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Editor:
Ian C. Hansen,
Member I.R.E. (U.S.A.)

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Television Principles and Practice—

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By K. Fowler and H. Lippert.

TELEVISION RECEIVING ANTENNAS AND THEIR INSTALLATION

1. INTRODUCTION.

Since television stations operate at a much higher frequency than ordinary broadcast stations and due to the particular requirements of the television receiver, the antenna system for a television receiver is far more critical than that required for an ordinary broadcast receiver.

If the best performance is to be realized from a television receiver, considerable care and thought should be given to the proper selection and installation of the antenna system, since a good antenna system is one of the most important items in assuring satisfactory television reception.

2. REQUIREMENTS.

The principle requirement for a good television antenna system are:

1. To obtain adequate signal pick-up, especially in location on the fringe of the service area of the television stations.
2. To avoid reflections in the antenna system itself which would cause smearing of the picture.
3. To prevent reflected signal from nearby structures or hills from being picked up by the antenna which would cause ghosts or multiple images to appear on the screen.
4. Proper placement of the antenna so as to reduce man-made sources of interference to a minimum.
5. The antenna system should be capable of working efficiently over a wide frequency range so as to provide good signal pick-up for the first five television channels which cover the frequency range from 54 to 88 mc, and the upper seven television channels which cover the range of frequencies from 174 to 216 mc. This, as will be pointed out later, is one of the most difficult requirements to meet.

3. CHARACTERISTICS AND RANGE OF TELEVISION SIGNALS.

Before considering how the above requirements are met, let us consider some of the characteristics and the range of television signals.

The frequencies that have been allocated to television stations are all in the very high frequency range above 40 mc and behave entirely different from the much lower frequencies that are used in the regular broadcast band of 550 kc-1600 kc.

When a signal leaves the transmitting antenna, it can be considered as being made up of two components: a ground wave, and a sky wave. The ground wave travels parallel to the ground, while the sky wave travels out into the upper atmosphere as shown in Figure 13-1.

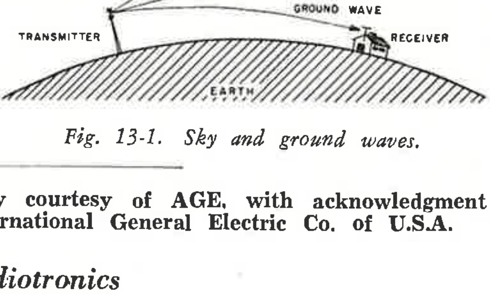


Fig. 13-1. Sky and ground waves.

By courtesy of AGE, with acknowledgment to International General Electric Co. of U.S.A.

At the frequencies used on the regular broadcast band, the ground wave is the most useful during the daytime and follows the curvature of the earth. During the daytime, the sky wave does not contribute to the signal strength appreciably and, for all practical purposes, is lost. However, at night, the refraction of the sky wave from the ionosphere is great and thus greatly increases the range of the transmitter beyond the active range of the ground wave.

However, at frequencies above 40 mc, the ground wave is greatly attenuated and tends to travel in a straight line rather than follow the curvature of the earth. Also, at these frequencies the sky wave is seldom refracted from the ionosphere and is of no practical use. For this reason television transmission depends upon waves passing directly from transmitter to receiver through the space above the ground as indicated by Fig. 13-2, and the most effective range of the transmitter is limited to the horizon range or line-of-sight range between the transmitting and receiving antennas.

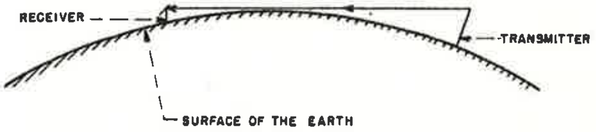


Fig. 13-2. Line-of-sight range.

From the above it can be seen that the transmitting and receiving antenna must be quite high so as to increase the effective range of transmission.

Usually, the line-of-sight range is taken as the reliable service area of a television station; however, fairly good reception is obtained at distances somewhat beyond this point, especially if the transmitter has considerable power. The reason for this is that although the signal is not refracted from the ionosphere, a certain amount of bending of the wave occurs by refraction from the (un-ionized) atmosphere and also from diffraction by the surface of the earth at the horizon, which extends the range at which television signals can be received for a given antenna height, by approximately 30% beyond the line-of-sight or horizon range as indicated in Fig. 13-3.

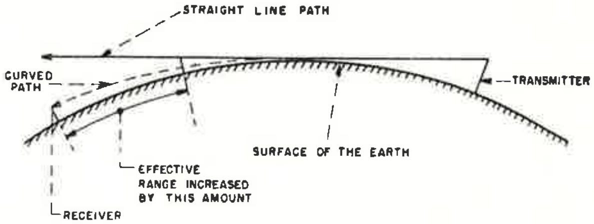


Fig. 13-3. Extended range due to bending of wave.

There have been cases where television signals were received considerably beyond the line-of-sight distance, but these were due to unusual circumstances.

The range of a station, considering only the straight-line path, depends upon the heights Ht and Hr of the transmitting and receiving antennas, respectively. The maximum distance for straight-line path = 1.23 $(\sqrt{Ht} + \sqrt{Hr})$ where the antenna heights are in feet and the distance is in miles. If we consider the atmospheric refraction of the wave and also diffraction of the wave as mentioned previously, then the distance is increased by a factor of 1.25 to 1.35, depending upon the earth's atmosphere.

In Figure 13.4 there are several curves showing the effect of antenna heights and atmosphere refractions upon the direct line-of-sight transmission. With the exception of the first curve which is for the straight line path, all curves are calculated on the basis of the effective range being increased by a factor 1.3 because of refraction by the earth's atmosphere.

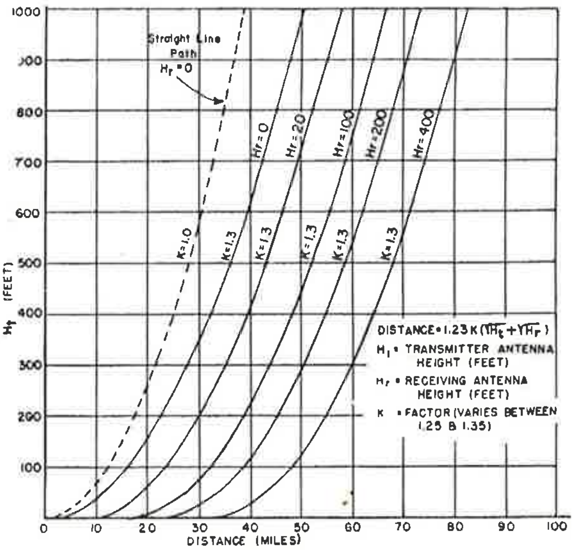


Fig. 13-4. Range of signal in relation to antenna height.

It is of interest to note that when one antenna is high (usually the transmitting antenna) and the other relatively low, a given number of feet increase in either antenna is much more effective in increasing the range if it is applied to the lower antenna. This fact may not at first be apparent until we consider the fact that the line-of-sight range is directly proportional to the square root of the height of either antenna. For example, if one antenna is 10 feet high and the other 1000 feet high, the straight line path in miles will equal:

$$D = 1.23\ (\sqrt{10} + \sqrt{1000})$$
$$= 1.23\ (3.16 + 31.6) = 42.75 \text{ miles.}$$

Now, suppose we increase the height of the lower antenna by 90 feet, the straight line path will now be:

$$D = 1.23\ (\sqrt{100} + \sqrt{1000})$$
$$= 1.23\ (10 + 31.6) = 51.8 \text{ miles.}$$

Now, suppose that instead of increasing the lower antenna by 90 feet we had increased the higher antenna by 90 feet, the straight line path would have then been:

$$D = 1.23\ (\sqrt{10} + \sqrt{1090})$$
$$= 1.23\ (3.16 + 33) = 44.5 \text{ miles.}$$

From the foregoing example, it is obvious that since receiving antennas are relatively low and transmitting antennas relatively high, increasing the height of the receiving antenna is much more effective than increasing the height of the transmitting antenna an equal amount. Therefore, the importance of placing the receiving antenna as high as possible when the receiver is located a considerable distance from the transmitter.

Since television signals have the characteristic of normally following a direct line-of-sight path from transmitter to receiver, this path is sometimes blocked by high hills or mountains or even large buildings which may be between the receiver and transmitter. This blocking of the signal will cause a very weakened signal or no signal at all to be received.

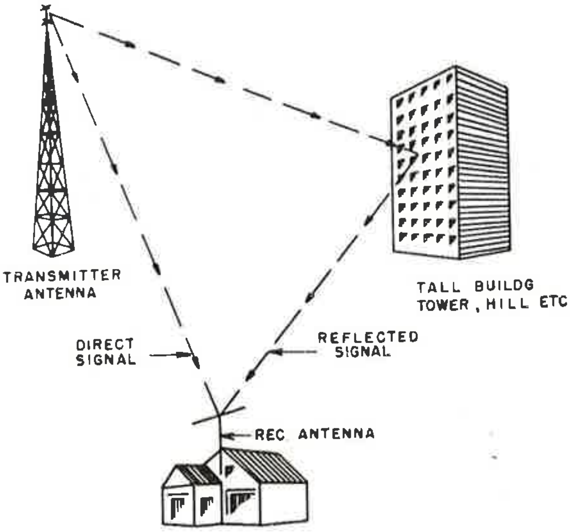


Fig. 13-5. Reflection of TV signal.

Another characteristic of television signals is that they are reflected by large objects, such as tall buildings and hills, which may be in the path of the television signal, in much the same manner as light waves are reflected. Due to this characteristic of television signals, it is quite possible for the signals from a transmitter to reach the receiver over two paths having different lengths from the transmitter, as illustrated in Figure 13-5. This will cause multiple images to be reproduced on the screen, known as ghosts, which are separated by an amount dependent upon the difference in the time of arrival of the two signals. These spurious images which appear on the screen due to reflected signals play an important part in television antenna installation and will be considered in much more detail when actual antenna installations are discussed.

4. RESONANT ANTENNAS.

There are various types of antennas that may be used for television reception. However, a resonant antenna is generally used since, for a given field strength, the maximum voltage will be developed in the antenna when it is resonant at the frequency of the signal that it is desired to pick up.

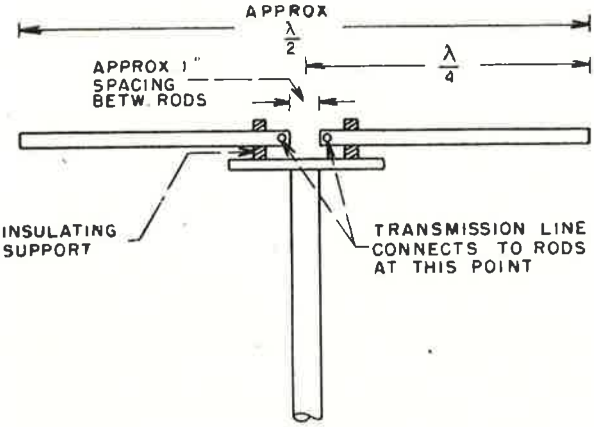
Although it may not be readily apparent, an antenna has a certain amount of inductance and capacity, together with resistance, and therefore acts in many respects as a resonant circuit. Instead of this inductance and capacity being lumped, as in a single coil or capacitor, it is distributed along the length of the antenna. In the case of an ungrounded antenna the antenna will be resonant whenever its total length approximates a multiple of a half wave length at the frequency that it is desires to receive. Thus, an ungrounded antenna will be resonant at a half wavelength, a full wavelength, a wavelength and a half, two wavelengths, etc.

Half-wave Dipoles.

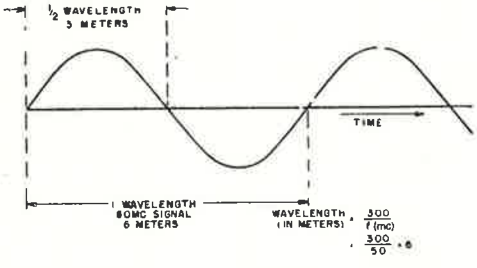
Since a half-wave antenna is the smallest antenna that can conveniently be made resonant at a given frequency, television antennas are usually of the half-wave dipole type. Fundmentally a half-wave dipole consists of two conductors, each a quarter wavelength long at the frequency of the desired signal to be received, as shown in A of figure 13-6. Actually, each conductor is one quarter wavelength long less one-half the small spacing at the centre where the transmission line connects. However, this spacing is quite small and each conductor can be said to be one-quarter wavelength long. It is resonant at the frequency to which its overall length is a half-wave length long. If the desired frequency to be received is 50 mc, then one wavelength of the signal would be

$$\frac{300}{f\ (\text{mc})} = \frac{300}{50}$$

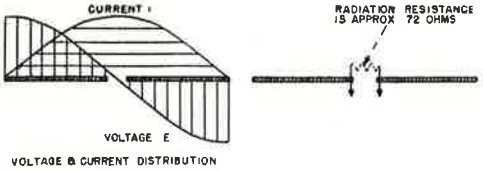
as indicated in B of figure 13-6, or 6 metres. Therefore, the overall length of the half-wave dipole in order to be resonant at 50 mc should be three metres. Converted to feet this would be equal to 3 X 3.28 = 9.84 feet. Actually, for reasons to be discussed later, the overall length of the dipole should be slightly less than its electrical half-wave length as just calculated.



A. Fundamental half-wave dipole.



B. Relation between wavelength and frequency.



C. Voltage and current distribution on dipole.

D. Representation of radiation resistance.

Fig. 13-6.

The voltage and current distribution for the half-wave dipole is shown in C of figure 13-6. It will be noted that the current is maximum at the centre of the antenna and minimum at the ends. The voltage disribution on the antenna is just the opposite from the current distribution, with the maximum voltage occurring at the ends of the antenna and he minimum voltage at the centre of the antenna: The voltage does not actually reach zero at the centre because of the resistance of the antenna at this point. This resistance consists of the actual ohmic resistance of the conductor and a resistance known as the radiation resistance. However, since the radiation resistance predominates, the ohmic resistance can be neglected for all practical purposes. Also, the current at the ends of the antenna does not actually reach zero since the impedance at the ends is not infinite. However, it is high compared to the impedance at the centre, therefore the current at the ends has a low value.

The antenna is usually fed (in the case of a transmitting dipole) at the point of maximum current and minimum voltage, which is at the centre of the antenna. In the case of a receiving antenna, the transmision line feeding the receiver is also connected at the centre of the antenna as indicated in A of figure 13-6.

It might be well to mention at this point that the properties of a receiving antenna are similar in practically every respect to the corresponding properties of the same antenna when it is used as a transmitting antenna. Therefore whatever is said concerning a transmitting antenna applies equally as well to a receiving antenna.

Impedance Characteristics of the Half-wave Dipole.

Since a half-wave dipole is in effect a tuned circuit, it must have a certain impedance value. The half-wave dipole my be compared to a series resonant circuit and as such its centre impedance is low at resonance, appearing as a pure resistance. The impedance at the centre of the ordinary half-wave dipole at its resonant frequency is approximately 72 ohms and is equal to its radiation resistance. The radiation resistance of an antenna is a purely fictitious quantity. However, the antenna acts as though such a resistance were present because the loss of energy by radiation (considering a transmitting antenna) is in its effects equivalent to a like amount of energy dissipated in a resistance. In other words, the radiation resistance of an antenna is that value of resistance which, if inserted at the centre of the antenna, would dissipate the same amount of energy as is actually radiated from the antenna system. This resistance might be represented by a fictitious resistor, shown in dashed lines, placed between the two conductors at the centre of the antenna as in D of figure 13-6.

Although the impedance of the half-wave dipole is low at the centre of the antenna (at resonance), being equal to its radiation resistance, the impedance at the ends of the antenna is of a relatively high value. The value of this end impedance depends upon several factors, especially the diameter of the conductor in relation to its length. If the diameter of the dipole conductor is very small, such as a #14 wire, then the end impedance will be considerably higher than if one-inch tubing were used instead. The centre impedance of the half-wave dipole, at resonance, remains essentially the same in either case. However, for frequencies above and below the resonant frequency of the dipole (the frequency at which the dipole is exactly a half-wavelength long) the centre impedance increases toward that at the ends. As indicated by fig. 13-7, the centre impedance is at a low value and is resistive at resonance. At frequencies above resonance the centre impedance is no longer resistive but appears as an inductive reactance. At frequencies below resonance, the centre impedance appears as a capacitive reactance. In either case, the centre impedance increases from its low value at resonance. The maximum centre impedance, which is the end impedance of the dipoles, will be reached at a frequency that is twice the resonant frequency. At this frequency the antenna will be a full wavelength long. If the dipole conductors are of small diameter then the centre impedance will increase much more rapidly at

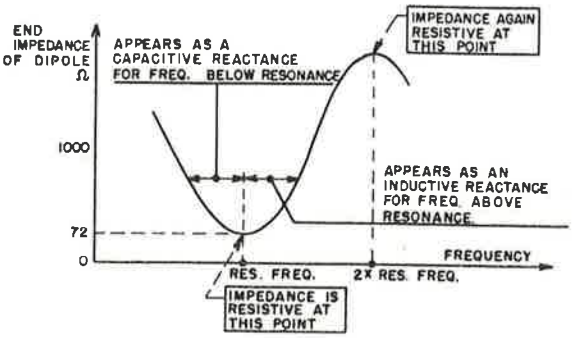


Fig. 13-7. Variation of dipole impedance with frequency change.

frequencies off resonance than if the dipole conductors are of large diameter. This is a very important point and will be considered in more detail in subsequent paragraphs.

Frequency Response Characteristics of the Half-wave Dipole.

As brought out earlier, the half-wave dipole may be considered as a series resonant circuit and as such it will be responsive to changes in frequency. As indicated by fig. 13-8, optimum signal transfer is obtained at the frequency to which the dipole is resonant or exactly a half-wavelength long. If the Q of this equivalent resonant circuit is high, then the response of the antenna will be very sharp, limiting the usefulness of the antenna to a narrow range of frequencies above and below its resonant frequency. In fig. 13-8 it is assumed that the Q of the antenna is such as to limit the range over which effective response is obtained to approx. 3 mc. Obviously such an antenna would not be satisfactory for television reception since a frequency range or band-width of only 3 mc is not wide enough to accept even one television channel.

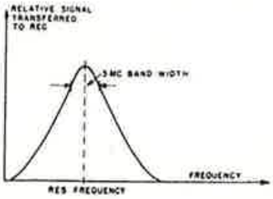


Fig. 13-8. Effect of high Q on frequency range.

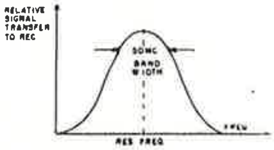


Fig. 13-9. Effect of low Q on frequency range.

Therefore, in order to satisfactorily receive a television channel the frequency response of the antenna must be broad enough to provide effective signal pick-up over at least at 6 mc range. Since it is desirable to have one antenna receive as many channels as possible, the frequency response of TV receiving antennas is made essentially uniform over a very broad band of frequencies. This is accomplished by making the Q of the equivalent resonant circuit quite low. As with any resonant circuit having a low Q, its response will be quite broad. Fig. 13-9 illustrates the effect of reducing the Q of the antenna and in this case its frequency response is broad enough to cover at least seven television channels, the upper seven for instance. The Q of the equivalent resonant circuit that the antenna represents depends upon the diameter of antenna conductors (quarter-wave elements) in relation to their length. If the diameter of the conductors is made large then the inductance per unit length decreases while the capacity per unit length increases. This results in a decreased L/C ratio causing the Q of the equivalent resonant circuit to decrease so that its response curve is broadened. On the other hand if the diameter of the conductor is made small, the L/C ratio is increased with a resultant increase in the Q of the resonant circuit. This results in a much sharper resonance curve and limits the range of the antenna to a narrow band of frequencies. Therefore a half-wave dipole whose quarter wave elements consist of three-inch tubing will operate over a much wider frequency range than if these elements were very small, such as a #14 wire.

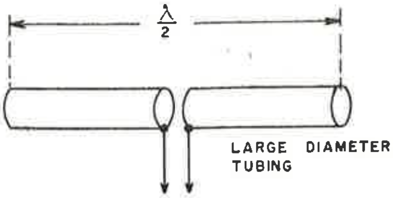


Fig. 13-10. Cylindrical antenna.

