmosphere. This atmosphere which envelopes the earth becomes less dense or more rarified as the height is increased from the ground and will eventually dissipate into the vacuum of space. The energy radiated from the sun is made up of various energy particles and types of electro-magnetic radiation and each has a different effect on the earth's atmosphere. As far as the ionosphere is concerned it is the sun's ultra-violet radiation which has the greatest effect. As the sun's radiation strikes the upper reaches of the earth's atmosphere it will begin to ionize the gas molecules there. However, since the atmosphere at that level is quite rarified, the amount of ionization will be quite small. As the radiation penetrates deeper into the atmosphere it will eventually reach a level where there are sufficient air molecules to absorb most of the energy, during the ionizing process. The intensity of the sun's radiation at a given time will depend on the amount of sunspot activity taking place at that time.

Also, the rate of ionization that takes place in the upper atmosphere depends on the intensity of the sun's radiation. Therefore, it follows that the amount of sunspot activity controls the formation of the ionospheric layers. If the sun's radiation is strong enough, it will not be completely absorbed in forming the first layer, but will continue to penetrate deeper into the atmosphere until it again reaches a level where the air molecules are dense enough, to again absorb the radiation. This process can continue, and a number of layers can be formed, as shown in Figure 2. As can be seen, up to four main layers can be formed during the daytime, the D, E, F1 and F2. During the night time however the D and E layers disappear and the F1 and F2 combine to form the F layer. Since the condition and density of the layers depends on the intensity of the sun's radiation, they will therefore vary throughout the day as the sun rises, reaches its meridian and sets. They will also vary with the seasons of the year and the eleven year sunspot cycle. Therefore, by considering these conditions, we will see that for any given point on the earth's surface the layers will vary throughout the day. Also, for any given time of the day, the condition of the layers will vary with geographical location.

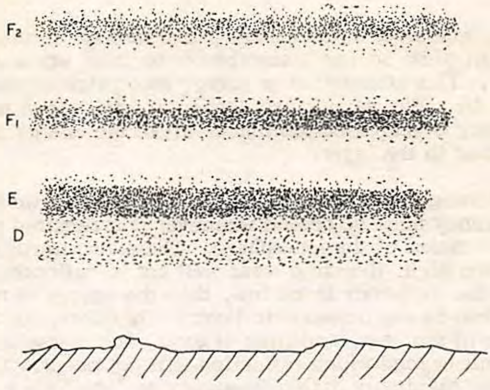

FIG. 2

Another factor must be taken into account when considering the highest layer F2. This layer apart from being formed by the sun's ultra-violet radiation is also heated by the sun's infra-red radiation. These two types of radiation both have opposite effects on the layer. The ultra-violet tends to increase the amount of ionization or increase the amount of free electrons in the layer. The infra-red radiation tends to cause the layer to expand due to heating, thereby reducing the density of free electrons in the layer. The resulting effect of this is that, the F2 layer does not reach its maximum level of ionization at the same time as the other layers during the day, but has a delay of approximately two hours.

Propagation via the Ionosphere

When a radio wave travels upwards and passes into one of the ionospheric layers, the interaction between the free electrons in the layer and the energy of the radio wave, causes the latter to change its direction of travel. The amount by which the direction is changed depends on the density of free electrons in the layer. The greater the density, the greater will be the amount of bending. Therefore, if a radio wave of a given frequency passes into an ionospheric layer which has a great enough electron density, the direction of travel will be changed enough that the wave will eventually travel back down to the ground. However, if the electron density of the layer is not great enough, then its bending effect will not be great enough to cause reflection of the radio wave back down to the ground. Also the higher the frequency of the radio wave, the smaller is the bending effect of the electrons on it. Therefore it can also happen that if the frequency of the radio wave is too high, the ionospheric layer will not reflect it, but will allow it to pass through and escape into outer space. Therefore, summing this up, the greater the electron density in the layer or the more highly ionized the layer is, the higher value of frequency it will reflect.

