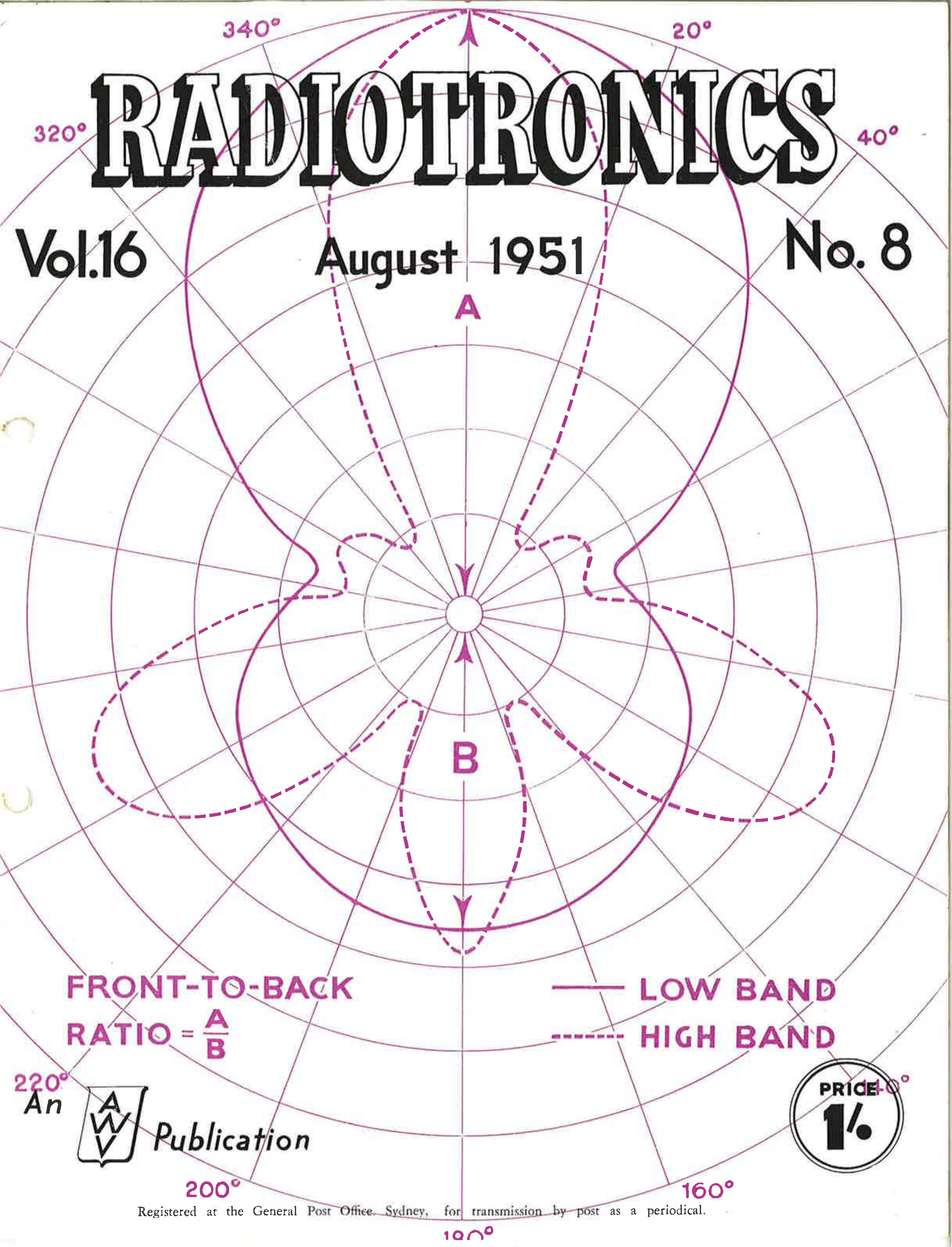
RADIOTRONICS

Vol.16 August 1951 No. 8



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By the way—

All Radiotronics from January, 1950, to June, 1951, are now out of print.

The first edition of the new spiral-bound Radiotron Valve Data Book, RV1, has been completely sold out.

A few copies of the Characteristics Chart are still available for those subscribers who may have overlooked ordering this completely revised publication.

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Our feature article this month, "Practical TV Antenna and Transmission Line Considerations" is reprinted by courtesy of RCA Service Company Inc., Camden, New Jersey, U.S.A.

In the May, 1951, issue, page 109, resistances R10 and R11 should total 45,000 ohms. This could be made up with a 20,000 and 25,000 ohm resistance in series each with a rating of 5 watts.

✓ Corrd.

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Practical TV Antenna and Transmission Line Considerations

Successful television reception is dependent upon the use of the proper combination of antenna and transmission line. Proper installation techniques are also of extreme importance.

The lecture to follow describes radio wave propagation and requirements of the television antenna system that are necessary to provide interception of this form of radiation.

Transmission line requirements are also discussed and installation techniques suggested.

R-F PROPAGATION

Radio and television signals are radiated into space where they travel in all directions when a nondirectional transmitting antenna is used. To receive this type of transmission which is propagated through space, it is necessary to intercept these waves, or some portion of them, and then apply the intercepted wave, or signal, to the receiver.

The further removed the receiver is from the transmitter, the more difficult it is to assure good reception. As the distance from the transmitter is increased, the strength of the signal decreases. Consequently, the range over which a usable signal can be received, will depend on the signal strength, the collecting ability of the receiving antenna, and the noise level at the receiving location.

Since these lectures are concerned primarily with television, standard radio wave propagation will be mentioned only briefly.

The behavior of high frequency radio waves in some respects is very similar to the behavior of light. If an analogy between radio transmission and light is drawn, the transmitting antenna can be imagined as an enormous light bulb sending out light in all directions.

Consider the eye as the receiving antenna which intercepts the light rays and carries the sensation of light to the brain. What, then would limit the distance at which the eye could see the light coming from the so-called transmitter?

There are several factors to be considered. As the distance from the transmitter is increased, the curvature of the earth will eventually interfere with seeing the light since the rays of light are essentially straight and will not bend around the curvature of the earth's surface.

If there is bright illumination in the vicinity of the location where "seeing" is attempted, the effect of this illumination in our immediate vicinity will wash out the light from the transmitter and it cannot be seen. This compares to noise which blanks out the radio waves. A simple illustration of this is to recall how many stars can be seen at night in the country as compared to the smaller number that can be observed on a brightly lighted city street.

It was previously stated that signal strength decreases as the distance from the transmitter is increased. Television transmission is usually limited to line-of-sight transmission, with a useful range of approximately 40 to 50 miles.

There are occasions when television stations are received at distances well beyond the horizon. This is similar to a "mirage" as evidenced when a person sees an object very far away due to an atmospheric condition which bends the light rays around the curvature of the earth. The same thing happens in television when, due to some condition of the atmosphere, the television signal is "bent" around the horizon.

Let us consider another condition encountered in television. Suppose that some distance away from the light bulb "transmitter", a large mirror is placed. What would be seen from a distance? At certain locations there would appear to be two sources of light, one directly from the light bulb and the other a reflection from the mirror. This again is identical to what happens in television. When a reflection or "ghost" is seen on the picture tube, it is due to the signal arriving at the receiver at a slightly different time interval, having been "reflected" from some object.

Suppose we wish to see the light from the light bulb at the greatest possible distance. We can raise the light bulb as high as possible or the observer can stand on as high a point as possible.

A further improvement is possible. We can use a pair of binoculars to increase the amount of light reaching our eye. The more powerful our binoculars, the greater the amount of light which will reach our eye. Also, the higher the power of our binoculars, the easier we can distinguish between our real signal and the reflected image. We can aim our binoculars directly at the original signal and thus eliminate any reflection pickup. Our one disadvantage is that the more magnification we achieve, the more accurately we will have to aim our binoculars.