It is possible to obtain this relatively large cross-sectional area of the antenna elements, necessary to efficiently cover a number of television channels, in various ways. Perhaps the simplest method is to use large diameter tubing for the antenna elements. This type of antenna is referred to as a cylindrical antenna and is illustrated in fig. 13-10. The over-all length of this type of antenna should be somewhat less than a half-wavelength, depending upon the diameter of the tubing, since increasing the diameter of the antenna elements reduces the length required to obtain half-wave resonance. Other types of wide-band antennas are the conical, diamond, double diamond and spheroidal. However, all these antennas are characterized by antenna elements which have a relatively large diameter-to-length ratio so as to provide a low Q.

Probably the most widely used type of broad-band antenna for television reception is the folded dipole, shown in fig. 13-11. Fundamentally, the folded dipole consists of two closely spaced half-wave antennas connected together at their ends with one of the dipoles fed at the centre from a balanced transmission line. As will be brought out later, the folded dipole permits the use of small diameter elements to produce wide-band characteristics.

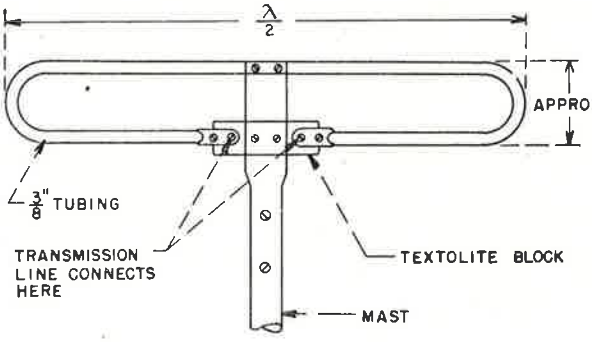


Fig. 13-11. Fundamental folded dipole.

This has the advantage that for a given diameter of antenna elements, the folded dipole will cover a much wider band of frequencies than the ordinary half-wave dipole and is, therefore, simpler to construct and mount than the other types of broad-band antennas. It also has other advantages, and considerbly more will be said concerning this antenna later in the chapter.

Calculation of Antenna Length.

As mentioned previously, maximum signal pick-up occurs when the antenna is resonant at the frequency of the desired signal, and in the case of the half-wave dipole this would be at a frequency to which it is a half-wavelength long.

If one antenna is to be used for reception over a number of channels it is usual practice to design the antenna so that it is a half-wavelength near the centre of the range of frequencies to be covered. If, for instance, the first six TV channels (54-88 mc) are to be covered, then for the antenna to be resonant near the centre of this range of frequencies its overall length should be such that it is a half-wavelength long at approximately 70 mc. Optimum signal pick-up will be obtained at the frequency to which the antenna is exactly one-half wavelength long. However, if the antenna elements have a sufficiently large diameter to length ratio, its response will be broad enough to give adequate signal pick-up on the television channels above and below the mean centre frequency of approximately 70 mc.

The overall length of a half-wave dipole for any desired frequency can be easily computed by the following equation.

$$\text{Overall length (in feet)} = \frac{492 \times 0.94}{\text{Freq. (mc)}}$$

Each rod or conductor of the dipole will then be one-half the overall length as computed by this equation. The spacing between adjacent ends of the dipole elements is not too critical and is usually made approximately one inch. The factor 0.94 compensates for the end effect of a half-wave antenna at high frequencies, therefore the actual length of a half-wave dipole will not be equal to a half-wave in free space, but will be approximately 5% less.

To illustrate the use of the above equation, suppose it is desired to make the antenna resonant at 70 mc. Substituting this value (70 mc) in the equation:

$$\text{overall length (in feet)} = \frac{492 \times 0.94}{\text{Freq. (mc)}}$$

it is found that the overall length of the antenna in feet

$$\text{is equal to } \frac{492 \times 0.94}{70} = 6.6\text{feet.}$$

The length of each half of the dipole will be 3.3 feet less one-half inch to allow for the one-inch spacing between elements.

Directional Characteristics.

If the frequency response characteristics of the antenna were the only consideration involved there would be little or no problem in obtaining satisfactory wide band operation, since by making the effective Q of the antenna low, as discussed earlier, the frequency response of the antenna can be made essentially uniform for all 13 TV channels. However, another very important characteristic of all antennas is directivity. Due to this characteristic, an antenna although it may have wide-band frequency response characteristics may or may not provide satisfactory wide-band reception, depending upon local conditions.

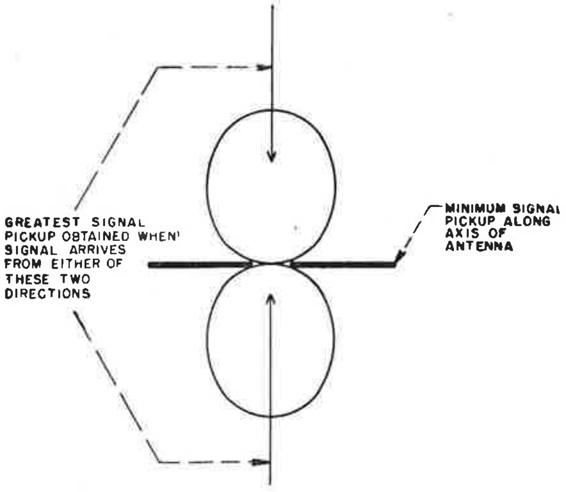


Fig. 13-12. Horizontal directivity for a half-wave dipole.

A dipole antenna exhibits definite directional characteristics and the horizontal directivity for a half-wave dipole is shown in fig. 13-12. This indicates that the signal pick-up is greatest when the signal arrives from a direction that is at right angles to the broad-side of the antenna. In other words, for maximum signal pick-up, the broad-side of the antenna should be pointed in the direction from which the signals are arriving, i.e., toward the transmitting antenna.

A further inspection of fig. 13-12 shows that in the direction along the axis of the antenna the signal pick-up is practically zero. Use can often be made of this fact in locations where there is noise or other unwanted signals by rotating the antenna so that its axis points in the direction from which the noise signal is arriving. Such an orientation may decrease the signal pick-up somewhat since the broad-side of the antenna may not be pointing exactly in the direction of the arriving television signal but will be beneficial because of the reduction in unwanted signal pick-up, such as noise or reflected signal.

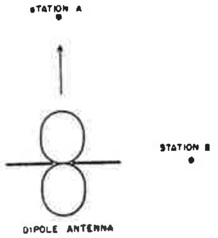


Fig. 13-13. Stations at right angle to each other.

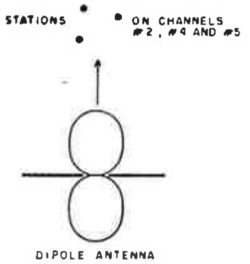


Fig. 13-14. Stations close together.

If two stations are exactly at right angles to each other as in fig. 13-13, then when the antenna is oriented for optimum pick-up on station A, little or no signal pick-up will be obtained from station B, or vice versa. This is one example of an antenna having a wide-band frequency response characteristic but inadequate signal pick-up on all channels. Fortunately, however, the television stations in most cities are located fairly close together so that the relative direction of the signal from each station is approximately the same. If these stations are all low band stations (54-88 mc), for instance, then a wide-band antenna cut to be a half wavelength long at approximately 70 mc will provide satisfactory reception, in the majority of cases, for the low band stations if the antenna is oriented for any one of these stations as indicated in fig. 13-14. This of course assumes the absence of multi-path signals (reflected signals) and that the antenna is located in the service area of these stations.

If the stations are separated to any extent it may not be possible to aim the lobe of the antenna at any one station as in fig. 13-14 and get satisfactory reception on the others. Instead, a compromise orientation will probably have to be made. The necessary compromise in orientation will be modified in most cases by the relative signal strength of the different stations. One station may be so strong that considerable misdirection may be permissible, without objectionable signal strength loss, so as to obtain a maximum signal from another station which is very weak.

As indicated in fig. 13-12, a dipole responds equally well to signals arriving in either direction (front and back) that are at right angles to the broad side of the antenna. This is helpful in cases where it is desired to receive two stations that are separated by 180 degrees. However, under certain other conditions, this characteristic of the dipole is undesirable. This point will be discussed in more detail when the use of parasitic elements, known as reflectors and directors, are considered.

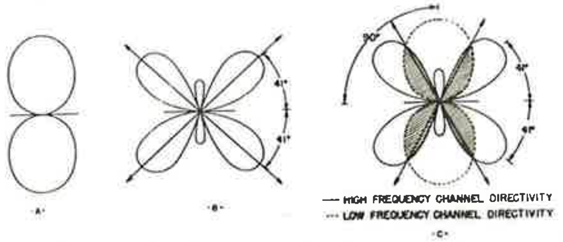


Fig. 13-15. Change in directivity with change in operating frequency.

The directivity pattern shown in fig. 13-12 is for a dipole antenna that is a half-wavelength long and represents the approximate field pattern for an antenna that is a half-wavelength at 70 mc, operating in channels #2 through #6 (54-88 mc). However, when this same antenna cut for 70 mc is used for reception in the high band channels, #7 through #13 (174-216 mc), its directivity pattern changes as indicated by A and B of fig. 13-15. In A is shown the approximate directivity pattern of the antenna for signals in the low band channels and is the same as the directivity pattern shown in fig. 13-12. When used to receive signals that are approximately three times higher in frequency (174-216 mc) than those of the low band channels, the antenna is no longer operating as a half-wave dipole but is operating at a wavelength and a half with a directivity pattern like that in B. From A and B of fig. 13-15 it can be seen that for a given antenna cut to operate as a half-wave antenna, over the low band channels, the direction of maximum signal pick-up tends to approach the line of the antenna itself as the range of frequencies to be received is increased to that of the high band channels. As shown in B, optimum signal pick-up on these higher frequencies is no longer broadside to the antenna. Instead, optimum signal pick-up is obtained on these high frequency channels at approximately forty degrees to the broadside of the antenna as indicated by the four major lobes. There are two minor lobes at right angles to the antenna as in A but they will provide very little pick-up.

Due to this change in directivity if the antenna is low channel oriented or pointed toward a station for maximum signal pick-up on a frequency at which the antenna is operating as a half-wave dipole, then this same antenna will provide considerably less pick-up from the same direction on some high channel station. In other words, if in a certain locality the high channel stations are located such that the signal arrives from the same general direction as the low frequency channels, then when the antenna is oriented for best signal pick-up on the low frequency channels the signal pick-up on the high frequency channels will be poor, and vice versa. This can be better illustrated by combining the directivity patterns of A and B of fig. 13-15, as in C of fig. 13-15. However, from fig. 13-15 it can be seen that there is an overlapping area (shaded) in the combined directivity pattern where the directivity is essentially the same for both the high and low frequency channels. The signal pick-up from these combined lobes (shaded) will be somewhat reduced but will remain essentially constant over the high and low channels. Thus, if the antenna is oriented so that any one of these shaded lobes is pointed toward a high or a low channel station, satisfactory reception should be obtained in many cases from all stations if they are located so that the signals come from the same general direction and if the antenna is located in the primary service area of these stations. The signal pick-up for any one particular station will not be as great as though the antenna were oriented for a single high channel or a single low channel station, but it will be considerably better insofar as all channels are concerned.

Where the high and low channel stations are located so that their signals do not arrive from the same general direction a single antenna by itself will not provide, in most cases, adequate signal pick-up on all channels. In this case it will be necessary to use at least two separate antennas, one cut to be a half-wavelength long on the low frequency channels and the other cut to be a half-wavelength long on the high frequency channels, mounted so that each antenna can be oriented independently of the other. Another method that might be used in this case is a motor driven antenna whose orientation can be controlled from the receiver. The antenna should be cut to be a half-wavelength long on the low frequency channels and should of course have a wide band frequency response characteristic. This and other special problems will be covered in detail later in the chapter.

Polarization of the Antenna.

Since a radio wave consists of magnetic and electrostatic fields at right angles to each other, the polarization of a radio wave simply means the relationship of the electrostatic field with respect to the earth as the radio wave travels into space. If the electrostatic field is vertical with respect to the earth, the radio wave is said to be vertically polarized. If the electrostatic field is horizontal with respect to the earth, the radio wave is then said to be horizontally polarized. If the elements of a dipole transmitting antenna are vertical with respect to earth then the antenna is said to be polarized vertically and for maximum induced voltage the receiving antenna should also be vertically polarized, i.e., the elements of the receiving dipole should also be vertical with respect to earth.

On the other hand, if the arms of the transmitting dipole are horizontal with respect to earth, then it will send out a horizontally polarized wave and therefore for maximum signal pick-up the receiving antenna should also be horizontally polarized, that is, the elements of the receiving dipole should also be horizontal with respect to earth.

It has been found that a horizontally polarized receiving antenna is less susceptible to ignition noise and other electrical interference, and consequently television transmitting antennas send out a horizontally polarized wave.

The Folded Dipole.

The folded dipole type of antenna has already been mentioned in connection with the frequency response characteristics of antennas. Since the folded dipole is so widely used as a broad band antenna it might be well to discuss it further. Although the ordinary half-wave dipole can be made to provide adequate broad band reception, the folded dipole type of antenna is more satisfactory for several reasons.

First, for a given diameter of antenna elements, the folded dipole will cover a wider band of frequencies than the ordinary half-wave dipole and is therefore somewhat simpler to construct and mount. Also, its centre impedance at twice its fundamental frequency where it acts as a full wave antenna is quite high, much higher at this frequency than for the ordinary half-wave dipole designed to cover the same broad band of frequencies. This characteristic of the folded dipole reduces the possibility of unwanted signals being picked up in the range of frequencies from just above 88 mc to just below 174 mc, which might interfere with reception on some of the TV channels.

A folded dipole consists of two closely spaced half-wave antennas connected together at their ends with one of the dipoles fed at the centre as indicated in fig. 13-11. The two antennas operate in parallel, each carrying half the total current so that the impedance at the centre of the antenna is four times the impedance of the ordinary dipole at resonance or very close to 300 ohms when the antenna conductors are all of the same diameter.

The impedance transforming properties of the folded dipole may be explained by considering the antenna from the point of view of a transmitting antenna. For instance, suppose that an ordinary half-wave dipole, A of fig. 13-16, which has a centre impedance or radiation resistance of 72 ohms, is transmitting 72 watts of power. Since the radiated power is equal to the square of the current (which is maximum at the centre for a half-wave dipole) times the radiation resistance, $W = I^2R$, then the maximum current in this case is one ampere since

$$I = \frac{\sqrt{W}}{R} \text{ or } \frac{\sqrt{72}}{72} = 1 \text{ ampere.}$$

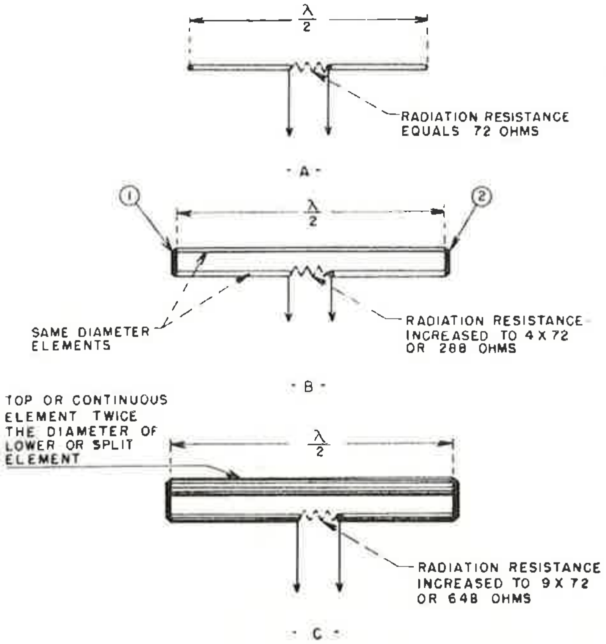


Fig. 13-16. Impedance transformation of folded dipole.

Now if another half-wave dipole of the same diameter is closely spaced to the first dipole and connected together at the ends as in a folded dipole, B of fig. 13-16, then the maximum current appearing at the centre of the first dipole (the one being fed by the transmission line) will be halved. Assuming that the power radiated by the antenna still remains the same as before, 72 watts, then the radiation resistance in this case must be four times what it was before the current at the centre was halved by the addition of the second dipole since $W = I^2R$. Equating $W = I^2R$ and solving for R, the actual radiation resistance in this case is equal to

$$\frac{W}{I^2} = \frac{72}{.5^2} = 288 \text{ ohms.}$$

This is often expressed in round numbers as 300 ohms.

Other values of radiation resistance may be obtained by making the two conductors have unequal values. For instance, if the diameter of this additional dipole were made twice that of the split dipole, instead of the same diameter, as in C of fig. 13-16, then the maximum current at the feed point of the antenna would be still further reduced. In this case the current at the centre of the split dipole would be approximately one-third, the value it would have been if the antenna were operating as an ordinary half-wave dipole. Again assuming the same power being radiated as before, the radiation resistance in this case will be approximately nine times that of a simple folded dipole or 648 ohms, which is often expressed in round numbers as 600 ohms.

Although the centre impedance of a folded dipole may be increased in the manner just discussed, the conductors of the folded dipole type of antenna, except for special cases, are made of the same diameter tubing so as to provide a 300 ohm centre impedance. Three-eighth-inch aluminium tubing is generally used. The spacing between the top and bottom sections should be quite close, not more than a few per cent of the wavelength of the frequency to which it is cut. This spacing is approximately three to five inches. The overall length of the antenna between ends, points 1 and 2, B of fig. 13-16, should be a half-wavelength, as with the ordinary dipole, and is computed by the same equation used for the ordinary dipole, where L in feet is equal to

$$\frac{492 \times 0.94}{\text{Freq. (mc)}}$$

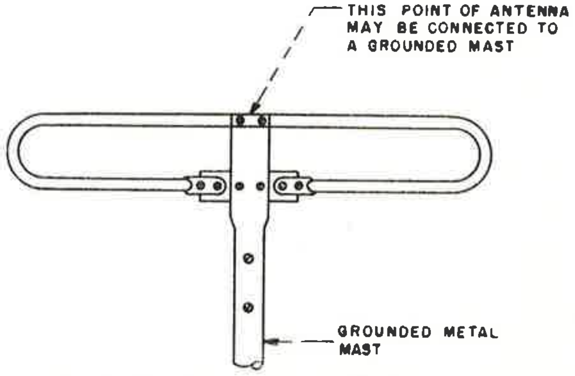


Fig. 13-17. Grounding of folded dipole to mast.

The directional characteristics of the folded dipole are essentially the same as for the ordinary half-wave dipole and the amount of signal pick-up at the frequency to which it is a half-wavelength long is approximately the same as for the ordinary dipole. Also the voltage and current distribution on the folded dipole is the same as for the ordinary dipole. An interesting point concerning the voltage and current distribution on the folded dipole is that the centre of the top section may be grounded as indicated in fig. 13-17. This can be done since the voltage wave on the antenna is passing through its zero axis at this point, making it "cold" with respect to ground.

If a folded dipole is cut to be a half-wavelength near the centre of the first five TV channels, 54-88 mc, it will operate as a half-wave antenna over the low band channels. Also, this same antenna will be $1\frac{1}{2}$-wavelengths long near the centre of the upper seven channels, 174-216 mc, and will operate as a $1\frac{1}{2}$-wavelength antenna over the high band channels. The frequency characteristics of such an antenna will provide satisfactory reception possibilities for all channels, assuming of course that all stations are favourably located and that a compromise orientation is made with respect to the high and low band directivity patterns of the antenna. The action of such an antenna over the low band TV channels, the band of frequencies between 88-174 mc and the high band TV channel is illustrated by figure 13-18.

Figure 13-18 indicates the relative signal transfer from antenna to transmission line as the operating frequency of the antenna changes, together with the voltage and current distribution on the antenna. Considering the low band TV channels, 54-88 mc, the maximum transfer of signal occurs at approximately 65 mc, the frequency at which the antenna is a half-wavelength long as indicated by the curve of fig. 13-18. The voltage and current distribution on the antenna at this frequency is shown directly below the 65 mc point of the curve and, as indicated, the voltage at the centre is at a minimum while the current at the centre is at a maximum. The centre impedance of the antenna at this point (65 mc) is approximately 300 ohms. It will be noted that as the operating frequency of the antenna increases toward 88 mc or decreases toward 54 mc, the amount of signal transferred from antenna to transmission line decreases from that obtained at 65 mc. However, due to the broad-band characteristics of the folded dipole this decrease in signal transfer is quite small, making the response of the antenna over this range of frequencies (54-88 mc) essentially uniform.