However, whenever a radio wave passes through an ionized layer a certain amount of its energy is absorbed or in other words the radio wave is attenuated. This attenuation or energy absorption increases as the frequency of the radio wave is decreased. It can happen therefore, that if the frequency is decreased too much, all of the energy in the radio wave will be absorbed in the layer.

From the foregoing it will be seen that, there are two limits within which a frequency must be chosen whenever it is required to propagate a radio wave by means of the ionosphere. These two limits are; if the frequency is too high, the radio wave will not be reflected back by the layer; and if the frequency is too low, then the energy in the radio wave will be absorbed by the ionospheric layer. Therefore, for a given sunspot count, season of the year, and time of day, each ionospheric layer has a frequency limit beyond which reflection will not occur. This frequency is known as the maximum usable frequency or "Muf" for a certain propagation path, and will apply only to that path. Similarily, an ionospheric layer will have a frequency below which any radio-wave will be attenuated too much to be able to provide a good signal in the target area. This frequency is known as the lowest usable frequency or "Luf". Therefore when a broadcasting organization wishes to choose the frequency or channel to be used for a transmission, it has to choose it between the limit set by this "Muf and Luf" for the transmission path.

Reception Conditions in the Target Area

When a radio signal finally reaches the target area, it then comes completely under the control of the SWL. The quality of signal picked up will depend completely upon the type of antenna that has been erected, because it should be remembered, that the antenna will make the difference as to whether it is a good or bad signal that is being fed to the receiver. It should always be kept in mind that, good results can be obtained from an inexpensive receiver by erecting a good antenna, and vice versa, a good expensive receiver is not much use without an antenna. Or in other words, the receiver is only as good as the antenna to which it is attached. In the target area the enemy of any incoming signal is noise. It is noise that tends to deteriorate the listening quality of the radio signal. This noise comes from many sources, but there are various ways of combating it. The first type of noise is receiver noise. This depends on the type of receiver being used, that is, its circuit and the components used in that circuit. Therefore, an SWL when buying a receiver should obtain one that gives him a high signal to noise ratio. The second type of noise is radio noise. This noise is made up from man-made noise, QRM, and natural noise, QRN, which in itself is made up from atmospheric and extra-terrestrial sources. The man-made noise is generated from sources such as electrical appliances and apparatus like electric drills, electric saws, car ignition systems, etc. The natural noise is composed of signals generated by electrical storms or radio signals coming in from cosmic sources. These two types of noises are more difficult to overcome. However, by the use of a high-gain, directional type of antenna, it is possible to obtain a stronger radio signal, thereby giving a better signal to noise ratio for feeding into the receiver.

THE WHIP ANTENNA

This type of antenna is the answer to the antenna problem for a great number of listeners who live in apartments or in cities where they do not have enough space to erect any other type of outside antenna, since it is one of the simplest to erect. It can be made either from an automobile antenna, or from a length of small diameter piping. When properly erected it can give very good results. Like any other antenna it should be erected as high as possible and away from any obstructions. Therefore the best place to erect it would be either on the roof, the chimney or on a high pole. This type of antenna is omni-directional which means that it will receive signals equally well from any direction. However, if it is erected on a window sill or along side a building this will of course impair its reception qualities, due to the large mass of the building along side it. The lead-in for this type of antenna can be either a shielded co-axial type or the normal insulated wire. If the listener lives in an area where the noise level is not too high, there can be some advantage in using the normal insulated wire as a lead-in since this, in effect, is similar to increasing the length of the antenna. Figure 3 shows a typical installation of this type of antenna on a pole. Under normal reception conditions the whip antenna will give very good results. However since it is a vertical antenna it is also very responsive to atmospheric and man-made noise.