The following paragraphs will bear out this analogy in more detail.

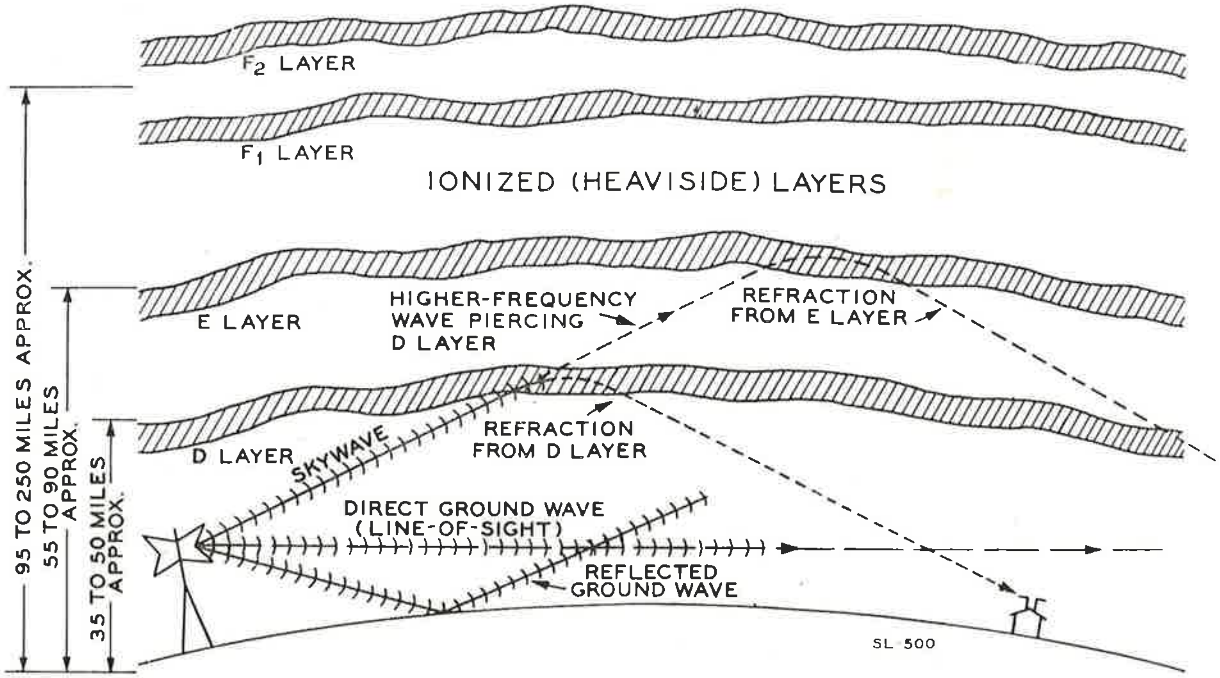


Fig. 1—Wave Propagation at Lower Frequencies

Radio Wave Characteristics

The signal radiated from a transmitting antenna has definite characteristics. Its structure can be considered as a wave made up of component waves. As illustrated in figure 1, one portion is radiated at such an angle that at some distance from the transmitting antenna it strikes the earth's surface and reflects upward at approximately the same angle that it approached the earth. Another portion travels essentially in a straight line parallel to the earth's surface. Both of these components are referred to as ground waves. The one traveling in a straight line is of most importance for television transmission and is generally referred to as the "line-of-sight" wave. A third component is the sky wave which travels at some angle, off into space where, depending on the frequency of the wave, and conditions existing in the upper atmosphere, it may or may not be refracted back to the earth.

The velocity of radio waves in free space is 186,000 miles per second or 300,000,000 meters per second. The latter figure is important since it becomes part of a formula used for determining wavelength.

$$\frac{300{,}000{,}000}{\text{Freq. (Cycles)}} = \text{wavelength in meters.}$$

$$\frac{300{,}000}{\text{Freq. (KC)}} = \text{wavelength in meters.} \qquad \frac{300}{\text{Freq. (MC)}} = \text{wavelength in meters.}$$

Ionized Layers and Refraction

In the earth's atmosphere there are stratified layers composed of gases. (See figure 1.) The lower layers called the "D" and "E" layers are predominantly a combination of oxygen and nitrogen. The upper layers are masses of hydrogen and helium and are referred to as the "F_1" and "F_2" layers. They are often referred to as the Heaviside layers. Their existence was established simultaneously by two men—an American named Kennelly and an Englishman named Heaviside working independently of each other.

Each of these layers is subjected to radiation from the sun and as a result the gases composing the layers become ionized.

When "bombarded" by the sun's ultra-violet radiation, the atoms composing the molecules of gas have one or more electrons torn from their orbital path around the nucleus, leaving the atom unbalanced or ionized. The electrons torn loose accumulate in free space and form a concentration of free electrons.

The time of day influences the ionized layers so as to cause them to shift their altitude and change their electron density. The depth of each layer is likewise affected. The "D" layer is present only during daylight hours. At night the "F_1" and "F_2" layers merge to form one distinct layer called the "F" layer.

The "D" layer is approximately 35 to 50 miles high. The "E" layer, 55 to 90 miles—the "F" layers, 95 to 250 miles.

Ionized layers have a decided effect on the sky wave portion of the R-F wave. The manner in which the wave is affected, however, depends greatly on the frequency of the wave and electron density of the layers.

Considering a wave of rather low frequency, after the sky wave has been traveling through free space for some distance, it encounters the "D" layer. The "D" layer having a concentration of electrons—or electron density—causes the sky wave to deviate or bend from its original course, often heading back toward the earth again where it may be picked up by an antenna as a usable signal voltage. This bending process is known as refraction.

A wave of higher frequency may not be bent sufficiently before piercing the "D" layer and may travel on to the "E" layer where refraction may again occur causing the signal to return to earth. Most of this activity has been in connection with the "E" layer. Very high frequency wave fronts may continue through the "F" layers and be lost completely.

VHF Peculiarities

The frequencies between 30 mc. and 300 mc. are considered as the VHF (very high frequency) range. As illustrated in figure 2, at these frequencies there are changes in behavior of the radiated signal. The sky wave is seldom refracted and the ground wave is attenuated rapidly. This leaves only the line-of-sight wave as the most usable portion of the transmission. This is the reason for television wave propagation being considered as line-of-sight transmission.

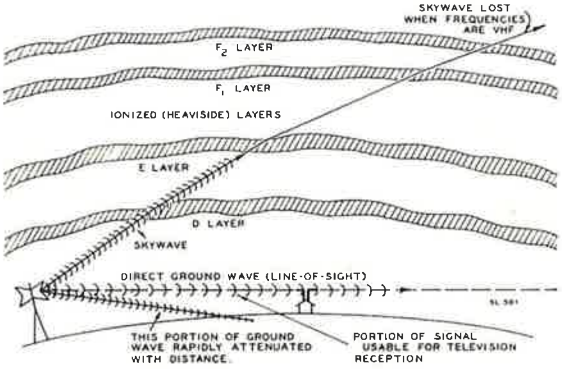


Fig. 2—VHF Wave Propagation

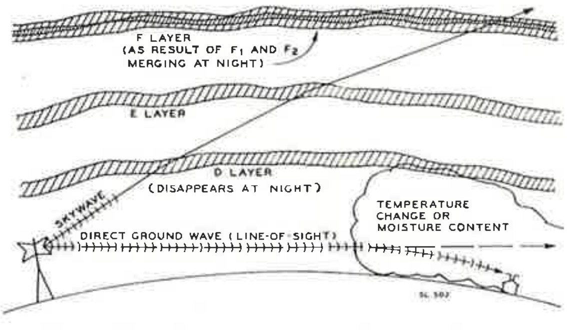


Fig. 3—Line-of-Sight Wave Extended Beyond Horizon

The distance from the transmitting antenna to the horizon has been considered as the useful range of reception for television. However, another peculiarity of VHF transmission is sometimes experienced since distances extending considerably beyond the horizon have been covered by television signals. It was previously explained under "Ionized Layers and Refraction" that a sky wave may be bent back toward the earth due to layers of varying electron density in the upper atmosphere. In a similar manner the direct or line-of-sight wave may encounter a condition near the horizon where the lower atmosphere has undergone a change in air density. This may be caused by a temperature change brought about by cold and warm air fronts coming together effecting a change in air density. Because of these conditions the direct wave may be refracted in such a manner as to cause extended wave propagation beyond the horizon. Also the moisture content of the air mass may contribute to this phenomenon. This condition is shown in figure 3.