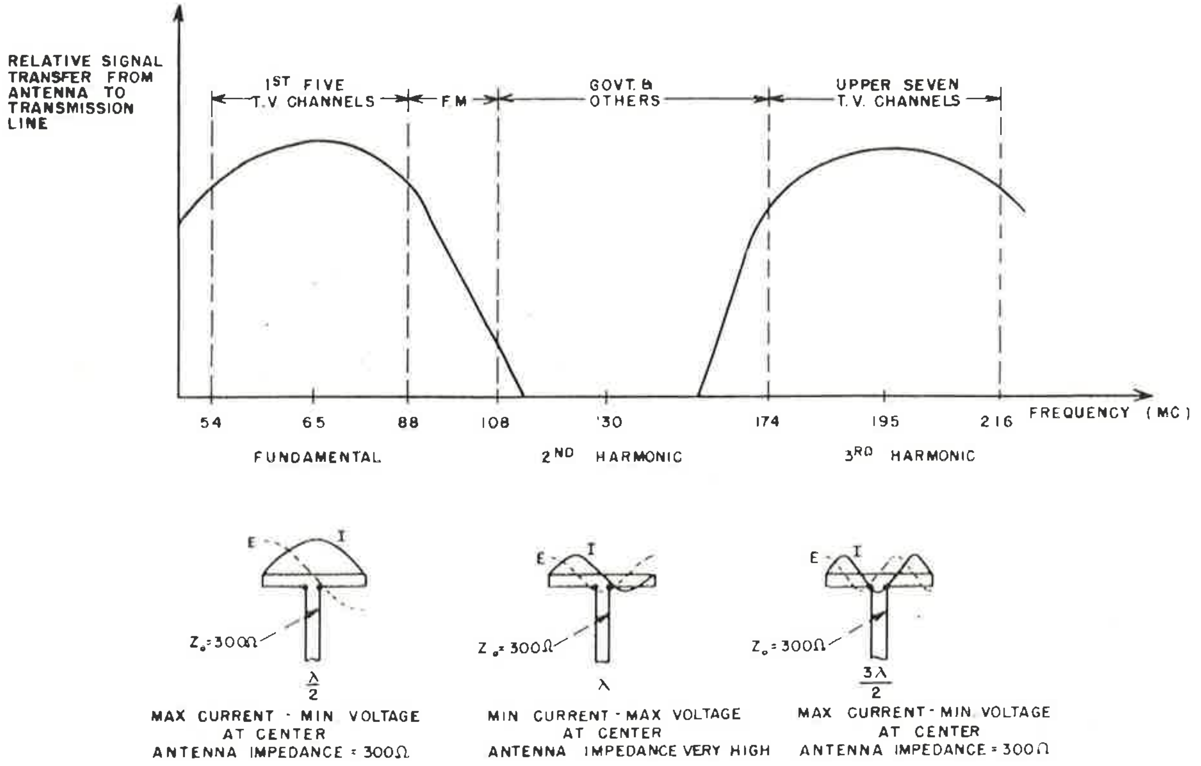


Fig. 13-18. Relative signal transfer from antenna to transmission line.

Considering the band of frequencies between 88-174 mc, the signal transfer decreases quite rapidly and reaches a very low value at approximately 130 mc where the antenna operates as a full-wave antenna with voltage and current distribution as shown in fig. 13-18. The centre of the antenna now represents a point of maximum voltage and minimum current, resulting in a centre impedance that is considerably greater than 300 ohms. Since the centre impedance of the antenna rises to a high value of this point, the amount of signal transferred from antenna to receiver will be quite low, for reasons to be discussed later in connection with transmission lines. This condition is very desirable since it reduces the possibility of signals in this region from just above 88 mc to just below 174 mc from causing interference on the TV channels.

Considering the high band TV channels, 174-216 mc, maximum transfer of signal from antenna to receiver occurs at approximately 195 mc where the antenna is operating at $1\frac{1}{2}$ wavelengths. The voltage and current distribution on the antenna for this condition is shown directly below the 195 mc point on the curve of fig. 13-18. As indicated, the centre of the antenna again represents the point of maximum current and minimum voltage, which is the same condition as obtained during half-wave operation over the low band channels (54-88 mc). Also the centre impedance of the antenna when operating at $1\frac{1}{2}$ wavelengths is approximately the same (300 ohms) as in the case of half-wave operation over the low band channels. As shown by the curve of fig. 13-18, the amount of signal transferred from antenna to transmission line at 195 mc is essentially the same as at 65 mc. Also, the decrease in signal transfer as the operating frequency varies from 195 mc up to 216 mc and from 195 mc down to 174 mc is quite small, due to the broad band characteristics of the folded dipole.

From the foregoing it can be seen that it is theoretically possible for a folded dipole type of antenna, cut to be a half-wavelength long near the centre of the low band channels, to provide satisfactory reception on the high band channels as well as the low band channels. However, in practice, this condition is not often obtained since a number of requirements must be met; both the high and low band TV channels must be located in the same general direction from the receiving antenna; the receiving antenna should be located in the primary service area of all stations; there must be an absence of reflected signals; the orientation of the antenna must be such as to provide a compromise between the high and low band directivity patterns as discussed earlier in connection with the directional characteristics of the dipole antenna.

Transmission Lines.

Thus far, the characteristics of the fundamental types of antennas used for television reception have been discussed and very little has been said concerning the actual transfer or transmission of the signal from the antenna to the receiver. In order to accomplish this important function of the antenna system satisfactorily a number of requirements must be met.

Probably the most important of these is that whatever the means used to transfer the signal from antenna to receiver, it should in no way affect the signal picked up by the antenna so as to alter the quality of the reproduced picture. Another important requirement is the transfer of the signal with minimum loss from the antenna to the receiver.

The above requirements are met by the proper selection and installation of a special line known as a transmission line. A properly selected and installed transmission line is as important to the quality of the antenna system as the antenna itself.

There are various types of transmission lines available, each designed for a specific purpose. However, three types of lines have come into general use for television receiver installation. They are:

1. The two-wire or parallel conductor line.
2. The shielded pair line.
3. The concentric or co-axial line.

The two-wire or parallel-conductor line, as the name implies, consists of two parallel conductors which are maintained at a fixed spacing and balanced to ground by a low-loss insulating material (polyethylene) placed between and around the conductors for the full-length of the line as shown in A and B of figure 13-19. The line is quite flexible and is made in the form of a flat ribbon for convenience of installation. The parallel-conductor line comes in two types — outdoor and indoor.

The outdoor line is of heavy construction and was designed particularly for outdoor use. As shown in A of fig. 13-19, the outdoor line is characterized by a much heavier insulation and is ovular in shape so as to shed water readily. It is superior to the indoor line in that it will maintain its low loss characteristics under severe atmospheric conditions. The outdoor line is recommended for all outdoor runs which exceed 20 feet or for even shorter runs if these runs are horizontal so that they can collect rain. Good practice calls for all outdoor runs to be made with the outdoor line.

The indoor line is of lighter construction and can be more conveniently installed around baseboards, etc. Since it does not have to withstand atmospheric conditions it is less expensive than the outdoor type. As shown in B of figure 13-19 it is flatter and uses considerably less insulating material between and around conductors than the outdoor line. The indoor line is not recommended for outdoor use since it is intended particularly for indoor runs where it is protected from the elements.

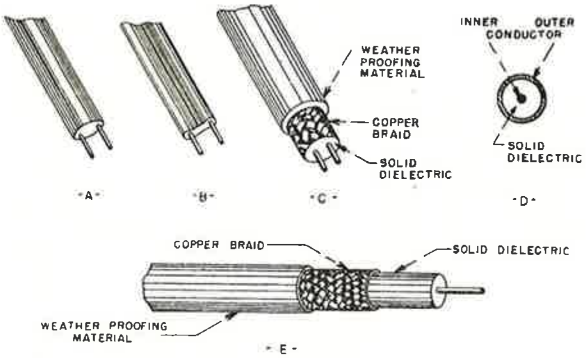


Fig. 13-19. Types of transmission line.

The two-wire or parallel conductor line (indoor or outdoor) has the advantages of low cost, flexibility in handling, good low loss characteristics and is balanced to ground. However, since this type of line is not shielded it has the disadvantage of being susceptible to noise pick-up and should not be used in extremely noisy locations.

The shielded pair type of transmission line consists of two conductors maintained at a fixed spacing by the insulating material surrounding them, as in the case of the parallel conductor line just discussed. However, in this case the conductors are contained within a copper braid shield which surrounds the conductors at a uniform spacing throughout their length, with the conductors being balanced to ground. The outside of the shield is then covered with a tough weather-proofing material to protect the cable against moisture and mechanical damage. The construction of the shielded pair is shown in C of figure 13-19. This type of line is used for special installations where it is important that the transmission line abstracts no energy from nearby noise or other waves where the antenna effect of an unshielded line in picking up noise and interfering signals would counteract the signal picked up by the antenna itself. The shielded pair type of line is also useful where it is necessary to conceal the transmission line in a conduit which for reasons to be covered later would upset the characteristics of the unshielded parallel pair type of line.

The shielded pair type of line is more difficult to handle, is more costly and introduces more loss in the antenna system than the two-wire parallel conductor type of line and should therefore be used only for special installations. This will be covered in more detail under INSTALLATION PROBLEMS.

The co-axial or concentric type of line also consists of two parallel conductors. However, as indicated by D of fig. 13-19, one of the conductors is placed inside of the other conductor with the outer conductor completely shielding the inner conductor. Since the outer conductor forms a complete circle around the inner conductor with the inner conductor uniformly spaced from the outer conductor so that the axis of each conductor is coincident, this type of line is called a co-axial or concentric line. In the type of co-axial line used for TV reception purposes, the outer conductor consists of stranded wire which surrounds the inner conductor at a uniform spacing throughout its length. The inner conductor is supported within the outer conductor by means of a solid dielectric material having very good low loss characteristics, such as polyethylene. The outside conductor, which also acts as a shield for the inner conductor, is covered with a tough weather-proofing material to protect the cable against moisture and mechanical damge. The construction of this type of line is shown in E of fig. 13-19.

Certain co-axial transmission lines have the advantage of introducing less loss in the antenna system than the other types of lines discussed and also abstract no energy from nearby noise or other sources of interference. It is useful in very weak signal areas where noise or other conditions may require the use of a shielded line. However, the co-axial cable is not balanced to ground and this is not desirable where the antenna input circuit of the receiver is balanced to ground as is the case with most modern TV receivers. Also, as in the case of the shielded pair line, it is more costly and more difficult to handle than the unshielded two-wire parallel-conductor type and should be used only where absolutely necessary under conditions to be discussed when actual installation problems are considered.

Impedance of a Transmission Line.

It is a well-known fact that for the maximum transfer of power, from the source to the load, it is necessary that the source impedance equal the load impedance. In the case of a receiving antenna system, the antenna represents the source and the receiver input circuit represents the load. Therefore, in order to obtain maximum transfer of signal from antenna to receiver, the input impedance of the receiver must equal the centre impedance of the antenna. For example, if a folded dipole which has a centre impedance of 300 ohms is used, then for maximum transfer of signal the input impedance of the receiver should also equal 300 ohms. Similarly, if the receiver input impedance is approximately 75 ohms (as in the older receivers) then for maximum transfer of signal an ordinary dipole antenna would be used which has a centre impedance of approximately 72 ohms.

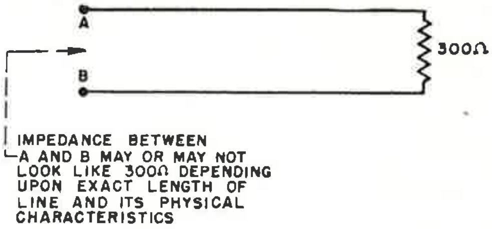


Fig. 13-20. Input impedance of transmission line.

However, the problem is not quite so simple as just selecting the proper antenna impedance to match a given receiver input impedance, and then connecting them together with a length of transmission line. Another very important factor must be considered, and that is the characteristic or surge impedance of the transmission line used between the antenna and receiver. At the high frequencies used in television if a certain load, say a pure resistance of 300 ohms, is placed across one end of a transmission line as in fig. 13-20, it may or may not look like a pure resistance of 300 ohms across the terminals A and B at the other end of the line (input end), depending upon the exact length and the physical characteristics of the line.

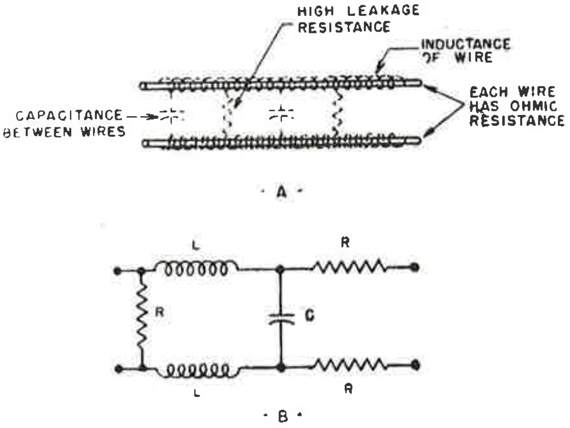


Fig. 13-21. Electrical constants of a transmission line.

Every transmission line has, in addition to the ohmic resistance of the conductors, the properties of inductance and capacitance which manifest themselves at the high frequencies used in television. These properties of resistance, capacity and inductance which are distributed along a short section of two-wire line are shown in A of fig. 13-21. The dotted turns represent the inductance of each conductor and its value depends upon the conductor size. A small diameter conductor will represent more inductance than a large diameter conductor. The dotted capacitors represent the capacitance between conductors along the length of the line. The value of this capacity depends upon the spacing between conductors and the dielectric constant of the insulating material between them. The resistance shown between conductors represents high resistance leakage paths, since no insulation is perfect and therefore a certain insulation resistance exists between conductors. B of fig. 13-21 shows these properties of resistance, capacitance and inductance lumped together as in conventional circuits. The value of this inductance, capacitance and resistance depends upon the physical characteristics or construction of the transmission line.

Due to these properties, every finite length of transmission line has a certain impedance which manifests itself at the high frequencies used in television. This impedance may be high, low, resistive, capacitive, inductive or any combination thereof, depending upon the length of the line and whether it is open circuited or short circuited. However, there is one value of input impedance, depending upon its L and C values, which any transmission line assumes if it is considered to be infinitely long. This impedance is called the characteristic or surge impedance of the line and is the impedance that would appear across the input terminals A and B of fig. 13-22 if the transmission line were infinitely long (no end to it).

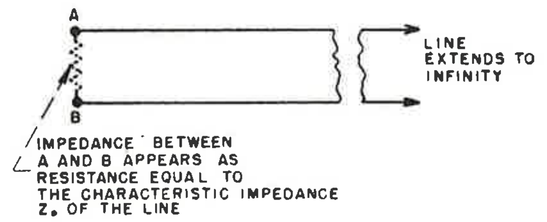


Fig. 13-22. Impedance of infinite transmission line.

This impedance would appear as a pure resistance across the input terminals A and B with its value being determined by the size of the conductors, the spacing between conductors and the type of insulation between conductors. In other words, this characteristic impedance of a theoretically infinite line depends upon the physical characteristics of the line. As mentioned earlier, these physical characteristics may be represented electrically as so much inductance and capacity per unit length of line. Using electrical quantities, the characteristic impedance of any transmission line is equal to the square root of the ratio of inductance to capacity per unit length of line. Thus Zo, which represents the characteristic impedance of a transmission line, is equal to $\sqrt{\frac{L}{C}}$.

Using physical quantities, the characteristic impedance of a parallel conductor line using air as the insulation between conductors can be calculated from the following formula: $Zo = 276 \log_{10} \frac{2D}{d}$

where Zo = surge impedance of line
D = spacing between centres of conductors, inches
d = diameter of conductor, inches.

In the case of a coaxial line its characteristic impedance, using physical quantities, can be calculated from the following formula:

$$Zo = 138 \times \frac{1}{K} \times \log_{10} \frac{D}{d}$$

where Zo = surge impedance of line
D = inside diameter of outer conductor
d = outside diameter of inner conductor
K = dielectric constant of solid insulating material between conductors.

As brought out earlier, the characteristic or surge impedance as calculated by any of the methods just given is the impedance that would appear across the input terminals of the line if it were infinitely long. This is the impedance that is referred to when a transmission line is said to have an impedance of 50 ohms, 75 ohms, 150 ohms, etc.

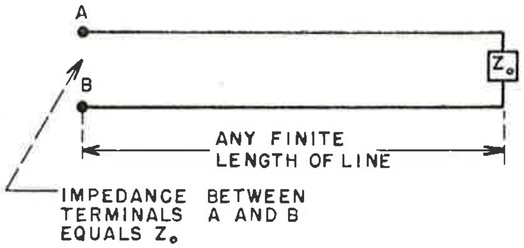


Fig. 13-23. Equivalent Circuit of infinite line.

Actually such an infinite line is impossible to attain. However, if a short or convenient length of line that would be used in practice is terminated by a resistive load equal to the characteristic or surge impedance of the line, it can be shown that this line will be equivalent to an infinitely long line and the impedance across its input terminals will equal Zo or the characteristic impedance of the line, regardless of its length. In other words, any length of line can be made to appear as an infinitely long line if it is terminated in its characteristic or surge impedance Zo, as indicated in Fig. 13-23. This is a very important fact from the standpoint of impedance matching.

Suppose that it is desired to make an impedance of 75 ohms look like the same impedance at the input end of a transmission line approximately 100 feet long. One method of doing this would be to use a transmission line of any characteristic impedance and very carefully adjust its length so that it is some multiple of a half-wavelength at the operating frequency of the line as in A of Fig. 24. If the line is some other length or if the operating frequency of the line changes then the 75 ohm load at the output end of the line will not look like 75 ohms at the input end. This method is very undesirable insofar as transmission lines for television reception are concerned since the line is resonant, making it very critical as to length and operating frequency.

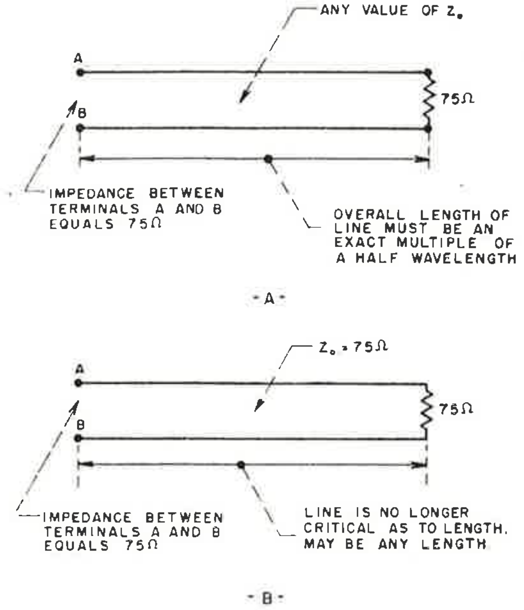


Fig. 13-24. Resonant and non-resonant transmission line.

A much better method of making the impedance at the output end of a transmission line repeat itself at the input end is to select a line having the proper characteristic impedance. In the case of the 75 ohm load, a transmission line having a characteristic impedance Zo, of 75 ohms should be used as indicated in B of Fig. 13-24. When the load at the output end of the transmission line equals the characteristic impedance of the line then the line is not critical as to length or operating frequency and the line is said to be non-resonant.

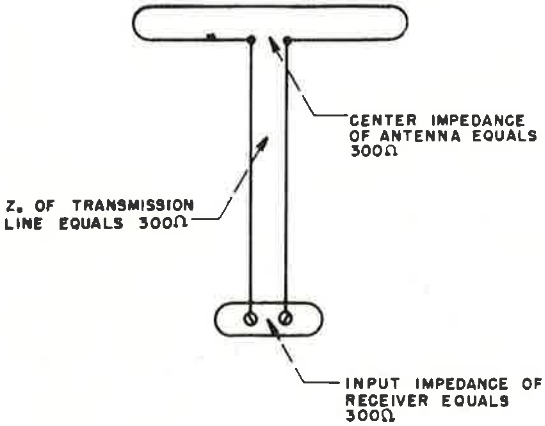


Fig. 13-25. Proper match between antenna, transmision line and receiver.

From the foregoing it is apparent that if it is desired to provide the maximum transfer of signal, from antenna to receiver, without regard to the length of the line or the operating frequency, then the characteristic impedance of the transmission line should equal the impedance of the antenna and receiver. This condition is shown in Fig. 13-25 where a receiver having an input impedance of 300 ohms is connected to a folded dipole having a centre impedance of 300 ohms. It will be noted that the characteristic impedance of the transmission line is also 300 ohms, which is the correct value to cause the 300 ohms load impedance of the receiver to appear as 300 ohms at the input terminals of the transmission line. Since the input terminals of the transmission line connect to the 300 ohms impedance of the antenna, a perfect impedance match is afforded between antenna and receiver. When the line is terminated in its characteristic impedance it is not critical to length and can be made any convenient length without disturbing the impedance match.