WHIP ANTENNA

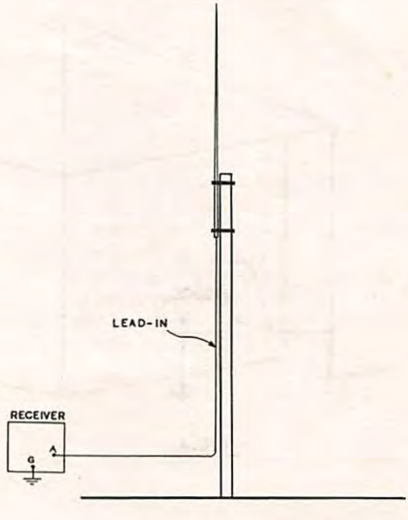

FIG. 3

THE VERTICAL ANTENNA

The Vertical antenna is another example of an omni-directional type. It is a simple long wire antenna anywhere from 20 to 60 feet long supported vertically. It can be hung from the overhang of the roof of the house or supported by a pole or hung from the branch of a convenient tree. Again as with other antennas, if a tree is used it would be advisable to use a pulley and counterweight arrangement to allow for the sway. The lower end of the antenna should be securely anchored to the ground. The lead-in should be attached to this end of the antenna and then run into the receiver. One advantage to erecting the antenna up the side of the house is that the lead-in would be, in this case, very short. This would then keep the amount of noise pick-up down to a minimum. However it should be born in mind that, the proximity of the antenna to the house, in this type of an installation, is likely to greatly affect its omni-directional properties. This problem can be solved however by installing the antenna away from any obstructions and then using a shielded lead-in to the receiver. Figure 4 shows a typical installation of this type of antenna.

VERTICAL ANTENNA

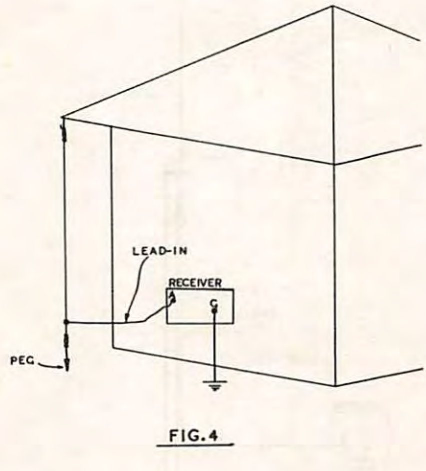

FIG.4

THE INVERTED "L" or MARCONI ANTENNA

This type of antenna is also omni-directional and therefore can be erected to suit the available space. A look at Figure 5 will show why this antenna has got the name of the Inverted "L". The horizontal section should be about 45 to 50 feet long made of stranded copper, if possible, in order to give it strength and be securely supported at either end. The down lead can be of the same type of wire as the antenna, but in this case it is advisable to have it insulated. This will prevent the signal from being shorted to ground should the wire accidently touch the building. Should one, or both ends of the antenna be attached to trees or some other support that is likely to sway in the breeze, it is advisable to have a pulley and counterweight arrangement at the ends. This will prevent the antenna from sagging or tightening too much, and so prevent any likely breakages. The lead-in should be connected to the end of the antenna that is nearest to the receiver, and this will therefore keep it as short as possible.

MARCONI INVERTED "L"

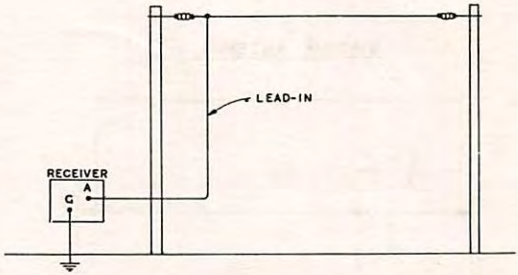

FIG.5

THE WINDOM ANTENNA

This antenna got its name, Windom, after the first experimenter to use and write an article about it. It is a directional type of antenna, and reception is best when the antenna is broadside-on to the incoming signal. The length of the antenna is a half wave length and is cut to the lowest frequency band to which the antenna will be used. The length therefore is determined by the expression;

$$L = \frac{468}{F}$$

where "L" is the required length of the antenna in feet, and "F" is the required frequency in megacycles per second.