Reflections of the VHF signals used for television transmission are also attributed to the strange behavior of VHF. Signals are bounced off tall objects, causing a change of signal path, resulting in reception of multiple images. A condition of this nature is shown in figure 4. This quite often presents receiving antenna orientation problems.

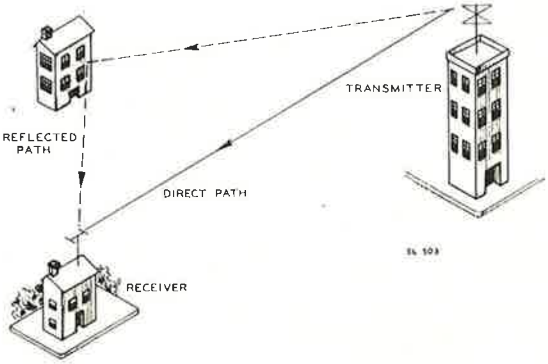


Fig. 4—Direct and Reflected Signals

A similar condition causing a changing brightness or flicker on the kinescope occurs when an airplane passes in the area of the received signal. (See figure 5.) This condition is sometimes referred to as

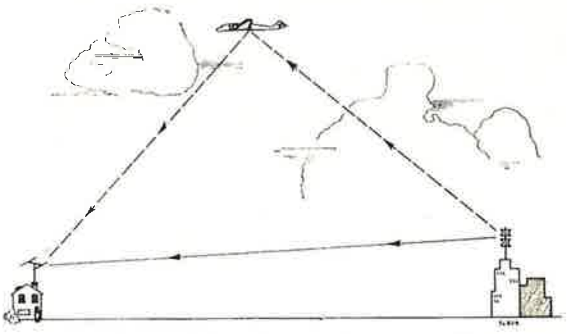


Fig. 5—Reflected Signal From Aircraft

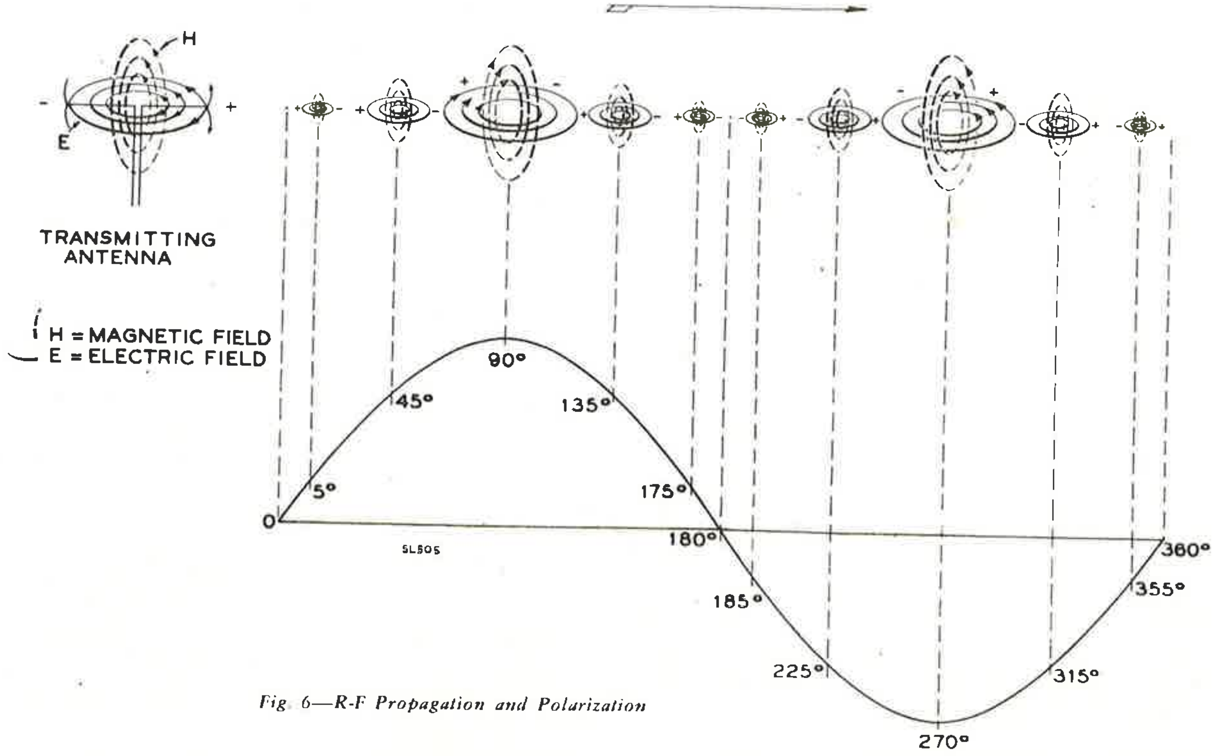


Fig. 6—R-F Propagation and Polarization

"flutter". The height and speed of the airplane determines the rate of flutter.

Signals from the direct wave and the wave reflected from the structure of the airplane may arrive in an out-of-phase condition causing picture displacement.

The antenna has very little discrimination against this type of reflected signal, however, AGC (automatic gain control) circuits in the receiver may tend to minimize the effect.

Knowledge of VHF behavior is a convenient tool and becomes helpful in solving antenna and receiver installation problems—particularly in conjunction with troubles dealing with multiple images or ghosts.

Polarization

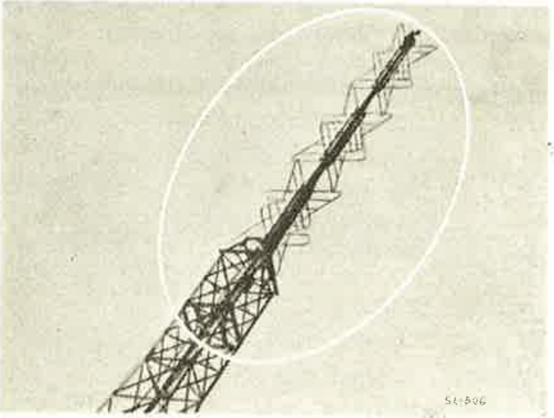
When an alternating current at radio frequencies is applied to a transmitting antenna, a periodically changing field composed of an electrostatic component and an electromagnetic component moves outward into space from the antenna. This is shown in figure 6. This constitutes the radiated signal or spherical wave front that the receiving antenna must intercept.

The electrostatic field, commonly referred to as the electric field, and the magnetic field constituting the radio wave are at right angles to each other. The direction of polarization is considered from the position of the electric field with respect to the earth's surface. If the electric field is vertical or perpendicular with respect to the earth, it is said to be vertically polarized and is usually being radiated from an antenna whose elements are erected vertically to the earth. In general, the receiving antenna's polarity should correspond to the polarity of the transmitting antenna if maximum signal voltage pickup is to be realized.