The importance of making the characteristic impedance of the transmission line closely match the input impedance of the receiver, so as to provide the desired impedance match between antenna and receiver, has been discussed only from the standpoint of providing the maximum transfer of signal. This consideration is very important, especially in weak signal areas, where every bit of signal is needed. However, there is another consideration that is even more important as far as picture quality is concerned. It is the effect on the picture of standing waves set up on the transmision line when the receiver input impedance does not properly terminate the line in its characteristic or surge impedance. A mismatch between the characteristic impedance of the line and the input impedance of the receiver permits reactive energy to travel back and forth on the line (reflections), depending upon the amount of mismatch, which will impair the character of the original signal picked up by the antenna, resulting in poor quality of the picture.

Reflections and Standing Waves.

As brought out earlier, the input impedance of a theoretically infinite line is resistive, this impedance being equal to the characteristic impedance of the line as determined by the physical characteristics of the line. If a signal were fed into such an infinitely long line, the signal would simply travel along it until it was entirely dissipated by the resistance of the line. Since the signal would be entirely dissipated by the line, there would be nothing left to reflect back into the line and standing waves would not exist on the line. The current and voltage on such a line would be in phase throughout the line, since the impedance presented to the signal appears as a pure resistance.

The equivalent of an infinitely long line can be obtained by terminating any finite length of line in a resistive load that is equal to the characteristic impedance of the line. Energy fed into a length of line terminated by a resistive load, equal to the characteristic impedance of the line, will be absorbed at the same rate as though the line were infinitely long, no faster, no slower. A signal fed into such a line will be completely absorbed by the load impedance and, as a result, there will be no signal reflected from the output end of the line to produce standing waves. Since the load impedance of a properly terminated line appears as a pure resistance to the signal, the current and voltage will be in phase. There will be no reactive energy travelling back and forth on the line and the line is said to be non-resonant. This is the condition desired for transmission lines used in antenna systems for television reception.

However, if on the other hand the line is not terminated in its characteristic impedance, then the line will not appear as an infinitely long line and all the signal fed into the line will not be absorbed by the load as before. The load will not appear as a pure resistance but will have a reactive component, either capacitive or inductive, depending upon the exact length of the line and whether the resistive portion of the load is higher, or lower than the characteristic impedance of the line. As a result, the signal not absorbed by the load will be reflected back into the line as reactive energy and the combination of the signal going into the line from the antenna and the reactive energy reflected back from the load end of the line (output end) produces standing waves on the line.

These reflected signals can destroy the clarity of the picture, since the portion of the original signal not absorbed by the load is surging back and forth on the line. If the transmission line is long, the difference in the arrival time of the original signal and the portion of the signal reflected in the line will cause a smear or actual displacement of the first or original image. Since the path of the second or reflected signal is from the receiver to antenna and back again to the receiver, the time difference or amount of displacement on the screen between the original image and the second or reflected image will be the time required for the reflected signal to travel twice the length of the transmission line. The longer the transmission line, therefore, the greater will be the amount of this displacement if reflections are present in the transmission line.

Standing Wave Ratio.

The standing wave ratio of a transmission line indicates the ratio of mismatch between the characteristic impedance of the line and the load impedance. That is, the standing wave ratio $= \frac{Zs}{Zt}$ where Zs is the characteristic or surge impedance of the line and Zt is the terminating or load impedance. From this, it is apparent that a standing wave ratio of unity represents a perfect match between the characteristic impedance of the line and the load impedance. Needless to say, the standing wave ratio on the transmission line of an antenna system for television reception should be very close to unity if no underisable reflections are to be set up.

It might be well to mention at this point that it is only necessary for the input impedance of the receiver to match the characteristic impedance of the transmission line in order to prevent reflections on the line. For instance, if the input impedance of the receiver equals or matches the characteristic impedance of the line, but the antenna impedance does not match the line, no reflections will be set up since the receiver input impedance properly terminates the line in its characteristic impedance thus absorbing all the energy sent down the line. However, failure to match the antenna impedance to the transmission line prevents the receiving antenna from delivering the maximum amount of signal to the receiver.

Too much stress cannot be placed on the fact that in order to obtain the optimum results from the antenna system, the antenna impedance should equal the input impedance of the receiver and, also that the characteristic impedance of the transmission line equal this same impedance. Any great variation from this will result in first: a loss of signal if either or both the antenna impedance and the receiver input impedance fail to match the line impedance, and secondly: a loss of signal and undesirable reflections on the line if the receiver input impedance does not match the line, regardless of whether or not the antenna impedance matches the line.

Transmission Losses.

The term transmission loss as used here refers to the loss in signal that may occur, for one reason or another, between the antenna and the receiver. This loss may occur in several ways. First, there is the normal loss in the line which is proportional to its length. This loss is due chiefly to the dielectric loss of the insulating material used to separate the conductors and increases with frequency. It is expressed as so many decibles of attenuation per 100 feet at a certain frequency. For instance, the loss or attenuation per 100 feet for the outdoor parallel conductor line, having a characteristic impedance of 300 ohms, is approximately 1 db per 100 feet at a frequency of 100 mc. At 50 mc, this attenuation is only approx. .70 db and at 200 mc this attenuation is approx. 1.5 db per 100 feet. The attenuation per 100 feet at 50 mc for the shielded pair type of transmission line, having a characteristic impedance of 100 ohms, is approximately 2 db.

It should be noted that the attenuation for the shielded pair type of line at 50 mc is approximately three times that of the outdoor parallel conductor line. Therefore, the parallel conductor type of line should be used wherever possible in order to keep transmission losses at a minimum. As an example of how this normal attenuation of the transmission line can seriously reduce the signal, suppose that 500 feet of the shielded pair line is used between antenna and receiver. It will be assumed that the antenna is delivering 500 microvolts of signal to the transmission line and that the receiver is operating on channel #2, 54-60 mc; since at 60 mc, the normal attenuation of this line is somewhat greater than 2 db per 100 feet, then the total attenuation for the entire 500 feet of line will be at least 5 x 2 or 10 db. An attenuation of 10 db represents a 3:1 reduction in signal between antenna and receiver, with the result that only $\frac{500}{3}$ or 167 microvolts of signal will reach the receiver. From this example it can be seen that it is essential to keep the transmission line as short as is practically possible and to use a type of line having the least attenuation, wherever possible, in order to obtain the maximum signal at the receiver.

As pointed out previously, a mismatch of impedances between the antenna, receiver and transmission line also introduces transmission losses. All three impedance values must be equal in order to obtain the maximum transfer of signal from antenna to receiver. Although these impedances may be perfectly matched at one particular frequency, a certain amount of mismatch will occur between the antenna and transmission line when operating over a wide range of frequencies. However, no mismatch of impedance will occur between the transmission line and receiver as the operating frequency is varied, provided, of course, that the antenna input circuit is properly designed so as to maintain an essentially constant input impedance at all frequencies. The transmission loss introduced by the mismatch between antenna and transmission line, when operating over a wide range of frequencies, is illustrated by the following example: Assume that a transmission line with a characteristic impedance of 300 ohms is properly terminated by a receiver having an input impedance of 300 ohms. Also, that a folded dipole type of antenna is used which is half-wave resonant at 65 mc. Since the impedance of a folded dipole is 300 ohms at this frequency, the maximum transfer of signal will occur at 65 mc where the antenna impedance is exactly matched to the 300 ohm impedance of the transmission line. This is shown by point (1) of Fig. 13-26. Fig. 13-26 indicates the approximate attenuation of the signal, in decibels, introduced by the mismatch between the folded dipole and transmission line over the range of frequencies from approximately 54 mc to 216 mc. As the operating frequency changes from 65 mc, the centre impedance of the antenna also changes and an exact match between antenna and transmission line no longer exists; therefore, the antenna does not deliver the maximum possible signal to the receiver and there is a loss of signal occurring in the antenna system depending upon the amount of mismatch between the antenna and transmission line. If a high Q antenna (narrow band) were used instead of a folded dipole, the centre impedance of the antenna would rise quite rapidly at frequencies off resonant and the loss due to a mismatch would be quite high at these frequencies. Since the folded dipole type of antenna has wide band characteristics, its centre impedance will not change very much, from its half-wave resonant impedance of 300 ohms, over the range of frequencies that it is desired to cover. Therefore, when a folded dipole is used, the transmission loss due to a mismatch of impedance between antenna and receiver will not be very great over the desired range of frequencies, as indicated by Fig. 13-26. It will be noted that over the first five TV channels, 54-88 mc, that a slight loss is introduced on either side of the resonant frequency of 65 mc. The loss introduced at 88 mc is approx. 3 db while the loss at 54 mc is approx. 3.5 db. This represents a maximum loss of only slightly more than 30% over the range of frequencies from 54 to 88 mc. This loss is not serious considering the range of frequencies covered and that it increases gradually on either side of the resonant frequency of 65 mc. It should also be noted that over the undesired range of frequencies, from above 88 to below 174 mc, the loss becomes very high. This is because of the fact that the antenna is operating as a full wave antenna, with a very high centre impedance, over this range of frequencies as indicated by point 2 of Fig. 13-26. Consequently, the transmission loss introduced by this severe mismatch of

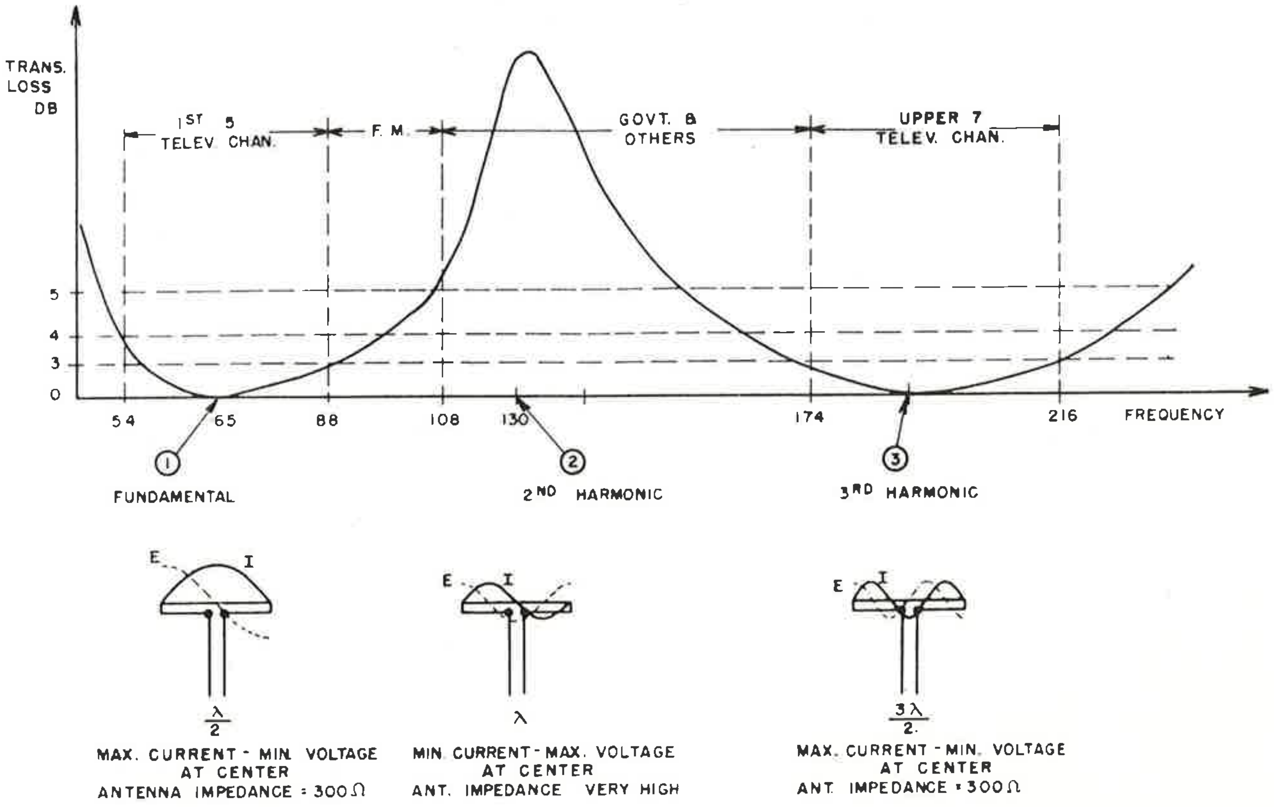


Fig. 13-26. Transmission loss due to mismatch between antenna and line.

impedances becomes quite high. This is desirable from the standpoint of attenuating these signals as much as possible so as to minimize their effect on some of the TV channels. Over the range of frequencies covered by the upper seven TV channels, 174-216 mc, the antenna operates at 1½ wavelength and its centre impedance is very close to 300 ohms at 195 mc. Minimum loss over the high band channels occurs at approx. 195 mc as indicated by point 3, with the loss gradually increasing on either side of this frequency. As in the case of the low band channels, the maximum loss over the high band channel (174-216 mc) is only slightly more than 30%.

In order to keep the transmission losses at a minimum so as to obtain the maximum transfer of signal from antenna to receiver, the following requirements must be met:-

1. The characteristic impedance of the transmission line must match the input impedance of the receiver.
2. The antenna must be designed so that its centre impedance closely matches that of the transmission line over the desired range of frequencies.
3. The length of the transmission line should be kept as short as possible so as to keep the normal line loss at a minimum. Also, a good quality of transmission line should be used whose insulation has a low dielectric loss.
4. The transmission line should be installed in such a manner that its characteristic impedance throughout its entire length is not changed in any way.

5. INSTALLATION OF TELEVISION ANTENNAS.

There are a number of factors involved in the proper installation of a television antenna which results in a variety of installations. Everything that has been mentioned in the previous paragraphs regarding the basic theory of dipole antennas and transmission lines applies directly to any installation. However, the particular type of antenna and transmission line used will vary considerably, depending upon various factors which are determined by local conditions.

Some of the factors which must be considered in determining just what type of antenna and transmission line to use for a particular installation are as follows:

1. Whether the antenna is to be located in an area of good signal strength, 5000 microvolts or more.
2. The proximity of the antenna system to man-made noise sources.
3. Whether the high and low band channels are all located in the same general direction from the receiving antenna or whether they are widely separated.
4. Whether the antenna is to be located in an area of poor signal strength (fringe area) where the signal strength may be considerably less than 5000 microvolts.
5. Whether the antenna is to be located in an area where there are multiple signal paths, due to reflections, that may be picked up by the antenna, the transmission line or both.

Fundamental TV Antenna Installation.

The problems involved in connection with an installation where ideal conditions prevail will be considered first. It will be assumed that the high and low band channels are all located in the same general direction, that the signal strength from these stations is good, that there are no multiple signal paths due to reflections, that there are no interfering signals from F-M, etc., and that there is no serious man-made noise interference. Such an ideal location might be found in a residential area some distance from the TV transmitters.

Since, in this case, all stations are favourably located and the signal strength is good with no reflections or serious noise conditions to contend with, a simple folded dipole type of antenna can be used with the unshielded two-wire or parallel conductor type of transmission line. The antenna should be cut so that it is half a wavelength long and approximately 65 mc, so that it will operate as a half wave antenna over the low band channels and as a one and a half wave antenna over the upper channels, as discussed earlier in connection with the folded dipole antenna. Assuming that the input impedance of the receiver is 300 ohms, which is generally the case, then in order to provide the maximum transfer of signal and to prevent reflections on the line, the characteristic impedance of the transmission line should also be 300 ohms.

As a general rule, for an installation of this type, the antenna need not be very high above the ground. A height of from 10 to 15 feet above the roof is, in most cases, satisfactory. However, it is advisable to keep the antenna as far as possible from metallic objects such as gutters, metal roofing, etc. The antenna should also be located as far from the street or road as convenient so as to reduce the possibility of interference from automobile ignition systems.

The antenna should be horizontally polarized for reasons mentioned previously. This means that the elements or arms of the antenna should be horizontal or parallel to the ground.

In order to provide satisfactory signal pick-up on the high and low band channels, a compromise will have to be made in the orientation of the antenna, as brought out earlier when the directional characteristics of the dipole antenna were discussed. Most stations transmit a regular test pattern, during certain hours of the day, which is very helpful in determining the best orientation of the antenna. There are several methods by which the results of orienting the antenna may be observed. The most usual method is to view the screen of the TV receiver and interpret the results of orienting the antenna in terms of signal strength and clarity of the picture. This should be carefully checked on all the channels that it is desired to receive so that the best compromise in orientation may be obtained. When this method of checking orientation is used, it is generally necessary to employ two men to make the installation — one on the roof at the antenna and the other at the receiver. An intercommunicating system of some sort is essential for communication between the two men. Another method that may be used for checking the results of orienting the antenna is to rectify the output of the video amplifier by means of a special probe that can be conveniently connected to the video amplifier. The rectified output is then carried to the antenna site by means of an extension cord and is fed into a meter where an increase in signal pick-up by the antenna will be indicated by an increase in the meter reading. This arrangement has the advantage that usually only one man is required to orient the antenna.

In addition to the considerations just mentioned, regarding the antenna and its proper placement, the following precautions should be observed when installing the transmission line:

1. Since the transmission line used in this type of installation will be an unshielded two-wire or parallel conductor line, it must be of the outdoor type so that excessive losses and standing waves will not be introduced on the line due to weather conditions changing its characteristic impedance.
2. The line must be kept clear from all metal objects, such as the metal mast supporting the antenna, tin roofs, drain pipes, etc., since if the line is allowed to run against metal surfaces this will change the capacity between conductors and upset the characteristic impedance of the line. This will cause a loss of signal and, worse yet, will cause reflections on the transmission line, making it impossible to obtain clear, sharp pictures.
3. The line should be kept clear from the sides of buildings (wood or otherwise) by at least an inch or two, using stand-off insulators.
4. Do not run the line inside a conduit of any type since this will change its characteristic impedance. If the transmission line must be run inside a conduit, then the shielded pair or coaxial type of line should be used. This point will be discussed in more detail later.
5. The line should be supported in such a way that it will not sway in the wind.
6. If the line is run across a flat roof, make certain in cold climates, that it clears the snow level.
7. If it is necessary to splice the line, be careful to maintain the characteristic impedance of the line. This is done by stripping the two lines back about ½ inch and then twisting the respective conductors together so that the insulation of one butts directly against the insulation of the other as indicated in A of Fig. 13-27. If this procedure is not followed and the splice is carelessly made with a large space between the parallel conductors, as in B of Fig. 13-27, the line impedance will be changed at that point and reflections may be set up. The recommended procedure will avoid such an air gap. The exposed wires which stand away from the line should be twisted tightly, soldered well and clipped short.
8. Do not paint the line, especially with lead or aluminium paint.
9. Never use window strips to bring the transmission line into the house since this will upset the impedance of the line. Instead, the line should be run through a hole drilled through the window casing or wall. In some cases, the line inside the house (indoor line) may cross the window sill so that the window closes down on it, provided the structure is of wood. The thinner indoor line, after crossing the window sill, may then be spliced to the heavier outdoor line. Do not run the line over a metal window ledge.

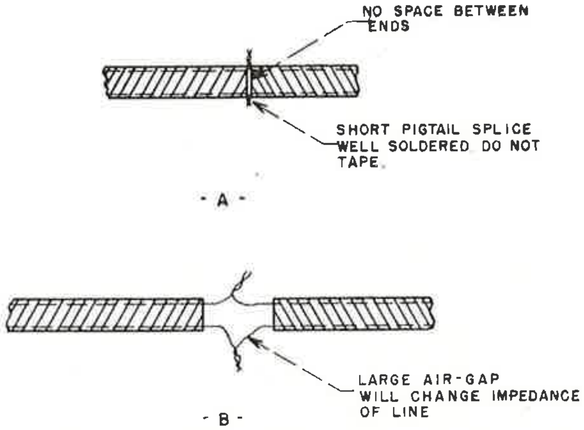
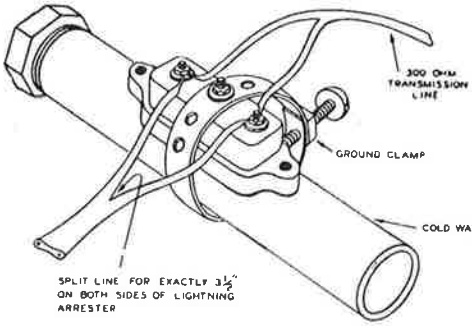


Fig. 13-27. Proper (A) and improper (B) spliced line.