It is important that the lead-in be connected at the proper position on the antenna and this should be at 1/3 of the antenna length from one end. Since the down-lead should also be kept as short as possible, it therefore follows that it will be best if the lead-in is connected one third from the end of the antenna that is closest to the receiver. Figure 6 shows a typical installation of this type of antenna. A lead-in can be made from the same type of wire as the antenna but it should be insulated to prevent it from shorting to ground. The antenna should be erected as high as possible and the lead-in should be allowed to drop freely from it, for as great a distance as possible, before any bends are made. A Windom antenna suitable for use from 10 to 80 meters, that is, through all the international shortwave bands would be 126 feet long and have the lead-in connected at 42 feet from one end.

WINDOM ANTENNA

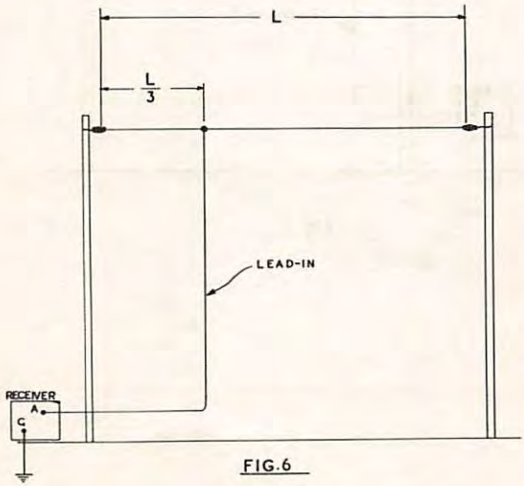

FIG.6

THE HALF-WAVE DIPOLE

This is another directional antenna with the best reception being obtained when the antenna is broadside-on to the incoming signal. It is a centre fed tuned antenna intended for best results over a relatively small band of frequencies. The total length of the antenna is, as its name implies, half the wavelength of the frequency for which it is to be used. However, this half-wave length is divided in the center by an insulator, thus giving two poles, each a quarter of a wave length long. The lead-in for this type of antenna should have an impedence of 75 ohms and can be either of the co-axial or twin lead type. If co-axial lead-in is used then the center conductor should be connected to one half of the antenna at the center insulator and the outer shield should be connected to the other half of the antenna at the other end of the center insulator. If twin lead is used then the conductors should be connected one to each side of the antenna at the center insulator. As with the Windom, the lead-in should be allowed to drop freely at right angles from the antenna for as great a distance as possible, before any bends are made. Then any bends that are necessary should be made as gradually as possible. Since the half-wave dipole is cut for a specific frequency band, it will therefore be necessary to erect a dipole for each band the listener wishes to use. If a series of half-wave dipoles are erected, it will be found convenient to connect all the lead-ins to a multi-switch. This will make it easy to select the antenna to match the band to which the receiver is tuned. Figure 7 shows a typical installation of the half-wave dipole. The following table gives the overall length of the half-wave dipole for the various meter bands.

Since these dimensions are the overall lengths then each dipole will be half of this length. The center insulator will then be placed in the middle dividing the two dipoles.

Table of Half-Wave Dipole Lengths

METER BAND	OVERALL LENGTH IN FEET
13 meters	21 feet
16 "	26 "
19 "	31 "
25 "	41 "
31 "	51 "
41 "	68 "
49 "	81 "
59 "	94 "