If the electric field is parallel to the earth's surface, the antenna radiating this field is erected with its elements parallel to the earth's surface and horizontal polarization exists. An exception to this is when the fields comprising the wave front undergo changes in polarization between the transmitting and receiving antennas.

Television antennas in this country are horizontally polarized. Although the transmitting antenna has a high vertically-erected mast, the radiating elements are located at the top. These elements are stacked dipoles, horizontally polarized and arranged to provide radiation in all directions. (See inset in figure 7.)

Fig. 7—RCA Television Transmitting Antenna



Consequently, receiving antennas are generally installed on a horizontal plane. This makes them less susceptible to pickup of man-made noises such as generated by ignition systems, neon lights, etc. These types of noise transmission are usually of vertical polarization.

TELEVISION ANTENNA PRINCIPLES

The basic principles of television antennas do not differ from those of any other antenna. All antennas may be represented by equivalent electrical circuits containing inductance, capacitance and resistance. As in the ordinary resonant circuit, changes in frequency cause changes in the current and voltage, which, in the case of an antenna, affect its gain, bandwidth, impedance, and radiation pattern. These four factors can be considered of practical importance, rather than of theoretical interest. A lack of knowledge of any of these factors may lead to unsatisfactory results when it is desired to choose an antenna for a specific application. In the following discussion, these factors are considered with regard to the television antenna, which must meet certain desirable requirements, if it is to be used successfully.

Antennas As Resonant Circuits

The receiving antenna must intercept a portion of the spherical wave front representing the radiated energy of a television transmitting antenna. This wave front creates a field around the receiving antenna which induces a voltage in the conductors forming the antenna. As the changing electromagnetic waves go through a cycle, the antenna attempts to follow these changes, and in so doing, reradiates some of the intercepted energy. Thus, a receiving antenna not only receives energy, but radiates energy. This reradiated energy represents approximately one half of the energy which is intercepted.

Fig. 8—Antenna Feed Systems

Because of the current and voltage distributions which exist on an antenna, it will be found that at some frequency, the inductive and capacitive components cancel, leaving only an effective resistance. The lowest frequency at which this occurs is the fundamental resonant frequency of the antenna, occurring when the antenna is a half wavelength long. This will also occur at frequencies which are harmonically related.

Depending upon the point where a transmission line is connected to an antenna, an antenna may be considered as a series or parallel tuned circuit. This is illustrated in figure 8. For an antenna which has a transmission line connected at its center, the current is a maximum and the voltage is a minimum at fundamental resonance or the lowest resonant frequency. The ratio of voltage over current is then low, which means the impedance is also low. This bears out the definition of impedance. This low impedance can be considered the result of resonating a series tuned circuit. For an antenna which has a transmission line connected at a half wavelength point, or is end fed, the voltage at this point is a maximum and the current is a minimum. The ratio of voltage over current is then high, resulting in a high impedance value. An end fed antenna may therefore be thought of as a parallel tuned circuit which has a high resistance at resonance. When the antenna is required to receive signals over a wide frequency range, the conditions in figure 9 are present. Regardless of the point where the transmission line is attached, the voltage and current distributions depend mainly upon the length of the antenna with respect to the frequency. At the fundamental and odd harmonic frequencies, the impedance is low, but at the even harmonic frequencies, the center impedance is high. Thus, it will be seen that an antenna required to receive a wide range of frequencies will present impedances which vary in a periodic fashion, or alternately present low or high impedances at various frequencies.

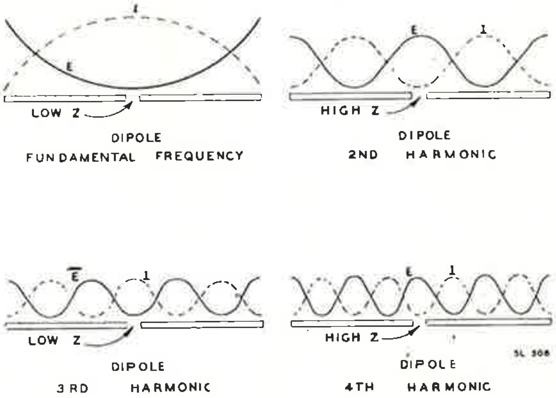


Fig. 9—Dipole Voltage and Current Distribution

At some resonant frequency, the antenna will present its lowest impedance. Under this condition the inductive reactance and capacitive reactance of the circuit cancel, leaving the circuit series resonant. Conversely, when the antenna passes through a value of maximum impedance, the reactive components have cancelled, providing parallel resonance. This condition is sometimes called anti-resonance. Figure 10 shows the variations in the inductive and capacitive reactances of a practical dipole antenna. As frequency increases progressively, there are cycles of series resonant and parallel resonant conditions constituting a series of impedance changes from low to high. The impression is a gradual variation of impedance made up of low to high impedance changes and gradually approaching 300 ohms. This point is illustrated in figure 11.

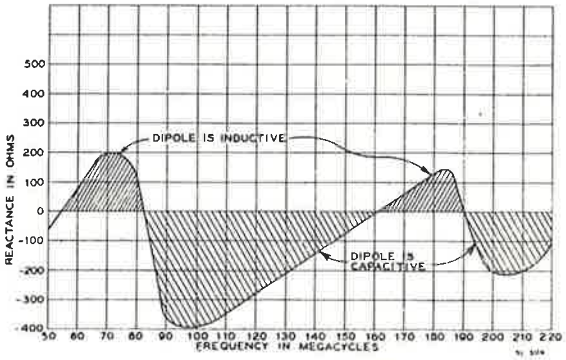


Fig. 10—Dipole Reactance Variation

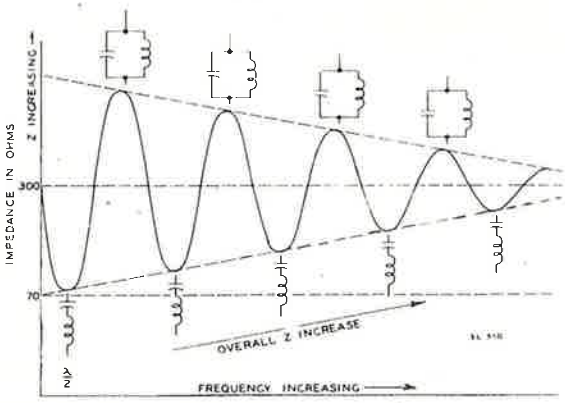


Fig. 11—Dipole Impedance Excursions

Unless special means are employed to reduce these impedance excursions, an antenna can be matched by a 72 ohm transmission line only at its fundamental and approximately at the odd harmonics. The variation in impedance with frequency for a practical dipole antenna is shown in figure 12. It will be noted that the minimum value is about 75 ohms and the maximum value about 750 ohms.

Television Antenna Requirements

Antennas for television use must, because of the frequencies involved, be self resonant in the television channels. This requirement is quite different than that at ordinary broadcast frequencies where a loop antenna or short piece of wire is used. Frequencies in the VHF range (30-300 mc.) suffer greater attenuation in their transmission through space, so that a more efficient antenna is required. Fortunately, antenna dimensions at these frequencies are reasonably short and therefore, half wave resonant antennas are generally used. For example, a dipole cut for Channel 2 picture carrier, (the lowest frequency channel and therefore the one requiring the largest antenna length), would be approximately 100 inches long. Compare this with the case at 1000 kc where an antenna 467 feet long would be required if it were to be self resonant.