10. The indoor type of line should not be used outdoors, except for very short vertical runs.
11. The indoor type of line should never be run for more than five feet under a carpet, since this will change the impedance of the line. However, the heavier outdoor line can be run up to 20 feet under a carpet without any serious impedance change.
12. When running the line indoors, it may be tacked against wooden floor moulding, but use tacks with small heads and only as many as is absolutely necessary. The line is far superior electrically if it droops somewhat between tacks; i.e., it is better than having it pressed firmly against the wood surface. Better yet, use special stand-off insulators made for this purpose.
13. Do not pull the transmission line around pipes, radiators or other metal objects — space it away from these.
14. Do not leave any excess length in the transmission line coiled up at the receiver. Leave only enough line to conveniently make connections to the antenna terminals of the receiver and to move the receiver away from the wall for servicing, etc.

The use of a lightning arrestor is recommended and in many cases required where the antenna is mounted outdoors. However, arrestors designed for ordinary antennas are not suitable for TV installations, since they will change the characteristic impedance of the line considerably. It is necessary to use a special type of arrestor, which does not change the characteristic impedance of the line and which also protects each side of the line (double pole type).

The connections to a lightning arrestor that has been especially designed for television receiving antenna installations is shown in Fig. 13-28. Three terminals are provided, the outside terminals connect to each side of the line while the centre terminal is grounded, preferably to a cold water pipe. In order to not change the characteristic impedance of the line, it is very important that the instructions, supplied with the arrestor for its proper connection in the line, be followed very carefully. In addition to the lightning arrestor, the metal mast on which the antenna is mounted should be connected to a good ground with at least No. 8 wire.



DIRECTIONS

SPLIT THE LINE AS INDICATED AND FASTEN TO LIGHTNING ARRESTER FASTEN ARRESTER TO PIPE BY MEANS OF THE GROUND CLAMP

Fig. 13-28. Connection of lightning arrestor.

The location of the receiver in the home is also of some importance, and the following factors should be considered:

1. Wherever practical, the receiver should be located so as to keep the transmission line as short as possible.
2. Accessibility to an a-c outlet.
3. The receiver should be so located that the room illumination in day-time or night-time can be controlled easily. If the daylight illumination cannot be controlled easily, locate the receiver in such a position that the light from a window does not fall directly on the picture tube screen. For night-time use turn out all lights when viewing. In fact, it is desirable to have a soft light fall on the viewing screen in order to minimize the possibility of eye-strain.
4. Leave about a three-inch air space if possible, between the wall and receiver. This provides good ventilation and permits better sound reproduction.

Need and Use of Shielded Type of Transmission Line.

In the foregoing discussion of a fundamental TV antenna installation, the use of an unshielded ribbon type of line was recommended since conditions were assumed to be ideal with no extraneous noise or other signals present that might be picked up by the transmission line. However, in many cases, the antenna itself may be ideally located insofar as adequate signal strength and freedom from noise pick-up are concerned but the transmission line may come in close proximity to man-made noise sources. Such a condition usually occurs in apartment house, commercial and tall building installations where a long transmission line is required and there is considerable man-made electrical disturbance generated in the building.

In such cases, it is necessary to use a shielded type of transmission line. There are various types of shielded lines available, unbalanced (coaxial line) and balanced (shielded pair line) as brought out earlier when transmission lines were discussed. The particular type of shielded line to use depends upon such factors as the amount of attenuation that can be tolerated on the line, cost, ease of installation and the antenna input circuit of the receiver.

Assuming that the input circuit of the receiver is 300 ohms, balanced to ground, the shielded pair type of line which is also balanced to ground ought to be used in most cases. The balanced type of line provides more immunity against noise since both conductors are shielded and also does not disturb the balance to ground of the receiver input circuit.

This type of line is available in two impedance values, 95 ohms and 300 ohms. The db loss per 100 feet (attenuation) in either case is approximately the same, being 3.4 db at 100 mc for the 300 ohm line and 3.6 db for the 95 ohm line at 100 mc. The 300 ohm line has the advantage of providing a direct match to the 300 ohm input impedance used in most TV receivers and also matches the 300 ohm centre impedance of the folded dipole type of antenna as indicated by A of Fig. 13-29.

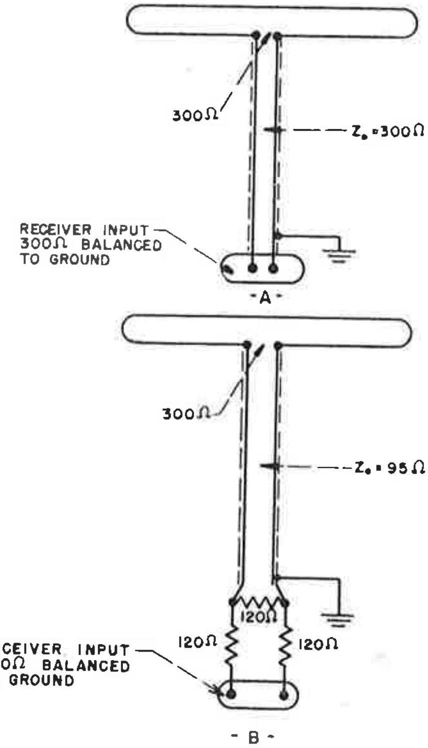


Fig. 13-29. Connection of shielded pair line.

Since no matching network, which would introduce a loss, is required with the use of the 300 ohm line, it should be used in those cases where the overall attenuation of the system must be considered. However, it is more expensive than the 95 ohm shielded pair type of line. In those cases where there is plenty of signal available at the antenna and the attenuation introduced by a matching network is no factor, then it would be advantageous, from a cost standpoint, to use the less expensive 95 ohm line. When the 95 ohm line is used to feed a receiver having a 300 ohm input impedance, a special resistance matching network must be installed between the line and receiver so as to prevent undesirable reflections from being set up due to a mismatch of impedance between the receiver and transmission line, as previously discussed. Such a resistance matching network with values is shown in B of Fig. 13-29. Carbon resistors with short leads should be used so as to minimize any inductive effect. No matching network between the antenna and line is used since a mismatch at this point simply reduces he amount of signal transferred.

Since no standing waves will be produced due to a mismatch at this point, as in the case of a mismatch at the receiver end of the line, the resistance matching network is omitted because it would only reduce the amount of signal transferred still further. Since the resistance matching network at the receiver and the impedance mismatch at the antenna will attenuate the signal considerably, then as mentioned before, the 95 ohm line should be used only where there is an abundance of signal being picked up by the antenna. Otherwise, the 300 ohm shielded pair type of line is more desirable.

In areas where the signal picked up by the antenna is quite weak and where due to extreme noise conditions a shielded type of transmission line is required, the attenuation introduced by either the 300 or 95 ohm shielded pair line would be too great to tolerate. In this case, a low loss coaxial cable such as the type RG 17/U should be used in conjunction with a special matching transformer that is now available. The characteristic impedance of the type RG 17/U is 52 ohms and its attenuation loss per 100 feet at 100 mc is only .85 db. This is even less than the attenuation loss per 100 feet for the twin conductor unshielded type of line. Since the impedance of the RG 17/U line is only 52 ohms, it is matched to a 300 ohm impedance by means of a special 50/300 ohm matching transformer which has wide band frequency characteristics. This transformer provides an essentially uniform impedance match for all channels with very little insertion loss. It also provides a means of connecting an unbalanced line to a balanced input circuit. A resistance matching network could not be used in this case due to its high insertion loss.

In addition to preventing noise from being picked up on the transmission line, a shielded type of line is often used to prevent a long line from acting as an antenna and picking up TV signals that are slightly out of phase with the signal being picked up by the antenna. This condition occurs when a rather long unshielded line is used in an area of very high signal strength and will produce either ghost images or a smearing of the picture. This will be discussed in more detail when reflections and ghost images are considered.

Still another use for the shielded type of line is in installations where, for one reason or another, the transmission line must be run inside a conduit. Since running an unshielded type of line inside a conduit would seriously change its characteristic impedance, it is necessary to use the shielded type of line for such installations. In this case, if line losses and the need for a balanced line (from the standpoint of minimum noise pick-up) are not important factors, it might be more convenient to use a high loss co-axial line such as the type RG 59/U, rather than the shielded pair type of line. This type of line has a characteristic impedance of 73 ohms and, when used with a receiver having a 300 ohm input impedance, a resistance matching network such as that shown in figure 13-30 must be employed.

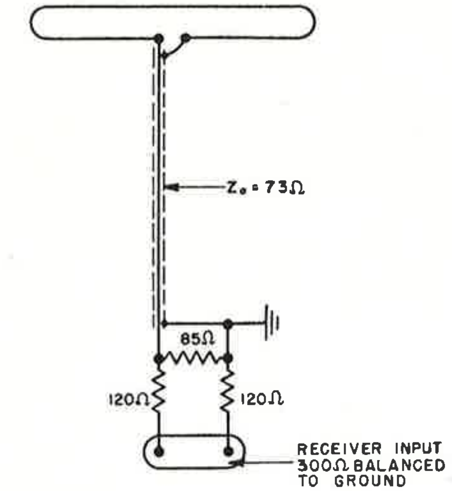


Fig. 12-30. Use of 73 Ω co-axial line.

Shielded transmission lines should be grounded at several points along the line to obtain minimum pick-up of unwanted signals. Also, if the shield at the receiver end of the line is thoroughly grounded, this will provide suitable protection against lightning.

Reflected or Multiple Path Signal Pick-up.

The next type of installation problem to be considered is that where multiple images or "ghosts" on the screen, due to reflected or multiple signal paths, are likely to be encountered.

As mentioned earlier, television signals possess the characteristic of being reflected by large objects, such as tall buildings and hills which may be in the path of the television signal, in much the same manner that light waves are reflected as shown in fig. 13-5. This characteristic of the television signal may result in two or more signals from the same transmitter being picked up by the receiving antenna. Since the paths of these signals will have different lengths, as indicated in fig. 13-5, there will be a time difference in their arrival at the receiver, with the reflected signal or signals arriving later than the direct signal since they must travel over a longer path. This will cause multiple images or ghosts to appear on the screen with the undesired or reflected image displaced to the right of the desired or direct image as indicated in fig. 13-31. These multiple or ghost images may be either positive or negative, depending upon the r–f phase relationship between the direct or reflected signals and may vary in intensity from a level equal to that of the direct image or be so weak that it is hardly noticeable.

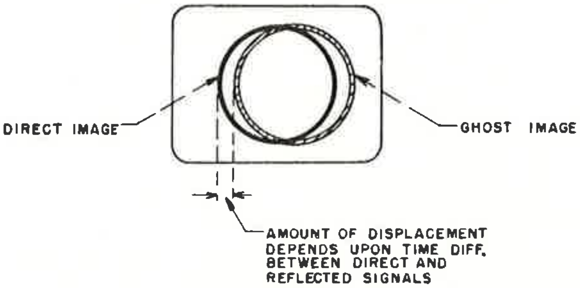


Fig. 13-31. Ghost image on the screen.

The ghost image may be displaced from the direct image only a very slight amount or it may be displaced several inches, depending upon the difference in time arrival of the two signals. Since the scanning spot of the picture tube moves at a very high rate of speed in tracing a picture from left to right, the time difference between the arrival of the direct signal and the reflected signal does not have to be very great to cause a noticeable displacement. In fact the time delay need be only a few millionths of a second as will be brought out later. The image due to the reflected signal is displaced to the right of the direct image because it arrives sometime after the spot has stated its trace from left to right. Since the picture information contained in the reflected signal is identical to that contained in the earlier arriving direct signal then the ghost or displaced image will look exactly the same as the direct or desired image, except that it will be displaced to the right of the direct image.

Reflected or multiple path signals are most prevalent in highly urbanized areas where the signal strength is high and there are many tall structures. Since there are many possible combinations between the relative location of the building or other object from which the signal is reflected and the TV transmitter and receiver, no specific rule can be established as to how these reflected signals can be prevented from being picked up by the antenna. However, this problem can usually be overcome or at least greatly minimized by the proper antenna and its correct orientation.

In cases where the reflected signal arrives at the receiver from one side as shown in A of fig. 13-32, it can be minimized by orienting the antenna as in B of

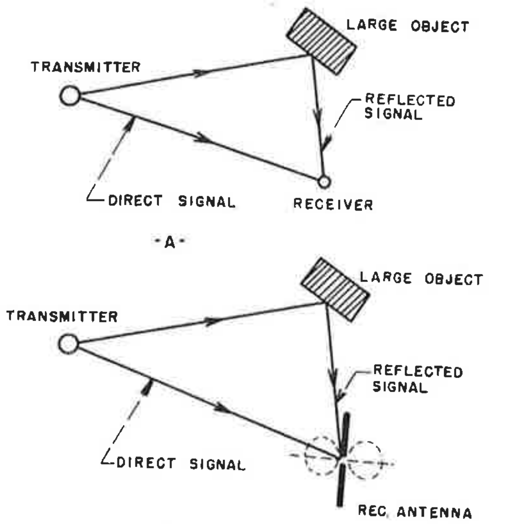


Fig. 13-32. Reflected signal arriving from one side.

fig. 13-32. It should be noted that the end of the antenna (point of minimum pick-up) is pointed in the direction of the reflected signal while the broadside of the antenna is toward the direct signal. If this simple procedure does not sufficiently reduce the pick-up of the reflected signal, then it will probably be necessary to make use of another antenna element, known as a reflector. The use of a reflector increases the directivity of the antenna (narrows the pick-up angle); increases signal pick-up in the desired direction and increases the front-to-back ratio by greatly reducing the response to signals arriving from a direction which is directly in back of the receiving dipole. A reflector is simply another rod which is placed parallel to and in back of the receiving dipole.

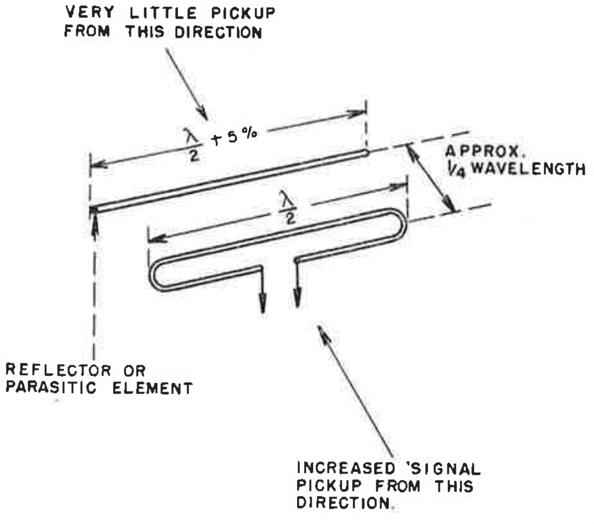


Fig. 13-33. Folded dipole with reflector.

The reflector element is usually about 5% longer than the receiving dipole and is usually placed one-quarter wavelength in back of the receiving dipole, as shown in fig. 13-33. Without a reflector, the dipole antenna responds equally well to signals arriving in either direction that are at right angles to the broadside of the antenna as indicated in fig. 13-12. However, the use of a reflector results in an increased response in a direction that is at right angles and in front of the receiving dipole and greatly reduces the response to any signals that may arrive from a direction which is directly in back of the receiving dipole as illustrated in figure 13-34. It also increases the directivity of the antenna by narrowing its pick-up angle, which is desirable in minimizing the type of reflection problem just considered.

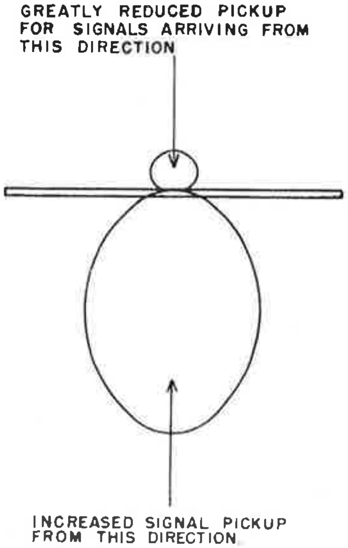


Fig. 13-34. Effect of reflector on horizontal directivity.

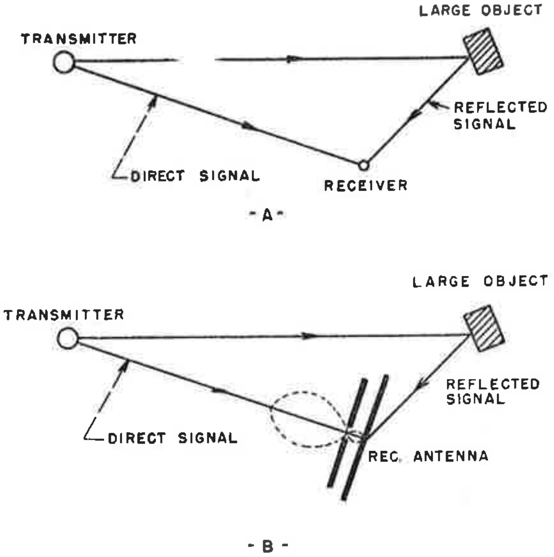


Fig. 13-35. Reflected signal arriving from rear of antenna.

Another type of reflection problem is that where the reflected signal arrives at the receiver from the rear as indicated in A of fig. 13-35. In this case the use of a reflector as shown in B of fig. 13-35 will prevent or at least greatly reduce pick-up of a reflected signal from this direction.

Probably the most difficult reflections to eliminate are those which arrive at the receiver from the same general direction as the direct signal. This condition is shown in A of fig. 13-36. About the only way to minimize this type of reflection is to increase the directivity of the antenna (narrow the angle of pick-up) through the use of a reflector and a director. If the angle between the direct signal and the reflected signal is not too narrow, the reflected signal can usually be attenuated to an acceptable level by this method. The director is another rod which is placed parallel to the main dipole and directly in front of it as indicated in fig. 13-37. The director element is usually made about 5% shorter than the receiving dipole and is placed approximately one-

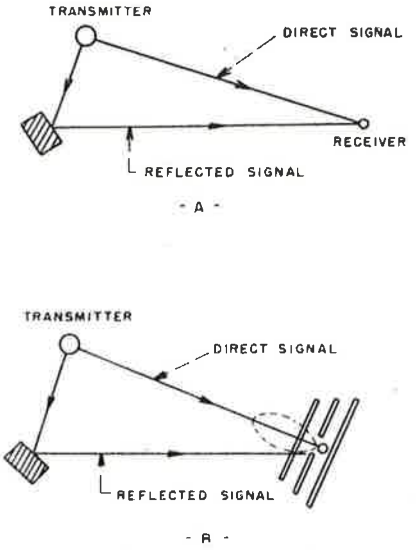


Fig. 13-36. Reflected signal arriving from some general direction as direct signal.

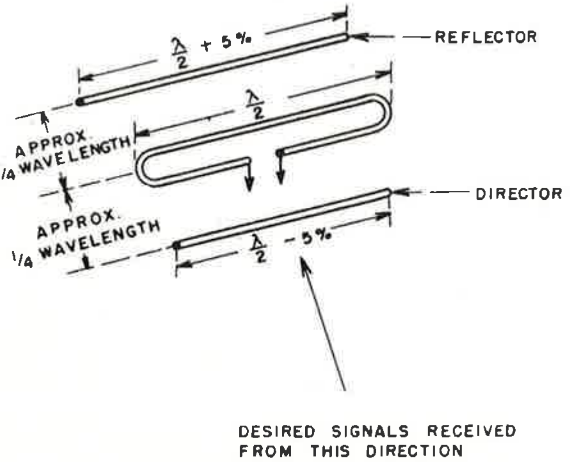


Fig. 13-37. Folded dipole with reflector and director.

quarter wavelength in front of it; that is, in the desired direction of reception. Since this type of antenna has a narrow band width, it will only cover a few adjacent channels. If wide band coverage is desired, using this type of antenna, it will probably be necessary to use several such antennas with some form of switching system at the receiver.

In locations where a number of reflected signals arrive at the receiver from several different directions, as indicated in A of fig. 13-38, it may be necessary to orient the antenna rather than the direct wave, as shown in B of fig. 13-38. In this case, the direct signal and reflections coming from the same general direction as the direct signal arrive at the rear of the antenna, while one of the reflected signals is being picked up by the front of the antenna. A dipole with reflector and director would offer considerable attenuation in this case, of the direct signal and reflections arriving from its rear and provide increased pick-up of the reflected signal arriving from in front of it.

In cases where the direct signal is blocked by an intervening structure, it may be possible to make use of a reflected signal, as shown in fig. 13-39, to provide satisfactory reception.