HALF WAVE DIPOLE

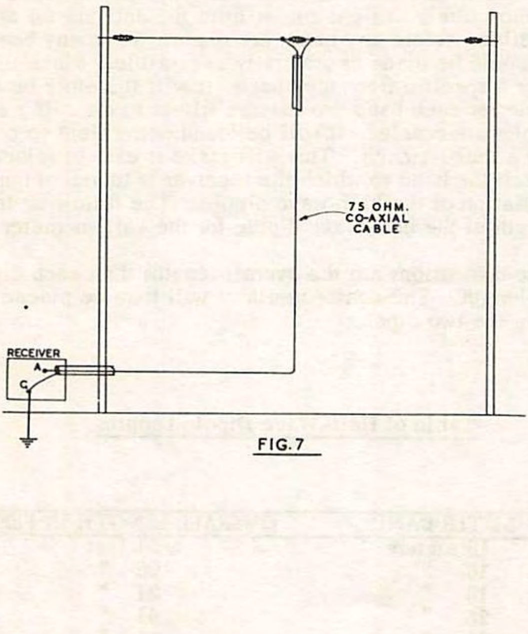

FIG.7

INTERNATIONAL SERVICE
CANADIAN BROADCASTING CORPORATION
P.O. Box 6000,
Montreal
P.Q.

THE FOLDED DIPOLE ANTENNA

This is another directional antenna with the best reception being obtained when the antenna is broadside-on to the incoming signal. The total length of this antenna is one whole wavelength. However, the two ends are folded in to the center and the lead-in connected to these ends. This then gives the antenna its name of folded dipole. Figure 8 shows a typical installation of a folded dipole. This type of antenna has an impedance of 300 ohms and therefore the lead-in should itself have an impedance of 300 ohms. A good type of lead-in for this antenna is TV twin-lead, that is the ribbon type of feeder which is used for TV antennas. It is possible to construct the entire antenna of TV lead-in and an installation of this type is shown in Figure 9. The lead-in should again be allowed to drop freely from the antenna at right angles for as great a distance as possible before making any bends. The folded length of the dipole is the same as that given for the half-wave dipole. However, the total length of the antenna is twice this. Since this antenna is also efficient only over the narrow band of frequencies for which it is cut, it will be necessary to erect a series of them to cover all the frequency bands required. It will therefore be found convenient to install a multi-switch to provide an ease of antenna selection.

FOLDED DIPOLE

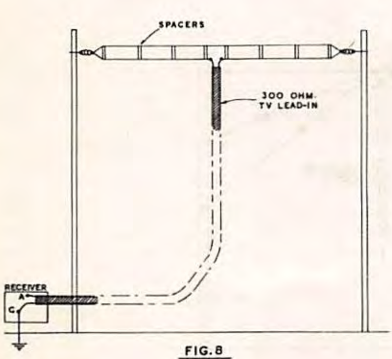

FIG. 8

FOLDED DIPOLE

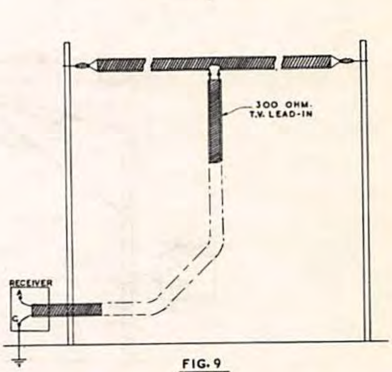

FIG. 9

THE TRIPLE DIPOLE ANTENNA

The triple dipole is a directional broadband type of antenna with its best reception being obtained when it is broadside-on to the incoming signal. It can be used from 5 to 30 Mc/s per second. As its name implies the triple dipole is made up of three dipoles, each cut to a different length and inter-connected with the others to give the antenna its broadband characteristic. The longest of the three dipoles is used to support the other two as shown in Figure 10. A suitable lead-in for this type of antenna would be a 75 ohm co-axial cable. As with the other dipoles, the lead-in from the antenna should be allowed to fall away freely for as great a distance as possible, before any bends are made. Then, as before, all bends should be made gradually. Figure 10 shows a typical installation of this type of antenna. The longest dipole which is used to support the other two is made of two 50 foot lengths of stranded wire separated by an insulator and with the ends connected to the supports. The next longest dipole is made up of two 35 foot lengths of wire. One end of each length of wire is connected to the center insulator and the other two ends are connected to the supports. The shortest of the three dipoles is made of two 12 foot lengths of wire. One end of each is again connected to the center insulator and the other ends connected to the supports. The angle or distance between the dipoles is not at all critical and will not have any great affect on the reception qualities of the antenna.