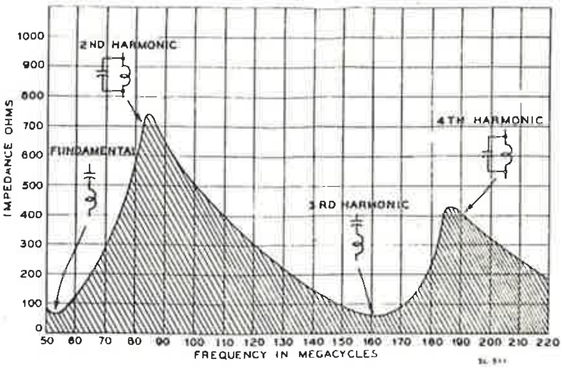


Fig. 12—Dipole Impedance Variation

A resonant antenna is an efficient receptor of radio frequency energy. Likewise, it is an efficient radiator if a source of R-F energy is connected to it. It is for this reason that oscillator radiation interference, as mentioned in Lecture Five, becomes more troublesome at these higher frequencies.

The television antenna must also be capable of being installed in a reasonable length of time, which indicates that it should be mechanically simple and should require no electrical adjustments when it is installed, no matter what television channels are used. Another requirement is that the television antenna must respond well over a wide frequency range. The means by which this is accomplished is known as broadbanding the antenna.

Antenna Bandwidth

One of the inherent difficulties in designing a satisfactory television antenna arises from the large bandwidth required. This frequency range extends from 54 mc. to 216 mc., giving a ratio of 4 to 1 in frequency or 200% from each side of a 108 mc. center frequency. For comparison purposes, it will be noted that the FM band (88 mc. to 108 mc.) has a ratio of only 1.2 to 1, although it is 20 mc. wide. The importance of bandwidth stems from the fact that it is desired to use only one antenna mainly for economic reasons. If it were necessary to use separate antennas for each channel, installation would be slow, complex, and expensive. Where more than two channels would be operating, this would result in an unsightly forest of antennas. Figure 13 shows the graph of an ideal frequency response curve for a television antenna.

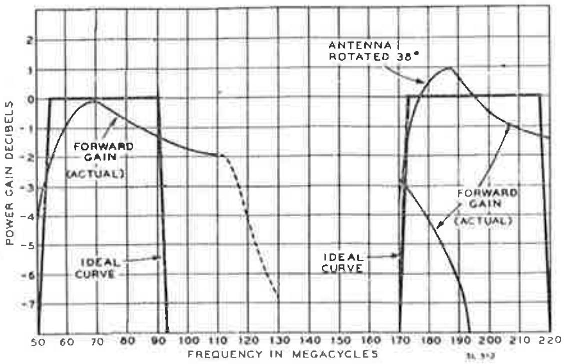


Fig. 13—Comparison of Ideal and Actual Dipole Response Curves

If we can obtain an antenna whose response curve approaches the ideal, this antenna can be used for satisfactory reception of any television channel, provided a satisfactory signal-to-noise ratio is obtained at the location where the antenna is used. The graph also shows the actual response curve obtained from a simple dipole connected to the receiver by 300 ohm transmission line.

Over any one television channel, the characteristic of flat response, as shown in figure 13, is desirable. An antenna, as explained earlier, may be regarded as a tuned circuit. If this tuned circuit (antenna) has a rapid variation in impedance due to a high "Q", undesirable phase shifts may be present which will affect the picture quality. Therefore, an antenna which is sharply resonant on one channel, may not be satisfactory if it is used on other channels. Characteristics of a "Yagi" antenna illustrate this point.

Methods of Increasing Bandwidth

Probably the easiest method of increasing the bandwidth of any antenna is to increase the diameter of the conductors. This increase in diameter prevents the impedance of the antenna from changing rapidly, thus wider bandwidth is obtained. This effect can be obtained in a practical manner by using rod or tubing for antenna elements rather than wire. For this reason television antennas are constructed of rod or tubing.

Another means of increasing the bandwidth of an antenna has been used very successfully—building the antenna in the shape of two cones which taper toward each other and have the configuration of a dipole antenna. This is generally referred to as a "biconical" antenna, although its performance can be explained in terms of the simple dipole.

In general, we can broadband an antenna by changing its shape in some manner to obtain the desired characteristics.

Another method which can be used to broadband an antenna is to use a transmission line with a higher impedance than that of the antenna at fundamental resonance. This is the reason why RCA antennas consisting of straight rod dipoles, and which have a nominal impedance of 72 ohms, are used with 300 ohm "Bright Picture" transmission line. The voltage at resonance is decreased, but the R-F voltage developed on the transmission line is increased at other frequencies. Hence the response curve of the antenna is effectively flattened, with resulting broadband antenna characteristics.

Antenna Dimensions

As mentioned previously, an antenna is resonant when its length is a half wavelength at the frequency used. This length, however, is not exactly a physical half wavelength; instead, it will be somewhat shorter.

As an analogy. suppose we build a tuned circuit and measure its resonant frequency before we place it in a chassis and connect it in a circuit. We would find that due to the additional capacity contributed by the various sources, that our tuned circuit would now resonate at a lower frequency. To resonate the tuned circuit to its original frequency, the number of turns on the inductance or the value of the capacitance would have to be decreased.

The antenna is affected in much the same way, except that the external circuit in this case is space itself. The coupling of the antenna to space is very much like adding capacity to the resonant circuit formed by the antenna. The length of the antenna must be decreased to restore the same resonant condition. A length slightly less than that of a physical half wavelength will provide resonance. The exact length of the antenna also is influenced by the presence of surrounding physical objects. Any calculations made are therefore approximate.

Neglecting the presence of surrounding physical objects—compensation for "end effect" as it is known, requires about a 5% reduction in length. From this we can obtain a formula giving the required length of a dipole antenna as:

$$L = \frac{984}{2} \times \frac{0.95}{F} \quad \text{or} \quad \frac{492 \times 0.95}{F}$$

where L= required length in feet and F is the frequency in megacycles. 984 represents the velocity in feet per microsecond of radio waves in free space. The factor 0.95 takes into consideration the "end effect" just mentioned. This factor depends upon the conductor diameter, so for a broadband antenna whose conductors are large, the antenna may be shorter because this factor is decreased.

Figure 14 shows a comparison of antenna lengths for the low and high television bands, and also for antennas of different diameters compared to a free space half wavelength. A typical length value for the average antenna used in television is approximately 0.90.

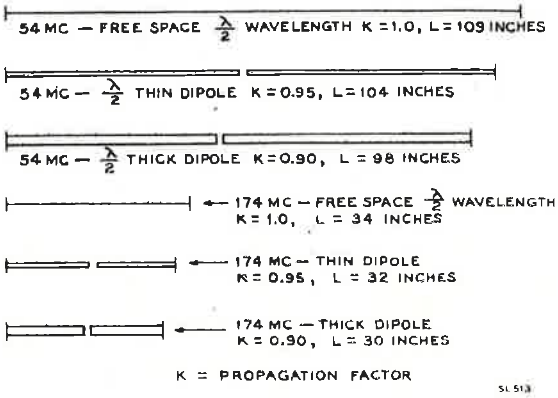


Fig. 14—Comparison of Antenna Dimensions

Antenna Directivity Patterns

An important factor to be considered when selecting an antenna is its directivity or lobe pattern. Because an antenna may radiate in any direction, it would theoretically be necessary to show a three dimensional radiation pattern to obtain a true picture of its directivity. However, it is generally sufficient to show various sections of the lobe pattern, which will give us the necessary information.