In locations where the reflected signals are strong, it is necessary to use a shielded type of transmission line since reflections picked up by an unshielded line would defeat the purpose of a properly oriented directive type of antenna. Also, in locations where the receiver is relatively close to the transmitter, an unshielded transmission line might cause a ghost or multiple image to appear on the screen although there may not be any reflected signals in the vicinity. This condition occurs when a relatively long unshielded transmission line is used and there is considerable pick-up of direct signal at the receiver end of the line as indicated in fig. 13-40. In this case, the direct signal picked up by the line will cause an image to appear ahead of, or on the left-hand side of the screen while the signal picked up by the antenna itself will appear to the right. This ghost image due to direct pick-up of the signal by the line will appear considerably weaker than the signal picked up by the antenna itself but will appear to the left of the stronger image. This is just the opposite from the usual type of ghost image which appears to the right of the stronger signal. The reason for this is that due to the long transmission line, the direct signal picked up by the antenna arrives at the receiver somewhat later than the direct signal picked up by the transmission line. This particular type of ghost image might be termed a "leading" ghost since it appears ahead of the strong or desired image. In addition to the direct pick-up of the signal at the receiver end of an unshielded line, a leading ghost may also be caused by direct pick-up of the signal by the r-f or 1st detector circuits of the receiver. In this case, both the transmission line and the receiver head-end circuits must be shielded to prevent this type of ghost from haunting the receiver.

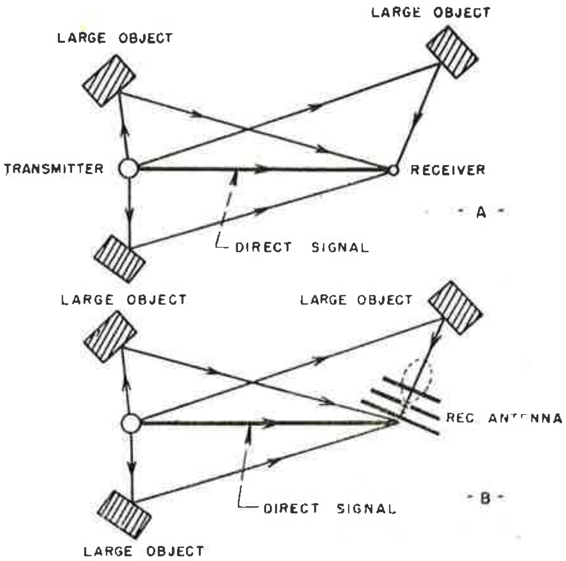


Fig. 13-38. Use of reflected signal rather than direct signal.

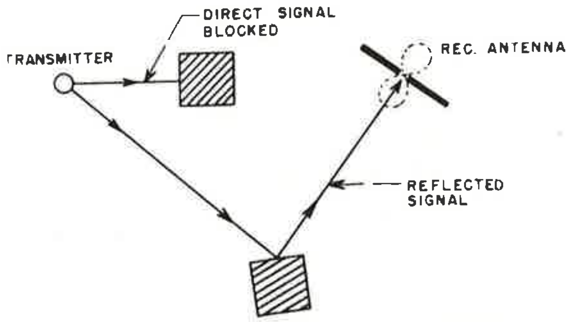


Fig. 13-39. Blocking of direct signal.

Airplane Flutter.

An aircraft in the vicinity of the receiving antenna will produce a ghost or multiple image on the screen that will

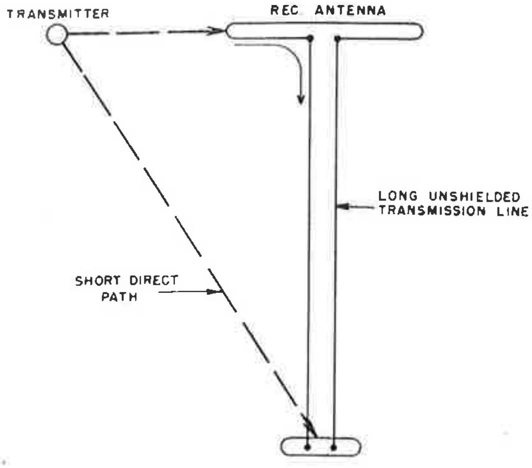


Fig. 13-40. Direct signal pick-up at receiver end of line.

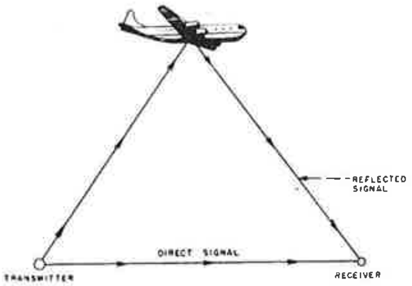


Fig. 13-41. Reflections from airplane: airplane flutter.

flutter or vary in intensity as the plane travels along. This condition is illustrated in fig. 13-41 and, as shown, two signals are picked up by the receiving antenna. One is the direct signal from the station and the other is a reflected signal from the aircraft. As the aircraft travels along, the relative phase of the direct and reflected signals being picked up by the antenna changes. Since the two signals alternately aid and oppose each other, this results in a fluctuation in the brightness of both the direct and ghost images. The relative height, speed and direction of the plane will determine the amount of picture displacement as well as the rate of flutter. This is one type of reflection over which the antenna system has little or no control. However, due to the high speed of aircraft this condition lasts for only a very short time and is not troublesome except in the vicinity of an airport. The use of AGC (automatic gain control) on the video i-f amplifiers will greatly minimize the effects of this type of reflection.

Locating Reflecting Object.

At times it may be helpful to know from which building or structure that the TV signal is being reflected. The approximate location of the reflecting object, or at least the additional air path distance travelled by the reflected signal, can be determined by measuring the amount that the ghost image is displaced from the direct or desired image, as indicated in fig. 13-42. The determination of the difference in path lengths of the direct TV signal and that travelled by a reflected signal, by measuring the amount of displacement on the screen, is based upon the following facts:

1. Since a reflected signal travels over a longer path than the direct signal, the reflected or ghost image will be displaced to the right of the direct image, the amount of displacement depending upon the difference in path lengths between the two signals.

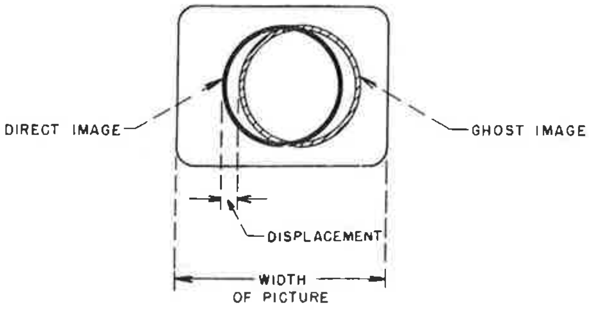


Fig. 13-42. Displacement of ghost images.

2. The entire horizontal sweep cycle, trace and retrace, occurs at the rate of 15,750 cycles per second. One cycle therefore represents 1/15,750 of a second or 63.5 microseconds. Asuming 16% retrace time, then the trace portion of the sweep will consume 84% of 63.5 microseconds or approximately 53 microseconds. In other words, it will take approximately 53 microseconds for the electron beam to move from the left side of the screen to the right side of the screen (form the visible portion of the picture) regardless of tube size. However, the rate at which the spot moves across the screen depends on the tube size. It is obvious that the beam will have to move at a much more rapid rate to cross a screen 12" wide in 53 microseconds than to cross a screen only 5" wide in the same length of time.
3. The speed at which a radio wave travels in free space is approximately 186,000 miles per second. This corresponds to a speed of .186 miles in a millionth of a second or (one) mile in approximately 5.3 microseconds. Therefore if the additional path travelled by a reflected wave is, say, (two) miles farther than the direct signal, it will arrive at the antenna 10.6 microseconds later than the direct signal.

Assume that the width of the picture is eight inches. Also that the distance as measured on the screen between the direct image and the ghost image is one inch. Find the additional air path distance travelled by the reflected signal.

Solution: (a) Since the time required for the spot to trace the 8-inch wide picture is 53 microseconds, then the time required for the spot to travel one inch is equal to $\frac{1}{8} \times 53$ or 6.66 microseconds. (b) Since the spot takes 6.66 microseconds to travel one inch on the screen and since the ghost image is displaced one inch on the screen, the reflected signal must arrive 6.66 microseconds later than the direct signal. (c) Since the difference in time between the arrival of the direct and reflected signals is 6.66 microseconds and since a radio wave travels at the rate of .186 miles per microsecond, then the distance in miles between the path travelled by the direct signal and that travelled by the reflected signal must be equal to $.186 \times 6.66$ or 1.23 miles.

If the ghost image were displaced two inches on the screen then the reflected signal would be travelling $\frac{2}{8} \times 53 \times .186$ or $\frac{2}{8} \times 9.85$ or 2.46 miles farther than the direct signal.

Therefore, in order to find the additional air path distance, in miles, travelled by the reflected signal, it is only necessary to divide the displacement in inches of the ghost signal by the width of the picture and then multiply this by the factor 9.85, i.e., $\frac{D}{W} \times 9.85$.

It is important to note that the distance thus calculated is not the actual distance from the reflecting object to the receiving antenna but is the additional distance travelled by the reflected signal. If the reflecting object were directly in back of the receiving antenna then the actual distance of the reflecting object from the receiver would be just half

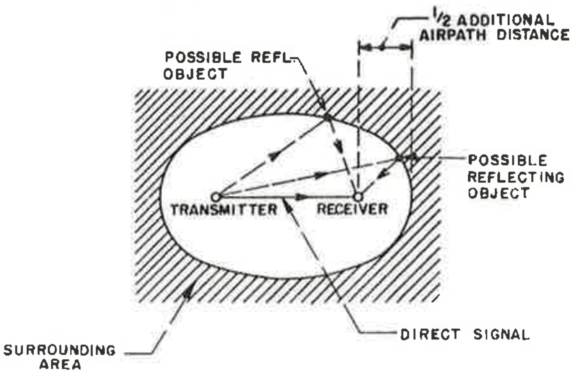


Fig. 13-43. Method of determining approx. position of reflecting object.

of the additional air path distance as calculated in the preceding examples. When the distance between the TV station and the receiving antenna is not very great, the approximate position of the reflecting object can be determined by placing the relative positions of the transmitter and receiver inside an elipse, as indicated in Fig. 13-43. The spacing between transmitter and receiver within this diagram should be the actual distance between them, brought down to a suitable scale. Also the spacing of the transmitter and receiver from either end of the elipse should be one half the additional air-path distance as calculated by the method just discussed. Since the additional air path distance for any reflecting object along this elipse is approx. the same, then any large structure along the line of this elipse might be the reflecting object as indicated by the dashed lines of Fig. 13-43.

Considerations for Hi-Lo Band Reception.

It was brought out earlier, in connection with the discussion on the dipole type of antenna, that if the high and low band stations are all located in the same general direction and if the signal strength from these stations is good, a simple folded dipole type of antenna will probably provide adequate reception. This, of course, assumes freedom from reflected signals. Such a condition is shown in Fig. 13-44 where a compromise orientation of the antenna is made for best reception on the five channels shown. The antenna operates as a half-wave antenna in receiving signals from the low band channels 2, 4 and 5 and as a one and a half wavelength antenna in receiving signals from the high band channels, 8 and 10. Another possibility, where a simple folded dipole might be used to receive both high and low band channels is where the location of the stations are 180° apart, as shown in Fig. 13-45. Since in this case the TV signals arrive at the antenna separated by 180°, a folded dipole without reflector can generally be used in areas where there is no reflection problem and where the signal to noise ratio is good.

In areas where the high and low band channels are not so favourably located, as in the previous examples, then the folded dipole type of antenna by itself will not prove satisfactory. Such a condition is illustrated in Fig. 13-46 where a number of low band channels are located at right-angles to a number of high band channels. The solution to this problem is to use two separate antennas, one cut to be a half wavelength at the mean frequency of the low band channels and the other cut to a half wavelength at the mean frequency of the high band channels. These antennas are usually mounted on the same mast but provision is made so that each antenna can be oriented independently of the other. If the signal strength is good, a simple folded dipole can be used for each antenna. However, in order to provide increased signal pick-up and to provide better rejection against noise, a reflector is usually placed in back of each dipole.

If the optimum transfer of signal is to be realized from such a hi-lo antenna combination, each antenna should be provided with a separate transmission line. Also a separate transmission line will prevent any undesirable interaction between the high and low band antennas. However, the use of two separate lines increases the installation costs and necessitates the use of a special switch at the receiver which will not disturb the impedance of the line. Also, if two transmission lines are used, they must be kept separated, if of the unshielded type, so as not to upset the line impedance. Since the use of two separate lines is expensive and also inconvenient because of the necessity of switching from one antenna to the other, a compromise is usually made concerning optimum operation and the signals from the two antennas are fed into only one transmission line. Some loss in overall efficiency occurs with this arrangement but in most cases it can be neglected.

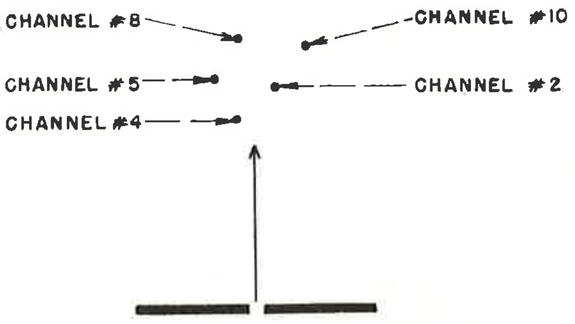


Fig. 13-44. High and low band stations in same general direction from antenna.

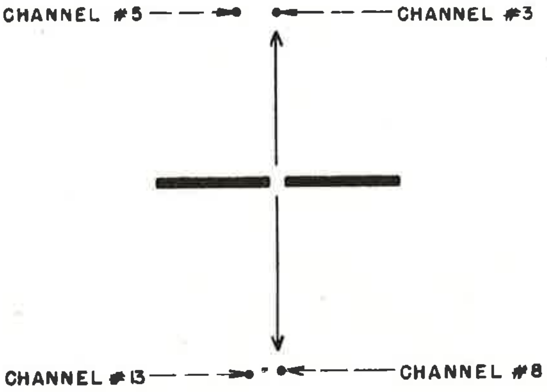


Fig. 13-45. High and low band stations 180° apart.

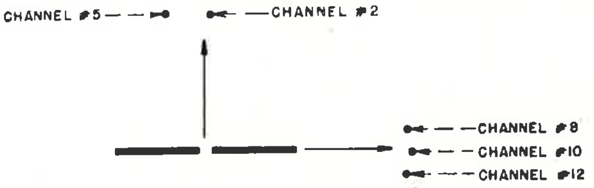


Fig. 13-46. High and low band stations at right-angles.

A typical hi-lo array employing only one transmission line is shown in Fig. 13-47. This hi-lo array is designed to provide good signal pick-up for the high and low band channels alike. Both antennas consist of a folded dipole and a reflector, the reflector being used to increase sensitivity and directivity. Each individual antenna may be oriented separately so as to obtain maximum gain and freedom from unwanted signal pick-up on all operating channels. Referring to Fig. 13-47, the high frequency antenna (bottom section) is connected to the low frequency antenna (top section) by means of a matching stub which provides a compromise impedance match of the hi-lo array to a 300 ohm transmission line which connects to the low frequency antenna. The impedance match thus provided is not perfect but as mentioned before the overall loss in efficiency with this arrangement is not serious.

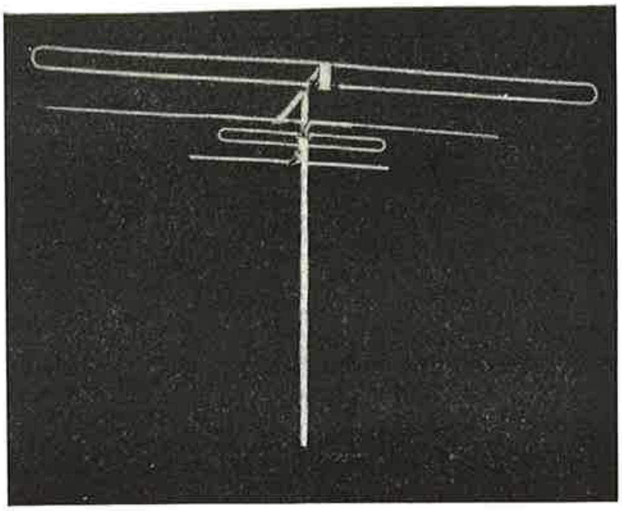


Fig. 13-47. High-low band array.

Since the low frequency antenna will operate as a one and a half wavelength antenna on the high band channels it might pick up undesirable high band reflections which would interfere with the proper operation of the high band antenna elements. Therefore, in order to minimize any possible interaction between the high and low band antenna elements, some hi-lo arrays of this type employ a filter network between the high and low band elements which attenuate any high frequency signals that may be picked up by the low frequency elements. This filter is connected in such a way that it has no effect on the high frequency signals picked up by the high band elements or on the low frequency signals picked up by the low frequency elements. This filter network may take the form of actual coils and capacitors as in A of Fig. 13-48 or a ¼ wave open stub connected to the low frequency elements as in B. With the arrangement used in B the ¼ open stub attenuates any high frequency signals picked up by the low frequency elements and prevents them from entering the transmission line to the receiver. In both A and B the transmission line is connected at a point where the filter network will have no effect on the high frequency signals picked up by the high frequency elements of the array.

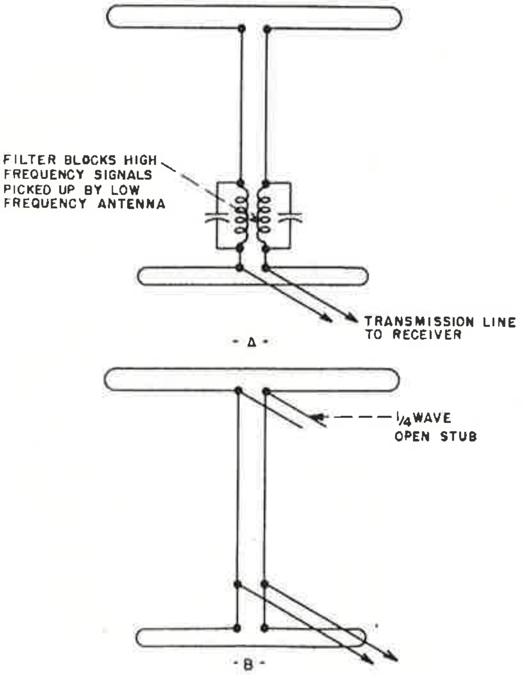


Fig. 13-48. Filter network between high and low band elements.

Unfortunately, there are some areas where the stations are so located that a hi-lo antenna array by itself will not provide satisfactory reception.

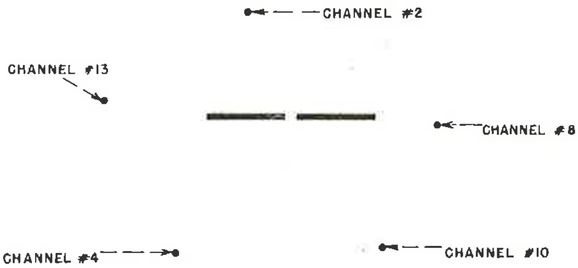


Fig. 13-49. High and low band stations located in all directions.

Such a condition is illustrated in Fig. 13-49 where the high and low band channels are located in all directions. One solution to this problem would be to use a number of individual antennas with separate transmission lines and provide an adequate switching system at the receiver. However, a more practical solution would be to use a single hi-lo broadband array and couple it to a rotator which can be controlled at the receiver. With such a rotating unit, the orientation of the antenna can be adjusted from the receiver for a full 360 degrees. The control unit of such a rotator usually allows the operator to swing the antenna backward and forward and stop it at the point where the absolute peak of reception is obtained. With this arrangement the orientation of the high frequency elements of the array could be adjusted for optimum pick-up when the receiver is tuned to any of the high band stations while the orientation of the low frequency elements could be adjusted for optimum pick-up when the receiver is tuned to any of the low band stations.

Weak Signal Reception.

A problem which requires special consideration is that of obtaining sufficient signal pick-up for satisfactory reception in areas of low signal strength, as in locations on the fringe (50 miles or more) of the service area of the television stations. Assuming that the sensitivity of the receiver is as high as it is practical to make it, consistant with good signal to noise ratio, then this can best be accomplished by increasing the gain or efficiency of the antenna system through the use of an antenna array. An antenna array is formed by the addition of extra elements to the fundamental type of dipole antenna. There are various types of arrays available for television reception, with numerous claims made for them; however, it is not within the scope of this chapter to cover all types. Therefore, only the fundamental types of antenna arrays will be discussed.

Reflectors.