TRIPLE DIPOLE

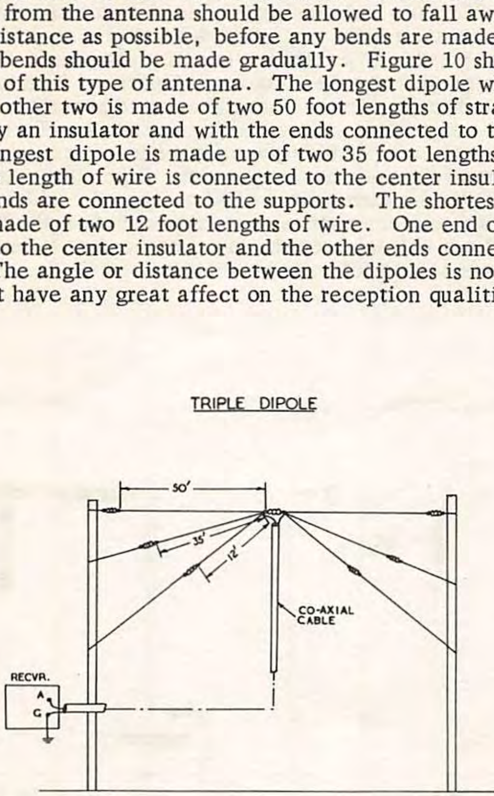

FIG. 10

THE VERTICAL DIPOLE ANTENNA

The vertical dipole is an omni-directional type of antenna and will have its greatest efficiency when cut to a specific length corresponding to a given frequency band. The dimensions of this antenna are exactly the same as those for a horizontal half-wave dipole. However, since it is erected vertically it takes on the omni-directional characteristics. Figure 11 shows a typical installation for this type of antenna. A length of a 75 ohm co-axial cable will make a suitable lead-in for this antenna. Those listeners wishing to obtain reception over a number of frequency bands, should but a vertical dipole for each of the frequency bands they require. This series of vertical dipoles can then be supported from a common support and each of the lead-ins brought into the receiver. In this case a multi-switch should be used between the lead-ins and the antenna connection to the receiver. This will provide a method for the easy selection of the required antenna. It should be remembered the lead-in will have to be taken away from the antenna at right angles, for as great a distance as possible. In this case it will mean therefore that special supports will have to be used. Like other types of vertical antennas, the vertical dipole is more responsive to man-made and atmospheric noise than horizontal types of antennas.

VERTICAL DIPOLE

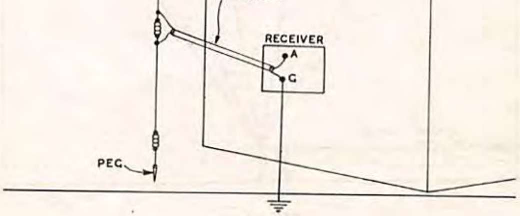

FIG.11

THE FAN VERTICAL ANTENNA

The fan vertical is a broadband omni-directional type of antenna, and gives good reception over the frequency range 5 to 30 Mc/s. However, since it is a vertical antenna it is more responsive to both man-made and atmospheric noise. The fan vertical is made up of five vertical antennas each cut to a different length. The bottom ends of these antennas are connected to each other at a common point. The upper ends of the antennas are spread out and connected to a common support as shown in Figure 12. It is from this method of erection that it obtains its name of the "Fan Vertical". The lengths for the five antennas are $25\frac{1}{2}$ feet, 20 feet, 15 feet, $12\frac{1}{2}$ feet and 10 feet. A very suitable type of common support would be a length of nylon rope erected between two supports. One of the supports should be higher than the other in order that the nylon rope will have a slope. The five antennas are then spaced equally along this support rope, with the longest one at the highest end the shortest one at the lowest end. A suitable type of lead-in for this antenna would be a 50 ohm co-axial cable. The bottom common ends of the antennas should be connected to the center conductor of this cable. The outer shield of the cable should be grounded at the bottom of the antennas. Again, since they are vertical antennas they will be more responsive to man-made and atmospheric noise, than horizontal types.