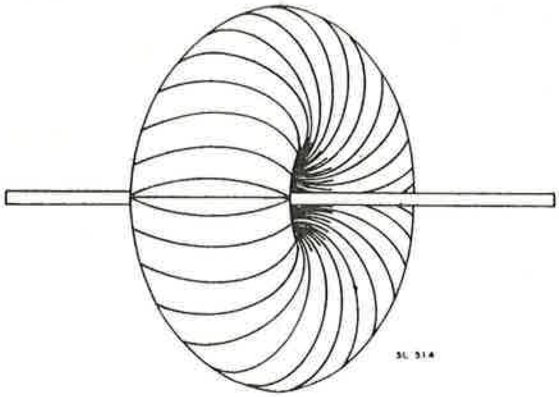


Fig. 15—Dipole Doughnut Field Pattern

Figure 15 shows the doughnut-shaped pattern of an ordinary dipole, representing the radiated energy in all directions. For the horizontal dipole, this radiation is minimum in a direction extending from the ends of the dipole. In a direction broadside from the dipole, the radiation is maximum. Usually the directivity pattern is shown for vertical and horizontal planes. Figure 16 shows these two patterns. It can be seen that a dipole has a non-directional pattern vertically which means that it will respond to any signal or noise arriving at any vertical angle.

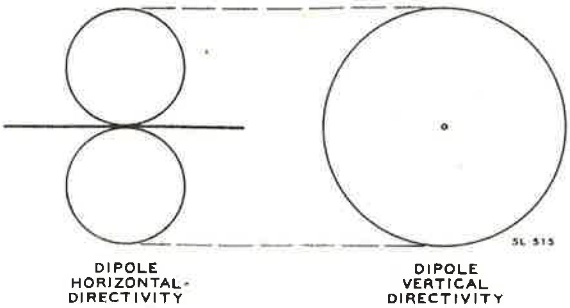


Fig. 16—Horizontal and Vertical Directivity Patterns

However, the simple dipole does have some directivity in the horizontal plane or "looking down" upon the dipole. It is bidirectional in a direction at right angles to the antenna and therefore does not discriminate against signals arriving from the rear. For this reason, in areas where reflections or co-channel interference are prevalent, it is generally not satisfactory.

The radiation pattern as shown is true only for operation of the antenna at its fundamental resonance. At other frequencies above this, the pattern splits into four lobes. The changing directivity pattern of a simple dipole for frequencies from 50 to 200 mc. is shown in figure 17. A "low band" antenna which is used for "high band" reception then has four major lobes. It has been found that these lobes are approxi-

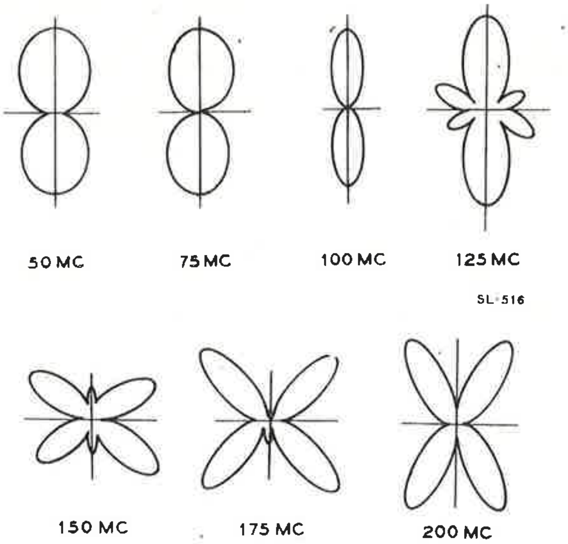


Fig. 17—Dipole Directivity Patterns

mately 38 degrees each side of the direction in which the dipole faces. Where signals from the high band television transmitter are weak, careful orientation of the simple dipole antenna is necessary to obtain optimum results.

Directivity Measurements

Directivity consideration is very important in television antenna work. While horizontal directivity is usually emphasized, the factor of vertical directivity should not be neglected. For most television purposes, however, horizontal directivity patterns are usually sufficient to give the desired information. Most television antenna directivity charts give only the horizontal directivity characteristics.

In making charts of directivity characteristics, the antenna is placed on a rotatable stand and a low power source of R-F energy is placed some distance away. A receiver, which has been designed especially for these voltage measurements, is connected to the antenna and used to obtain the measurements desired. In more elaborate setups, the directivity or lobe patterns may be drawn by automatic curve-tracing apparatus.

A special type of graph paper is used to plot antenna characteristics. As shown in figure 18, a center on the graph paper is chosen, representing the location of the antenna at this point. Concentric circles are then drawn about this center. These circles represent the magnitude of the voltage developed at the antenna terminals. Straight lines are now drawn which pass through the center. These lines represent the orientation angle of the antenna. The point where the antenna lobe pattern intersects one of the lines and a concentric circle indicates the voltage developed at a particular orientation angle. Figure 18 shows that at 27 degrees the voltage developed by the antenna is 0.70 of the maximum voltage. Since this also represents half the power, the antenna beam width is twice 27 degrees or 54 degrees. It is conventional to place the 0 degree point at the top of the graph paper, in line with the eye of the observer. Figure 18 has been simplified to demonstrate the principle involved. Graph paper, as actually used, contains a greater number of straight lines and concentric circles, so that greater accuracy in plotting can be obtained.

In general, lobe patterns of an antenna for all television channels are not essential for practical analysis. Experience has indicated that four diagrams, two for the low channels and two for the high channels, are sufficient to determine the expected response, front-to-back ratios and side lobes, if any.

Antenna Gain

Antenna gain refers to the voltage developed across an antenna, using a simple dipole at fundamental resonance for comparison. Thus, if an antenna being compared to a reference dipole provided 2 volts of signal, over the reference dipole's 1 volt, the voltage gain would be 2 or a power gain of 6 db.

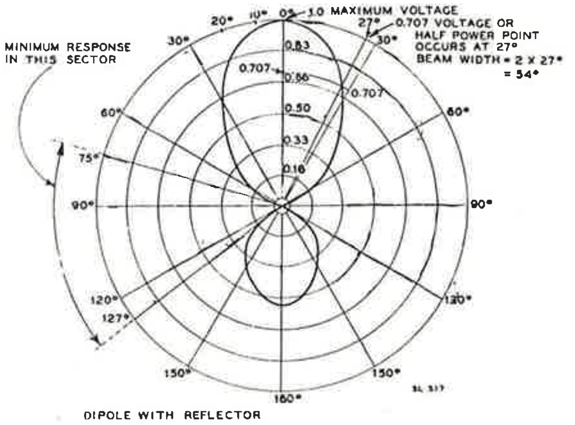


Fig. 18—Antenna Polar Diagram

Antenna gain may be obtained by the use of parasitic elements or by employing stacked arrays. Generally, a gain of 1 or 2 db can be obtained from a simple dipole with reflector. The use of a conical antenna may provide some additional gain and may have a more constant response over the television channels.

An antenna power gain diagram is shown in figure 19. The gain is not constant, but varies somewhat. Performance between the "low" and "high" television channels is purposely omitted. In a well designed antenna, response in that region is somewhat reduced. The gain for a stacked array is also shown in figure 19. Note that the gain for the stacked array has increased on all channels.

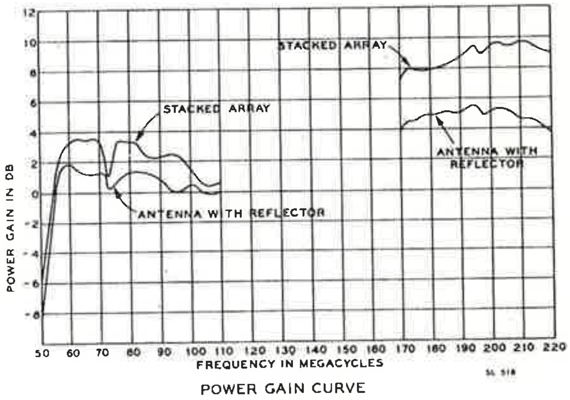


Fig. 19—Power Gain Curve

Parasitic Elements

It was mentioned previously that an antenna collects energy in its elements and reradiates approximately one half of this energy. This will occur independently of any transmission line connected to the antenna. If two antennas are placed in close physical proximity, the reradiated energy will produce an interaction between the antennas elements.