The simplest type of antenna array consists of a dipole antenna with a reflector. This was discussed in some detail earlier in connection with the problem of reflected signals when it was pointed out that a reflector greatly increased the front to back ratio of a dipole and also provided added signal pick-up. The resulting gain in signal pick-up over the fundamental dipole type of antenna is approximately 3 db. There is no electrical connection between the dipole antenna itself and the reflector which is known as a parasitic element. A reflector can be used equally as well with either the folded dipole or the plain dipole. In either case, the reflector is made approx. 5% longer and is placed parallel to and in back of the dipole antenna itself with a spacing of approx. one-quarter wavelength as indicated in Fig. 13-33.

Fundamentally, a reflector operates as a reradiation device, that is, a voltage is induced in the reflector element from the induction of the main dipole. The voltage thus induced produces currents in the reflector element causing it to reradiate energy which is picked up by the main antenna, thereby increasing its efficiency. All the energy picked up from a TV station by a dipole is not absorbed in the load connected to the antenna. Some of this energy is reradiated by the antenna and would ordinarily be lost into space. However, some of this energy that would ordinarily be lost can be reflected back to the antenna by placing another element, having the proper length and spacing, directly in back of the antenna element. The reradiated energy from the antenna element, picked up by the reflector element, causes the reflector element itself to reradiate energy, which when reflected back, adds to the total energy pick-up of the main antenna. For opitmum results, the phase of the signal picked up by the antenna directly from the station and that picked up from the reradiation field of the reflector must be in phase. The length of the reflector and its spacing in back of the main antenna determines this phase relationship. Usually, the reflector element is made 5% longer than the main antenna. It is generally spaced approximately one-quarter wavelength in back of the main dipole and with this spacing provides a gain of approx. 3 db.

The use of a reflector lowers the centre impedance of the main antenna and if spaced closer than one-quarter wavelength will reduce its impedance considerably. However, with one-quarter wave spacing, the impedance of a folded dipole is not materially reduced, changing from 300 ohms to approximately 250 ohms. A folded dipole with a reflector spaced at one-quarter wavelength will have sufficient bandwidth to cover the low band channels if the elements are cut to the mean frequency of these channels. Likewise if the elements are cut to the high band channels, the bandwidth will be sufficient for these channels. If the spacing is reduced to .15 wavelength, somewhat increased gain will be obtained but the impedance of the antenna will be considerably reduced as well as its bandwidth.

Directors.

Additional gain may be obtained by the use of another parasitic element known as a director. A director is simply another rod placed parallel with and directly in front of the main antenna as indicated in Fig. 13-37. The director element is made approximately 5% shorter than the main antenna element and is placed approximately one-quarter wavelength in front of it. As in the case of the reflector, a director acts as a reradiation device and adds approximately 3 db gain to the antenna.

When a director is used in conjunction with a reflector as in Fig. 13-37, a gain of approximately 4 to 5 db is obtained over the fundamental dipole. In addition to providing considerable increased signal pick-up, the use of a director and reflector provides a high front to back ratio which, as brought out earlier, is desirable from the standpoint of rejecting reflected signals. However, the use of a director and reflector reduces the centre impedance of a folded dipole antenna from approximately 300 ohms to 120 ohms. This necessitates the use of an impedance transforming device, such as a stub, when this type of array is used with a 300 ohm line. Impedance transforming devices will be discussed later. The bandwidth of such an array is reduced considerably and can only be used to cover one or possibly two channels at the most. This type of array is recommended for areas of low signal strength where only one channel is to be received or where reflected signals are a problem.

Stacked Arrays.

Increased signal pick-up can be obtained by stacking two dipole elements and associated reflectors vertically, one above the other, as shown in Fig. 13-50. An array of this type will result in an increase of signal pick-up of approximately 5 to 6 db over the fundamental type of antenna, assuming proper phasing and matching is observed. This gain is obtained as follows: first, a dipole with reflector provides a power gain of approximately two or a voltage gain of approximately 1.4. Expressed in decibles this is equivalent to a 3 db gain. Secondly, when two similar antennas are stacked one above the other, as in Fig. 13-50, the intercepted power is increased, resulting in approx. another 3 db gain. Thus, by stacking two dipole elements and associated reflectors in this manner the db gain is equal to the 3 db gain of a dipole and reflector plus approx. 3 db gain obtained by stacking or a total gain of approx. 6 db. This corresponds to a power gain of four to one or a voltage gain of two to one.

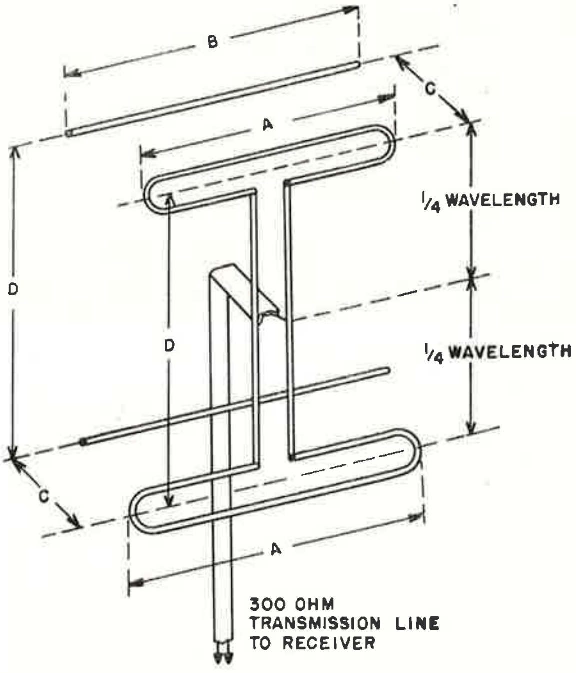


Fig. 13-50. Single channel stacked array.

The particular array shown in Fig. 13-50 is designed to operate efficiently over one channel only. However, an array of this type can be made to provide wide-band pick-up over the low band channels or over the high band channels. The wide band array will be discussed after considering some of the fundamentals of the single channel array.

Referring to Fig. 13-50 the spacing between the top and bottom sections is one-half wavelength, that is, one-half wavelength at the operating frequency. This is the dimension "D" and its value in feet is equal to $\frac{492}{f\ (mc)}$ where f is the mean frequency of the particular channel that the array is to operate on. The spacing between each antenna and its respective reflector is one-quarter wavelength at the operating frequency and is the dimension "C". The value of "C" in feet is equal to $\frac{246}{f\ (mc)}$. The length of each folded dipole is slightly less than one-half wavelength and is the dimension "A". The value of "A" is equal to $\frac{468}{f\ (mc)}$. The length of each reflector is approximately 5% greater than the folded dipole and is the dimension "B". The value of "B" is equal to $\frac{492}{f\ (mc)}$.

If the maximum transfer of energy is to be obtained between the array and the transmision line, then the impedance of the array at the point where the line connects must equal that of the transmission line. A 300 ohm unshielded line is usually used with this type of an array due to its low loss characteristics and since it also matches the 300 ohm input impedance of most receivers. Therefore the impedance of the array at the point where the transmission line connects is made to look like 300 ohms.

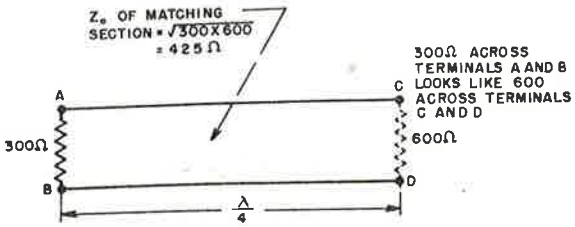


Fig. 13-51. Quarter wave section of transmision line as impedance transforming device.

This is accomplished by the two vertical conductors which connect the two dipoles together. These vertical conductors, which are parallel to each other, form a matching section that make the impedance of the array match that of the 300 ohm transmision line.

This method of impedance matching makes use of the fact that a quarter-wave section of line can be used as an impedance transforming device. An example of such a matching section is shown in fig. 13-51 where a 300 ohm impedance at the input end of a quarter-wave section of line is made to look like 600 ohms at the output end. The amount of impedance transformation which takes place depends upon the characteristic or surge impedance of the quarter-wave section itself. The value of this characteristic impedance for a given impedance transformation is determined by the equation $Z_o = \sqrt{Z_1 \times Z_2}$ where Z_o = the characteristic impedance of the quarter-wave matching section.

Z_1 = the impedance at the input end of the matching section.

Z_2 = the impedance that is desired at the output end of the matching section. Thus in figure 13-51, where it is desired to make a 300 ohm impedance at the input end look like 600 ohms at the output end, the characeristic impedance of the quarter-wave matching section must be equal to

$$\begin{aligned} Z_o &= \sqrt{Z_1 \times Z_2} \\ &= \sqrt{300 \times 600} \\ &= 425 \text{ ohms.} \end{aligned}$$

After determining the correct value of characteristic impedance for the matching section, the next step is to obtain a quarter-wave section having the desired impedance value. As brought out earlier, the characteristic impedance of an open parallel conductor line is determined by the diameter of the conductors and the spacing between them. This value is given by the equation

$$Z_o = 276 \log_{10} \frac{2D}{d}$$

where Z_o = characteristic impedance of line.
D = spacing between centre of conductors.
d = diameter of conductor, inches.

Thus, if the diameter of the conductors is decided upon, $\frac{1}{8}''$ tubing for instance, then through the use of this equation the correct spacing between conductors can be determined to provide he desired characteristic impedance. There are also tables available which give the correct spacing and diameter of conductors for various values of characteristic impedance.

Referring to the array of fig. 13-50, it should be noted that the spacing between the terminals of each antenna and the centre of the array, where the transmission line connects, is one-quarter wavelength. Therefore two quarter-wave matching sections are provided. The quarter-wave section connected to the upper folded dipole makes the upper dipole impedance appear like 600 ohms at the centre of the array as indicated in A of fig. 13-52. Likewise, the quarter-wave section connected to the lower folded dipole makes the lower dipole impedance appear like 600 ohms at the centre of the array as in B of fig. 13-52. When these two 600 ohm impedance are connected together at the centre of the array, then the total parallel impedance is 300 ohms, is indicated in C.

With one quarter-wave spacing of the reflectors, the centre impedance of each folded dipole is reduced from 300 ohms to approximately 250 ohms. Therefore in order to make the 250 ohm impedance of each dipole appear as 600 ohms at the centre of the array, the characteristic impedance of the quarter-wave matching section must be made equal to

$$\begin{aligned} &= \sqrt{Z_1 \times Z_2} \\ &= \sqrt{250 \times 600} \\ &= 390 \text{ ohms} \end{aligned}$$

Proper phasing of the signals from each antenna is obtained due to the connection of the transmission line to the mid-point of the array, since the signal travels the same distance (one quarter-wave) from each antenna to the transmission line.

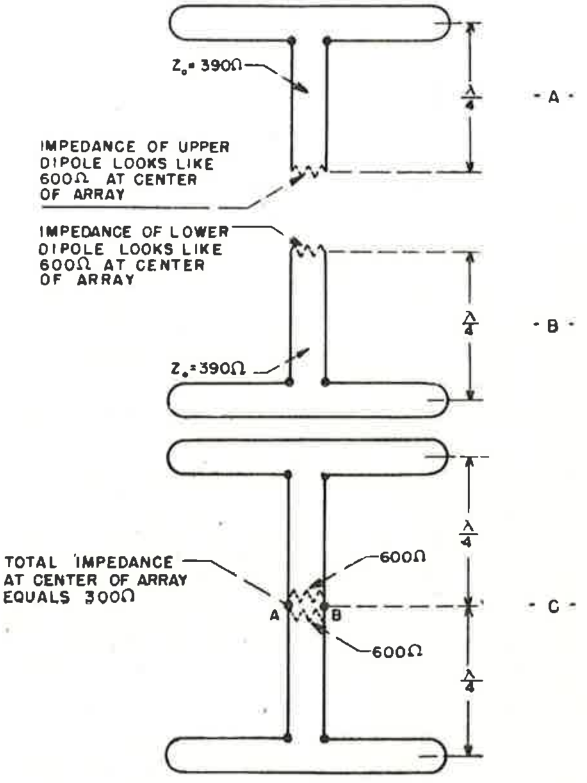


Fig. 13-52. Quarter-wave matching section of single channel array.

The antenna array just discussed will provide good signal on the particular channel for which it is cut. However, it will not provide satisfactory reception on the other channels due to the fact that the matching sections will not be one quarter-wavelength at the frequency of the other channels. Consequently, the signal pick-up drops off rapidly due to the severe mismatch between the array and transmission line at these other frequencies.

Broad-band Stacked Array.

The stacked array shown in fig. 13-53 overcomes the narrow-band limitations of the array shown in fig. 13-50 and permits operation over all the low band channels or over all the high band channels, depending upon whether the elements are cut to the mean frequency of the low band or the high band channels.

This array is similar in many respects to the array previously discussed in detail. Two folded dipoles with associated reflectors are stacked with approximately half-wave spacing between antenna elements. The reflector spacing is approximately one quarter-wavelength. The frequency used in calculating the length and spacing of the elements is the mean frequency of either the low band channels, if low band operation is desired, or the mean frequency of the high band channels, if high band operation is desired. This array provides essentially the same gain as the one discussed previously, except that it

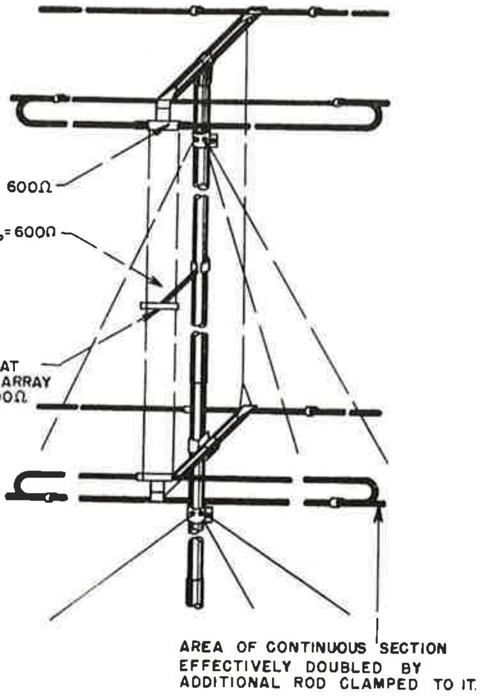


Fig. 13-53. Broad band stacked array.

covers a much wider range of frequencies.

The important difference between the wide-band array of fig. 13-53 and the narrow band array of fig. 13-50 is in the method used to match impedances. The narrow band array is matched by means of a quarter wave matching system, which is limited to a narrow range of frequencies. However, the method used in the wide band array of fig. 13-53 is considerably different. The first thing to note in this respect the rods which are clamped to the continuous section of each folded dipole. These rods are of the same diameter as the folded dipole and in effect doubles the diameter of the continuous section of each dipole. This, as brought out earlier in the discussion on folded dipoles, increases the centre impedance of the folded dipole from 300 ohms to 600 ohms. Thus, by this means, each folded dipole now has a centre impedance of 600 ohms. If the top and bottom sections are now connected together by means of a transmission line, having a characteristic impedance of 600 ohms, the impedance of the array will be 300 ohms at its centre or at either end, since the 600 ohm impedance of each antenna will be connected in parrallel. The section running between the two antennas now merely acts as a non-resonant transmission line, and not as a quarter wave impedance transformation device. Therefore, the impedance of the array will remain essentially uniform over a much wider range of frequencies than in the case of the narrow band array.

The 300 ohm transmission line going to the receiver is connected to the centre of the array in order to obtain proper phasing of the signal picked up by each antenna. Insofar as impedance matching is concerned, the transmission line could just as well be connected to the lower end of the array, since the impedance of the array at this point is also 300 ohms. However, if the line were connected to this point it would be necessary to transpose the connections, at the lower end of the 600 ohm line running between antennas in order to obtain proper phasing.

Yagi Array.

In weak signal areas where a receiving antenna is located between two stations operating on the same channel as indicated in fig. 13-54, a form of interference known as co-channel interference may be experienced. This type of interference appears in the form of dark bars moving up and down on the screen, and is often referred to as the "venetian blind" effect. In order to eliminate or at least minimize this form of interference, an antenna having the highest possible front to back ratio with high forward gain should be used.

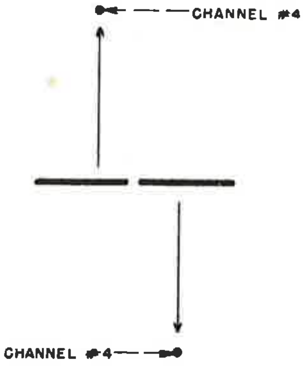


Fig. 13-54. Co-channel interference.

One of the most practical antennas for this purpose is the Yagi. As shown in fig. 13-55 a Yagi consists of a dipole antenna element in conjunction with a number of parasitic elements. The Yagi shown in fig. 13-55 consists of a folded dipole with one reflector and two directors to form a four element beam which has a high forward gain, a high-front-to-back ratio and is sharply directional. Its high front-to-back ratio provides considerable rejection of signals arriving from the rear. With a spacing of approximately .2 wavelengths between elements, this array will provide a forward gain of approximately 10 db. This corresponds to a voltage gain of slightly more than 3:1 over a fundamental dipole. This type of antenna cannot be used to receive several channels since its response is limited to a comparatively narrow range of frequencies. In fact, its frequency response is just about broad enough to cover one channel satisfactorily.

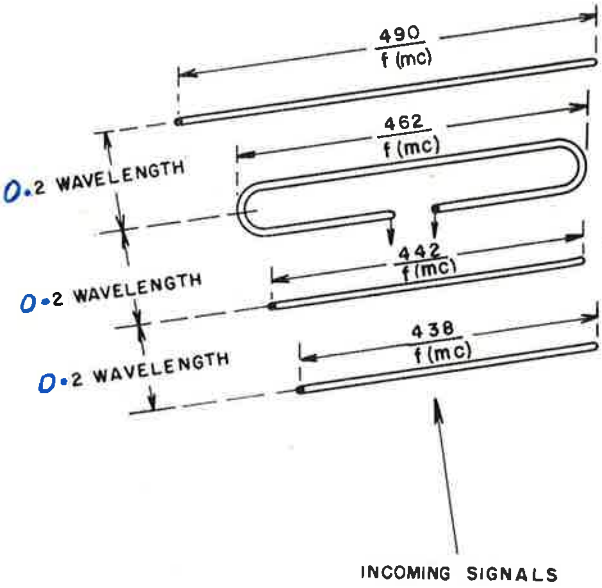


Fig. 13-55. The Yagi array.

The folded dipole element is cut to be a half wavelength at the mean frequency of the desired channel as determined by the formula $\frac{462}{f\ (mc)}$. The reflector element is made slightly longer as determined by the formula $\frac{490}{f\ (mc)}$. The length of the first director (the one closest to the folded dipole) is made slightly shorter than the folded dipole and is equal to $\frac{442}{f\ (mc)}$. The length of the second director is still shorter being equal to $\frac{438}{f\ (mc)}$.

With a spacing of approximately .2 wavelength between elements, the centre impedance of the folded dipole is reduced from 300 ohms to approximately 50 ohms. A quarter wave matching stub can be used to match this low impedance to a 300 ohm line as indicated in fig. 13-56. The characteristic impedance, Zo, of this matching section will be equal to $\sqrt{Z_1 \times Z_2} = \sqrt{50 \times 300} =$ approx. 125 ohms.

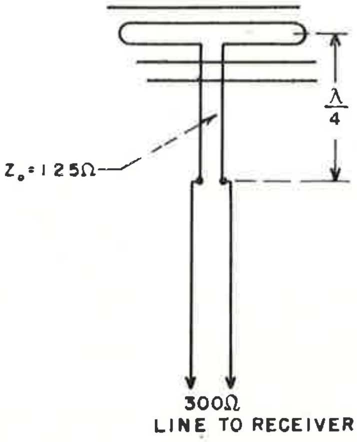


Fig. 13-56. Matching Yagi to 300 line.

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Another method of providing a satisfactory impedance match to a 300 ohm line is to step up the impedance of the folded dipole so as to compensate for the reduction in impedance produced by the parasitic elements. This can be done by increasing the diameter of the top or continuous section with respect to the lower or split section. As brought out earlier, doubling the top or continuous section increases the impedance of the folded dipole (over that of a straight dipole) approximately 9 times, making it approximately 9 x 72 or 648 ohms. Tripling the diameter of this section increases the impedance approximately 16 times and so on. Therefore, by selecting the proper diameter ratio for the folded dipole, the impedance of the Yagi array can be made to directly match a 300 ohm line without the need of a matching section.

The Rhombic Antenna.

This type of antenna provides good gain, has excellent directive characteristics and is wide band in its frequency characteristics. However, it has the drawback of requiring considerable space for its erection.