FAN VERTICAL

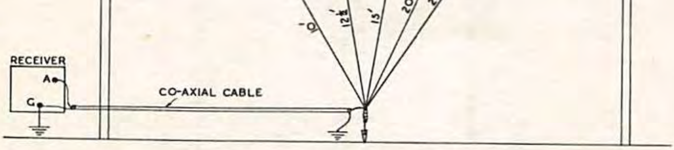

FIG.12

THE LONG WIRE ANTENNA

The long wire antenna is a broadband type of antenna with its best reception being received, when it is pointed towards the target area. It receives its directional properties due to its long length, and should not be any shorter than approximately two wavelengths at the highest frequency for which it is to be used.

The following formula can be used to determine the length of the antenna - $\frac{984\,(N-0.025)}{F}$

Where "N" is the number of full wavelengths that the antenna is to be and "F" is the frequency in megacycles per second. Using this formula therefore, the length of an antenna two wavelengths long for receiving up to 20 Mc/s would be 97 feet or approximately 100 feet long. If the antenna is made any longer than this it will become more highly directional. However if this is done it will have to be pointed more accurately towards its target area. This type of antenna will work reasonably well over all of the International Frequency Bands. However if the listener wishes to have it work more efficiently over one given frequency band, he can then trim down the length until maximum pick-up is received on that particular band. The height of the antenna should be about 30 feet above the ground. A typical installation of this type of antenna is shown in Figure 13. A support pole should be placed at approximately every 75 feet along the length of the antenna. This will prevent too much sag or strain being placed on the antenna due to its own weight. A suitable down-lead for this type of antenna would be 600 ohm co-axial cable. It is a good safety precaution to install lightning arrestors at both ends of this type of antenna.

LONG WIRE ANTENNA

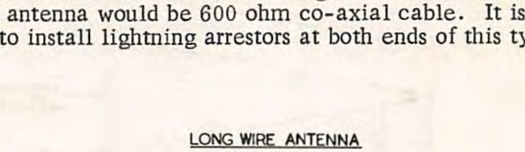

FIG. 13

THE V-BEAM ANTENNA

The V-beam antenna is made by joining two long wire antennas such that they form a V. The two legs of the V should be exactly the same length and this length can be determined exactly the same as it was for the simple long wire antenna. For a given antenna length, the V-beam will be more directional than the simple long wire. However, it can be made still more directional by increasing the length of the legs. The V-beam requires three supports, as shown in Figure 14, and it should be located such that the open end of the V is pointing towards the required target area. It should be pointed out that the two legs of the V are each an individual antenna and are not joined together at the point of the V. Therefore a suitable lead-in for this type of antenna would be a 600 ohm twin lead. Each conductor of the twin lead would be connected one to each leg of the antenna. It is possible to make different combinations of V-beams. One of these would be to stack two Vs one above the other about half a wave length apart. Another method is to erect two Vs side by side so that they form a W. With this method five poles will be needed to support this combination antenna and also two separate lead-ins. These combinations of V-beams will give an increase of 3 to 5 db over a single V-beam.