A parasitic element may be regarded as an antenna without a transmission line connection which is coupled to the main antenna system, but not by a direct physical connection. Antenna elements which have transmission line connections are known as driven elements.

The simplest antenna array, and the one most familiar to television technicians, has one driven element and one parasitic element. Examples of this type are: The dipole with reflector, the folded dipole with reflector, or the conical antenna with reflector. A dipole with reflector is shown in figure 20.

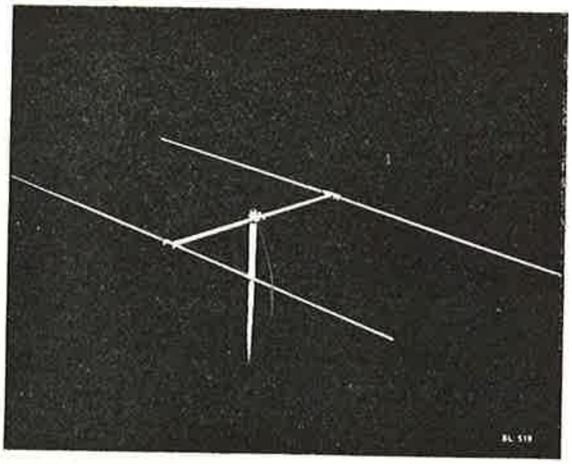


Fig. 20—Simple Dipole with Reflector

In television applications, the parasitic element is generally operated as a reflector and is positioned to make the lobe pattern essentially unidirectional. In this case it is located behind the driven element. However, parasitic elements have a much narrower bandwidth than the driven element because they are not loaded by a transmission line and so have a high "Q". Since the spacing between the reflector and the dipole is usually fixed, this distance with increasing frequency represents a greater and greater proportion of a wavelength, until at higher frequencies, the parasitic element is effectively decoupled from the driven element.

The following results can usually be expected when a reflector type of parasitic element is added to a dipole. The impedance of the array is decreased below that of a simple dipole. In terms of percentage, this may be 30% to 70% depending upon the length and spacing of the reflector. The directivity pattern is made essentially unidirectional at the resonant frequency. The bandwidth of the array may be decreased over that of a simple dipole. The gain of the array, however, is greater. As much as 4 db may be added by careful design. Basically, the increased gain by use of a reflector is as follows: The reflector element intercepts energy the same as the driven element of the antenna. This energy is reradiated from the reflector and is "picked up" by the driven element and adds to the signal that the driven element intercepts. As mentioned above, this action is only effective over a portion of the bandwidth encountered. As the frequency is increased, the reflector is effectively decoupled from the driven element. It should be realized that television antenna design requires many compromises between conflicting factors.

More than one parasitic element may be used with a driven element but the impedance and bandwidth of the antenna array is reduced so much that little net gain will result except over one or two channels. However, a special type of parasitic antenna array, known as a Yagi has been used for special applications. A Yagi antenna may be defined as one which has two or more parasitic elements. In this case, one of the parasitic elements is placed behind the driven element and is used as a reflector. The other parasitic elements are placed in front of the driven element and are known as directors. A Yagi antenna has a very narrow bandwidth and is generally effective only over one channel. A three element antenna array of this type is shown in figure 21.

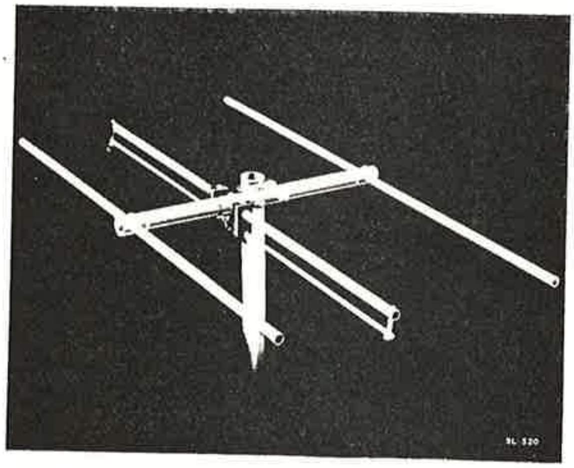


Fig. 21—Folded Dipole with Parasitic Elements

To produce the necessary phase difference for proper operation of parasitic elements, it is necessary to make the parasitic elements different in length than the driven element. A reflector will generally be made at least 5% longer than the driven element, and a director will be made 5% less. This can only be regarded as approximate, as much will depend upon the spacing of the elements.

Another requirement which does not arise with the simple dipole, but is of especial importance in antenna arrays, is that the antenna must present a reasonable impedance to the transmission line so that good efficiency can be obtained even though the line need not be exactly matched. A dipole with reflector and director elements may have an impedance as low as twenty-five ohms, due to the influence of the parasitic elements. To provide an increase in impedance, folded dipoles may be used as illustrated in figure 22.

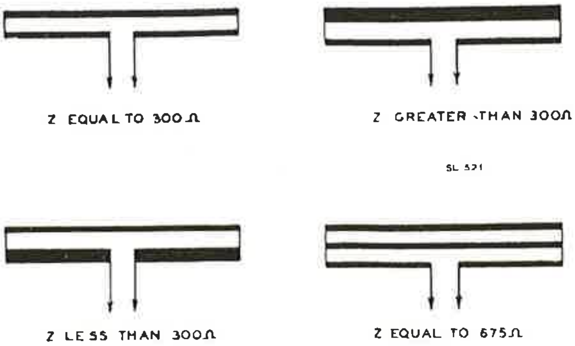


Fig. 22—Folded Dipole Impedances

Besides the standard 300 ohm dipole antenna with its upper and lower elements of equal diameter, a folded dipole can be used which has the upper element several times larger than the lower element. The impedance then becomes greater than 300 ohms, the exact value depending upon the ratio of the element diameters. If a very large initial impedance is required before parasitic elements are added, a three element folded dipole can be used. The use of these arrangements permits the direct connection of 300 ohm line to a Yagi type array. Reasonable efficiency can therefore be obtained and special matching methods are not required.

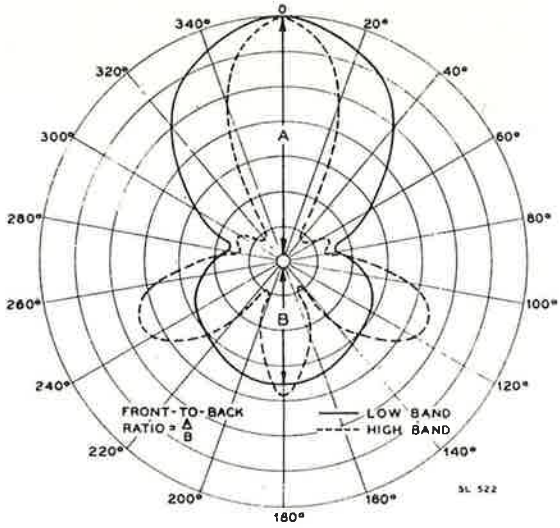


Fig. 23—Front-to-Back Ratio

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Front-to-Back Ratio

Front-to-back ratio of an antenna is a factor used to indicate its sensitivity to signals received at the rear with respect to signals received at the front. This is determined by measuring the voltage ratio at these two angles. Thus, if an antenna develops 1 volt at zero degrees, and 0.1 volt at 180 degrees, the front-to-back ratio would be 1/0.1 or 10 to 1, indicating that the antenna is 10 times more sensitive to signals arriving in the desired direction. In actual practice, however, ratios of this extent are the exception.