As indicated in fig 13-57 a rhombic antenna consists of four wires arranged in the form of a rhomboid or diamond. The wires are terminated at one end with a resistor so as to make them non-resonant. When the wires are made non-resonant by proper termination in a resistance, the wire dimensions are not critical. Also proper termination of the wires provide a high front to back ratio making the antenna unidirectional. The value for this terminating resistor is approximately 800 ohms. This is also the impedance of the antenna at the point of connection for the transmission line. Since this type of antenna is non-resonant, when properly terminated, the antenna impedance remains essentially at 800 ohms over a wide frequency range.

Since an increase in length of the legs of this antenna causes an increase in power gain and directivity, the antenna becomes more efficient at the higher frequencies. For best operation over the TV channels, the length of each leg should be approximately five wavelengths at the lowest frequency channel to be covered. With proper design and a leg length of five wavelengths, a gain of approximately 12 db, referred to a half wave dipole, is possible. The approximate dimensions for operation over the TV channels are shown in fig. 13-57 and are for the lowest TV channel to be covered by the antenna.

Although the rhombic posesses wide band characteristics, wide band operation is not easily obtainable due to its high impedance of 800 ohms. Because of this high impedance some sort of impedance transforming device must be used, such as a quarter wave stub, in order to match the antenna to a practical transmission line. This limits the operation of the rhombic to one channel unless some means is provided for switching in various stubs for each particular channel. The characteristic impedance for a quarter wave stub to match the 800 ohm impedance of the rhombic to a 300 ohm transmission line is equal to $\sqrt{800 \times 300} = 489$ ohms. A quarter wave section of 500 ohm line will work satisfactorily in this case.

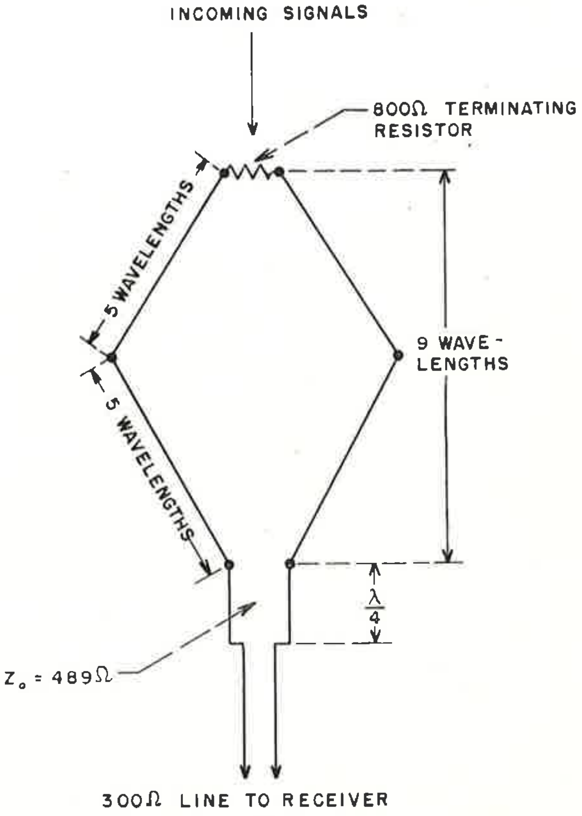

Fig. 13-57. The rhombic antenna.

As indicated in fig. 13-57 the end of the antenna with the terminating resistor is pointed in the direction of the TV station. The antenna should be mounted on insulated supports at least 10 to 15 feet above the ground.

The Horn Antenna.

Another type of antenna that has wide band characteristics, good directional qualities and provides high gain, especially on the upper TV channels, is the horn antenna,

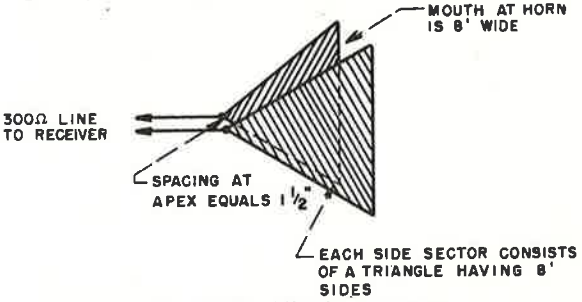

Fig. 13-58. The horn antenna.

shown in figure 13-58. However, as in the case of the rhombic antenna, the dimensions of the horn antenna are somewhat excessive. As shown, this antenna consists of the two vertical side sectors of the horn, with each sector being insulated from the other. A balanced transmission line connects to the apex of the horn, with one side sector connecting to one of the conductors and the opposite side sector connecting to the other conductor.

This type of antenna is unidirectional, with maximum signal pick-up being obtained from the direction in which the mouth of the horn is pointed. Very little signal is picked up from the sides or from the rear (apex) of the horn.

When properly designed, the impedance of this type of antenna will be slightly higher than 300 ohms and will remain at this value over a very wide range of frequencies. Therefore, a 300 ohm transmission line will provide a satisfactory impedance match without the necessity of using an impedance matching device as in the case of the rhombic antenna.

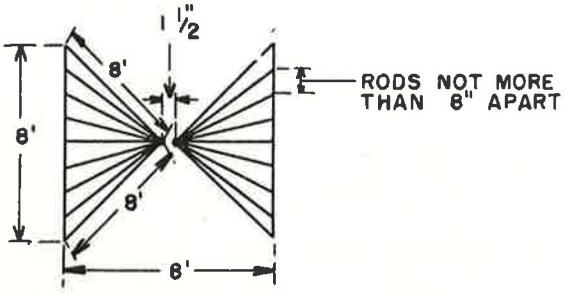

Fig. 13-59. Use of rods to reduce wind resistance of horn antenna.

In order to cover the low band channels as well as the high band channels, each side sector must be made quite large as indicated in fig. 13-58. Each side sector is actually a triangle having 8 foot sides, with the mouth of the horn forming an 8 foot square. The gain of this type of antenna increases with frequency, with considerably more gain being obtained on the high band channels than on the low band channels. With the dimensions shown this antenna will provide a gain, at 213 mc (channel #13), of approximately 14 db over a fundamental half wave dipole. In order to reduce wind resistance, the sectors of the horn can be made from rods, spaced not more than 8" apart, as shown in fig. 13-59.

Multiple Dwelling Installations.

In apartment house or multiple dwelling installations, some sort of master antenna system is often insisted upon by the landlord so as to prevent disfigurement of the building by a maze of antennas cluttering the rooftop.

Master antenna systems are more or less of a specialized problem, however some of the basic requirements for a satisfactory master antenna system are as follows:

1. Provide adequate noise and reflection free reception on all channels in a particular area.
2. Provide sufficient isolation between receivers so as to eliminate local-oscillator feedback through the distribution system.
3. Provide for connection of the receivers so as to eliminate any possible interaction between receivers due to switching, shorts, etc.
4. Provision for handling a wide range of signal levels from the antenna without overloading the system.
5. Provide for connection to receivers having either a 300 ohm or a 75 ohm input impedance.

There are a number of master antenna systems now available that will satisfactorily meet these requirements.

Antenna systems of this type generally employ several antennas, sometimes one antenna for each TV station in the area in order to obtain a signal that is from undesired reflections. The signal from these antennas is then boosted by an r-f amplifier and then fed into a distribution network which provides for the necessary isolation between receivers and for the proper termination of each receiver outlet. Coaxial cable is most generally used since there is considerable man-made noise present in multiple dwelling units. Also, the use of coaxial cable simplifies the installation since it can be run through conduit or alongside metal objects without disturbing its characteristic impedance.

Use of Attenuation Pads.

In areas close to the transmitter it is sometimes necessary to reduce or attenuate the signal before feeding it into the receiver. This is accomplished by means of a resistor network, known as an attenuation pad, placed between the transmission line and the receiver. An attenuation pad should be used in the following cases:

1. Where a TV signal is so strong that proper contrast cannot be obtained by means of adjusting the contrast control.
2. Where proper picture contrast can be obtained, but adjustment of the contrast control is very critical.
3. Where a strong TV signal may overload the r-f circuits and produce cross modulation or other undesirable effects.
4. Where a reflection still persists after everything possible has been done on the antenna system to eliminate it. Very often it is possible to reduce the level of the reflected signal, by means of an attenuation pad, to the point where it is not objectionable. The attenuation pad will reduce the direct signal also, but if it is strong compared to the reflected signal it will still be useable.

The first requisite for an attenuation pad is that it properly terminate the transmission line in its characteristic impedance. Otherwise undesirable reflections will be set up on the transmission line. A typical attenuation pad, for use between a 300 ohm transmission line and a receiver input circuit of 300 ohms is shown in A of fig. 13-60.

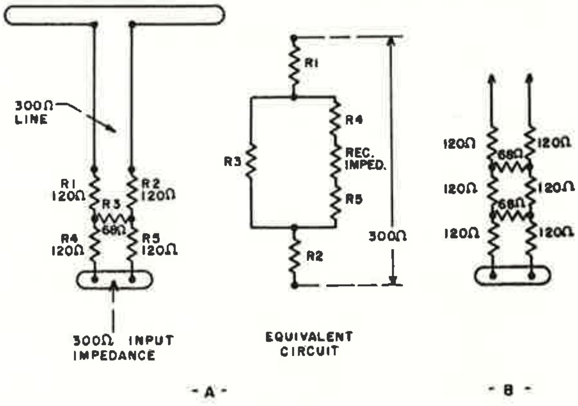

Fig. 13-60. Attenuation pad between 300 Ω line and 300 Ω input receiver.

It should be noted that the 300 ohm line is looking into essentially a 300 ohm impedance consisting of resistors R_1 and R_2 in series with the parallel combination formed by the resistors R_3, R_4, R_5 and the receiver input impedance, as indicated, by the equivalent circuit. With this arrangement, the receiver is also looking into essentially a 300 ohm impedance. If more attenuation is desired, it can be obtained by adding another section as shown in B of fig. 13-60. Carbon resistors should be used throughout and the leads should be kept short as possible so as to minimize inductive effects.

In most cases where an attenuation pad is required, it will only be needed on one or possibly two stations whose signal is very strong. If it is desired to receive other stations whose signals are comparatively weak then some means must be provided to switch the attenuation pad in and out of the circuit. A suggested switching arrangement is shown in figure 13-61. In order to prevent the switching arrangement from seriously affecting the impedance match, the switches should be double-pole double throw toggle switches and all leads should be made as short and direct as possible. If it is found that this switching arrangement

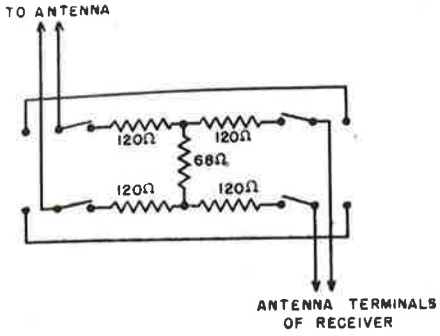

Fig. 13-61. Switching arrangement for pad.

does seriously affect the impedance match, then when it is desired to receive the weaker stations it will be necessary to connect the transmission line directly to the antenna terminals of the receiver without passing through a switch.

Connecting Several Receivers to one Antenna.

If a large number of receivers are to be connected to one antenna system, as in the case of an apartment house installation, then some sort of master antenna system must be employed. However, in cases where it is desired to connect only a few receivers to one antenna, such as in a dealer's display room, it is possible to provide satisfactory operation by means of a simple resistor network.

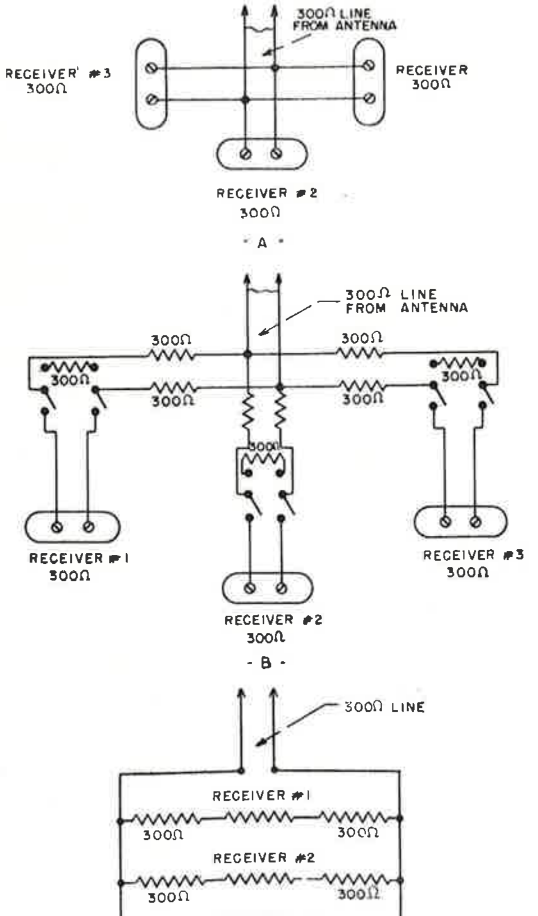

Fig. 13-62. Connecting three receivers to one antenna

When more than one receiver is connected to a single antenna system, some form of impedance matching device is required in order to prevent standing waves from being set up on the transmission line. For instance, suppose that it is desired to connect three receivers, each having an input impedance of 300 ohms to a 300 ohm balanced transmission line. If the three receivers were simply connected directly in parallel to the transmission line as in A of figure 13-62 then the line would be terminated in $\frac{1}{3}$ of 300 ohms or only 100 ohms. Due to this mismatch, reflections would be set up on the transmission line. Also there would be considerable interaction between receivers since no means of isolation is provided. In order to overcome these difficulties, the arrangement shown in B of fig. 13-62 can be used. In this case, the impedance presented to the transmission line by each receiver is equal to 900 ohms, as indicated in C of figure 13-62, since the two 300 ohm resistors in series with the 300 ohm input impedance of the receiver totals 900 ohms. With three branches of 900 ohms connected in parallel, the total impedance presented to the line will be $\frac{1}{3}$ of 900 or 300 ohms. This, of course, is the correct terminating impedance for a 300 ohm line. The 300 ohm resistors also help to isolate each receiver and thereby minimize interaction between receivers.

The double pole double throw switches enable a substitute 300 ohm dummy load to be switched into the circuit in the event that one of the receivers is removed or turned off. It will be recalled that the input impedance of many receivers is the dynamic impedance of the input circuits and when the receiver is turned off this impedance may rise to a very high value. This, of course, would upset the impedance match of such a system and therefore means is provided to substitute a 300 ohm dummy load in the event that the receiver is turned off or removed. Needless to say, carbon resistors should be used throughout. Due to the attenuation which takes place in a resistor network of this type, this system can only be used where the signal picked up by the antenna is relatively strong.

Another arrangement of this type is that shown in A of figure 13-63. This arrangement will provide satisfactory operation for any one or all of five receivers connected

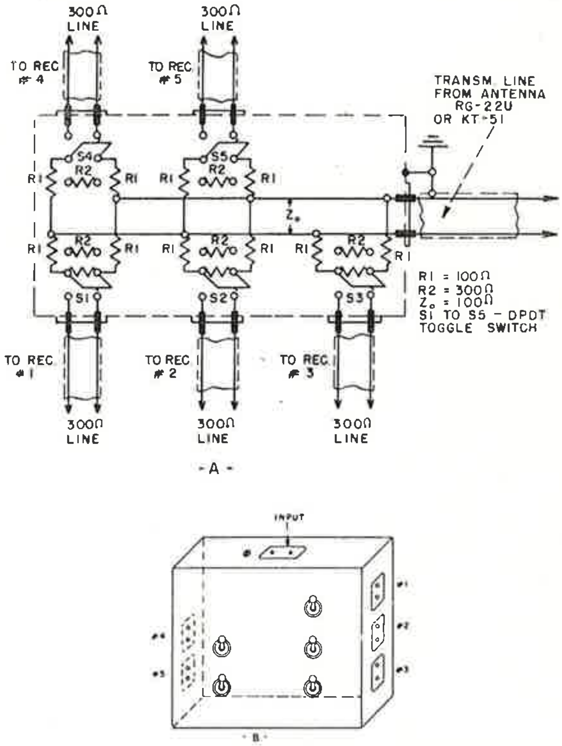

Fig. 13-63. Circuit of five receivers connected to one antenna.

to a single antenna in areas where the signal is strong. This particular arrangement has been used with good results in a number of dealer installations.

As shown in A of fig. 13-63 the resistors have been so chosen that each channel presents an impedance of 500 ohms to the transmission line. Since five channels, which look like 500 ohms each, are connected in parallel, then the total impedance represented by the five channels will be $\frac{1}{5}$ of 500 or 100 ohms. This will provide an almost perfect match to a 95 ohm shielded pair line such as the type RG-22U line. A 95 ohm shielded pair line was selected for the transmission line running between the antenna and matching unit for several reasons. First of all since an installation of this type would probably be made where there is considerable man-made noise, the possibility of a fairly long unshielded transmission line picking up noise would be quite high. Furthermore, if a 300 ohm line were used, higher value resistors would be required and the attenuation in the matching network would be considerably greater.

A suggested layout of the unit is shown in B of figure 13-63. It consists of a chassis with six terminal strips, five output and one input. Five double pole double throw toggle switches are mounted on top of the chassis and provide a means of substituting a 300 ohm dummy load in the event that a particular receiver is not being used. A short length of 300 ohm shielded pair line is used between the matching unit and each receiver as shown. This eliminates the need for an additional matching network at the receiver which would be required if 100 ohm line were used throughout. The short length of 100 ohm line running inside the unit, to which the matching resistors are connected, could be a piece of flat 100 ohm ribbon line spaced away from the chassis with stand-off insulators or two wires of the proper diameter and spacing to provide a characteristic impedance of 100 ohms. Carbon resistors should be used throughout and the connections should be as short and direct as possible. If the level of man-made noise is not very high, unshielded 300 ohm line may be used between the matching unit and each receiver instead of the 300 ohm shielded line shown.

THIS CONCLUDES THE SERIES

New RCA Releases

Radiotron 21EP4 and **Radiotron 21EP4-A** are directly viewed, rectangular, glass picture tubes of the magnetic-focus and magnetic-deflection type. The 21EP4 has no external conductive bulb coating which, with the internal conductive coating, forms a supplementary filter capacitor. Except for this difference, the two types are alike.

Each of these types has a Filterglass faceplate with a cylindrical outer surface and a screen size of 19⅛" x 13⅞" with slightly curved sides and rounded corners. The cylindrical outer surface effectively reduces in the vertical plane and reflections of bright objects as compare to the reflections produced by a spherical contour. In addition, the neutral light-absorbing material incorporated in the Filterglass faceplate reduces ambient-light reflections from the phosphor and reflections within the faceplate itself in a much higher ratio than it reduces the directly viewed light of the picture. As a result, improved picture contrast is obtained.

The 21EP4 and 21EP4-A utilize an electron gun of the ion-trap type requiring an external, single-field magnet.

Radiotron 21FP4-A is a directly viewed, rectangular, glass picture tube of the low-voltage electrostatic-focus and magnetic-deflection type. It features a Filterglass faceplate with a cylindrical outer surface. The 21FP4-A has a screen size of 19⅛" x 13⅞" with slightly curved sides and rounded corners.

The cylindrical outer surface of the Filterglass faceplate effectively reduces in the vertical plane any reflections of bright objects as compared to the reflections produced by a spherical contour. In addition, the neutral light-absorbing material incorporated in the Filterglass faceplate reduces ambient-light reflections from the phosphor and reflections within the faceplate itself in a much higher ratio than it reduces the directly viewed light of the picture. As a result, improved picture contrast is obtained.

The 21FP4-A has an external conductive bulb coating which with the internal conductive coating forms a supplementary filter capacitor; and an ion-trap gun requiring an external, single-field magnet.

Radiotron 6293 is a small, sturdy, beam power amplifier tube intended for pulse modulator service in both fixed and mobile equipment. It can deliver a peak plate current of 3 amperes during a pulse length of 30 microseconds under conditions with duty factor of 0.003 and plate-supply voltage of 2000 volts; or a peak plate current of 1.4 amperes during a pulse length of 200 microseconds under conditions with duty factor of 0.02 and plate-supply voltage of 3500 volts.

Small in size for its power-output capability, the 6293 has a rugged button-stem construction with short internal leads, a T_{12} bulb, triple base-pin connections for grid No. 3 and cathode (both joined to internal shield inside the tube), and an octal base with short metal sleeve having its own base-pin terminal. The plate lead is brought out of the bulb to a cap opposite the base.

RADIOTRONICS Technical Bulletins 1953

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