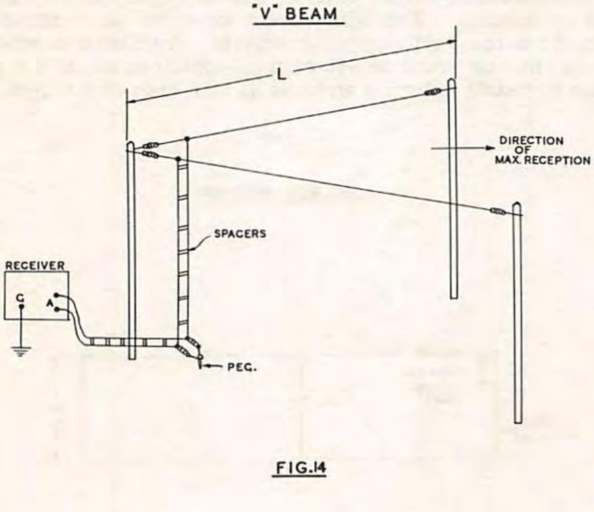

FIG.14

THE RHOMBIC ANTENNA

The rhombic antenna is made up of four long wire antennas or two V-beam antennas to form a diamond or a rhombus shaped, antenna. The rhombic is a broadband, high gain, highly directional type of antenna. And for maximum pick-up should be pointed towards the target area or incoming radio signals. The rear or back end of the antenna is the end to which the lead-in is connected. Its directivity will be greatly improved, and it will give an excellent signal to noise ratio, if its front end is suitably terminated with a resistor. This means, if an 800 ohm non-inductive resistor is connected between the two front leads. A suitable lead-in for this type of antenna would be a 700 to 800 ohm open wire line. A typical installation of this type of antenna is shown in Figure 15. As will be seen a great deal of space is required for the erection of this type of antenna usually in the order of several acres. However if space is available and this type of antenna can be erected the listener will be well rewarded by the increase in the amount of stations that are now available to him for listening.

RHOMBIC ANTENNA

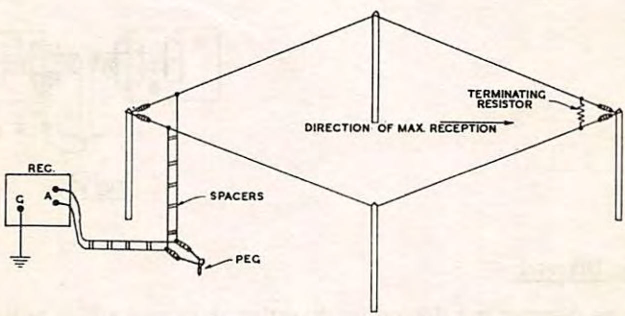

FIG.15

ANTENNA ACCESSORIES

Multi-switches

A multi-switch can be used when a series of antennas have been erected and ease of selection of antenna is required. All of the lead-ins from the antennas are brought to the multi-switch, which then makes selection of the required antenna easy. Different types of multi-switches can be used depending on the number of antennas or lead-ins that have been erected. One of the better types of switches would be the rotary selection type, which can be obtained commercially. Figure 16 shows diagramatically the method of connecting-up the multi-switch. It is by no means intended to give a pictorial view of a rotary selection switch.

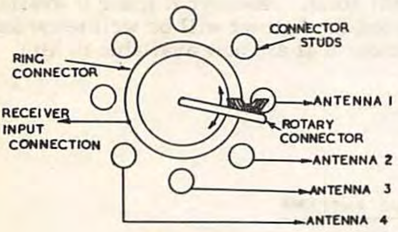

FIG 16

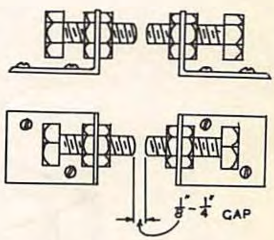

FIG 17

Lightning Diverter

A lightning diverter is a device for diverting to ground a high voltage which may appear on the antenna. This high voltage can appear on the antenna due to accumulation during electric storm conditions, particularly if the antenna is a long one, or by a lightning strike. The most popular type of lightning diverter is the simple sparkgap which is shown in Figure 17. It is necessary to have some means of removing the high voltage that has accumulated on the antenna, since it can do damage to the receiver. The sparkgap should be set between 1/8 to 1/4 of an inch, since any gap larger than this would allow a higher voltage to accumulate on the antenna.