The use of front-to-back ratios should be considered carefully as misconceptions may otherwise result. Figure 23 shows an antenna with a 2 to 1 front-to-back ratio, but with additional side lobes at the higher frequencies that make the factor of a front-to-back ratio somewhat meaningless unless all factors are considered.

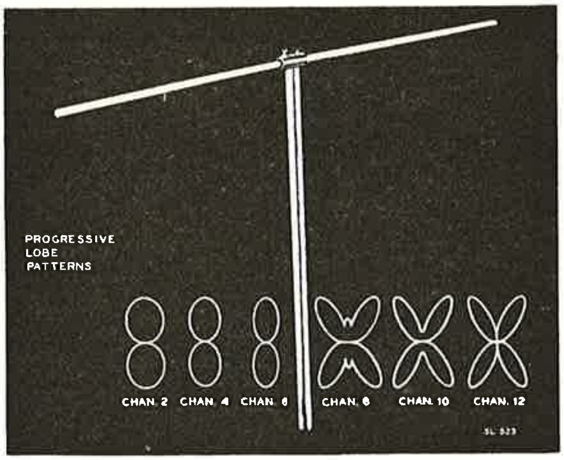


Fig. 24—Simple Dipole

TELEVISION ANTENNA TYPES AND ARRAYS

The selection of a proper type antenna can best be made when the characteristics of the many types are known and understood. It is equally important to know the conditions which exist in conjunction with a particular installation—channels to be received, transmitter location, distance, surrounding terrain, receiver input impedance, receiver sensitivity, etc.

A discussion of the various types and their characteristics may help to make an appropriate selection.

The Simple Dipole

The simple dipole (figure 24) used for television reception is usually a half-wave antenna consisting of two quarter-wave sections fed at the center. The impedance of this antenna is approximately 72 ohms at fundamental resonance. On frequencies either side of resonance the impedance of the simple dipole increases, and to some extent, compensates for mismatch in the transmission line. For example, at a higher frequency than the fundamental resonant frequency, a simple dipole connected to a 300 ohm load, delivers more power than a folded dipole. For this reason a simple dipole is recommended for wide band coverage.

The simple dipole is essentially bi-directional. This is true at lower channel frequencies, however, directivity will change since the major lobes split into multiple lobes on higher frequency channels. (See progressive lobe patterns, accompanying figure 24.)

In areas where signal strength is adequate and there are no obstructions to cause serious reflections, and noise conditions are at a minimum, the simple dipole will provide satisfactory performance. Its erection is less complicated and less expensive.

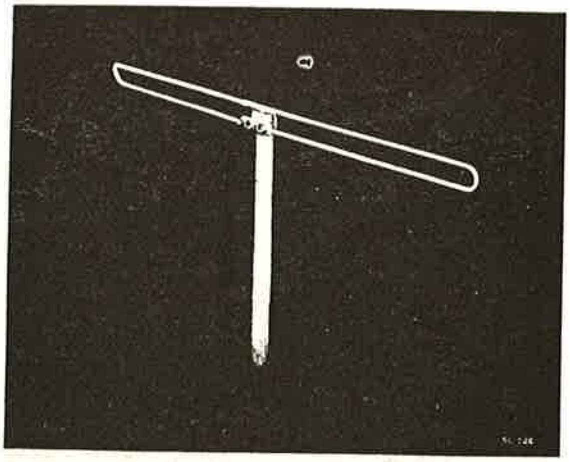


Fig. 25—Folded Dipole

The Folded Dipole

The folded dipole can be considered as two half wave antennas spaced approximately 0.03 of a wavelength apart, one above the other. Their ends are connected together (in parallel). The lower section is opened and fed at the center or quarter wave point. A folded dipole is shown in figure 25.

The impedance of the folded dipole is four times that of the simple dipole, or approximately 300 ohms. This makes it an optimum match for 300 ohm transmission line and 300 ohm receiver input circuits.

The folded dipole has broad bandwidth and exhibits characteristics similar to the simple dipole. It is bi-directional, under the same conditions as the simple dipole, easy to install mechanically and is inexpensive.

A point of interest is that the top-element center point may be grounded to the mast. The wave on the antenna at the resonant frequency is traveling through zero voltage at this point. Thus, the voltage is zero with respect to ground. Use of the folded dipole may be considered where signal strength is adequate and where reflections and noise possibilities are negligible.

Each of the above types will have increased signal gain and directivity when used with directors and reflectors, as discussed under "Television Antenna Principles"

High-Low Band Combination

Television frequency allocations are not continuous. One band extends from 54 to 88 mc. and another extends from 174 to 216 mc. These are referred to as the low and high bands, respectively. The gap between 88 mc. and 174 mc. is occupied by FM and other services.

The High-Low Band Combination shown in figure 26 (compared to a single antenna) will provide better efficiency in an area where a combination of low band and high band channels is to be received

The flexibility of each antenna on a single mast provides independent orientation for each antenna section. The vertical spacing between the high and low band sections should be sufficient to prevent serious interaction between the two antenna sections. This spacing should be approximately 36 inches. The use of reflectors provides additional gain and directivity.

Both antenna sections may be connected to one common transmission line as shown in figure 26, or separate lines if desired

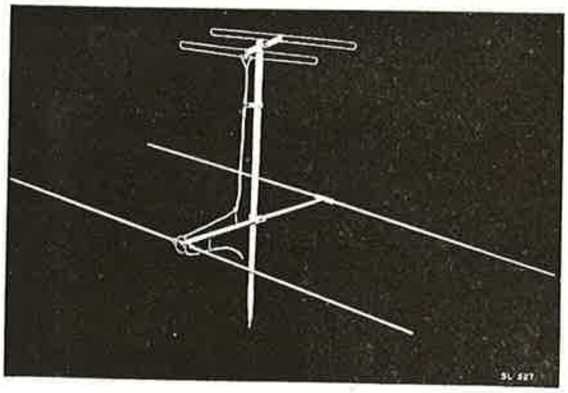


Fig. 26—RCA High-Low Antenna

RCA Antenna "V" Attachments

The dipole and reflector antenna shown in figure 27 has the added feature of RCA "V" attachments or "wings". To illustrate the effect of the "V" attachments, a lobe-pattern graph is shown in figure 28. As pointed out previously, at high band operation the figure eight pattern that is normally experienced at the lower channel frequencies splits into multiple lobes, forming a clover leaf pattern and possibly some minor or parasitic lobes. Figure 28 shows how "V" attachments prevent splitting of the major lobe, providing improved response and directivity. It has likewise been previously mentioned that under high band operation, the low frequency reflector has virtually no effect in adding signal to the driven element.

Close inspection of figure 27 will reveal that a small reflector has been placed behind the "V" attachments.

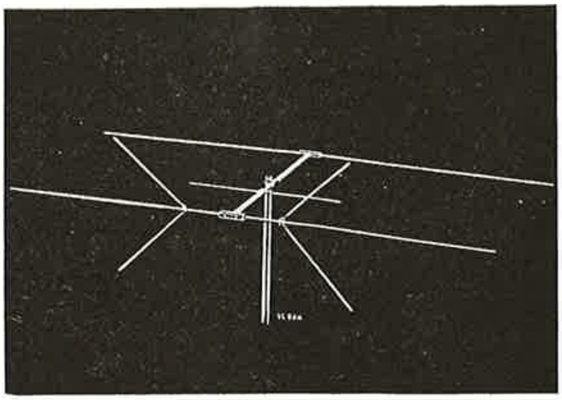


Fig. 27—Dipole with Reflector and "V" Attachments

This high frequency reflector provides increased gain and directivity. However, if high frequency channels are to be received from the rear, the high frequency reflector should be removed.

The "V" attachments provide efficient operation at high band frequencies and contribute to rise in gain as frequency increases.

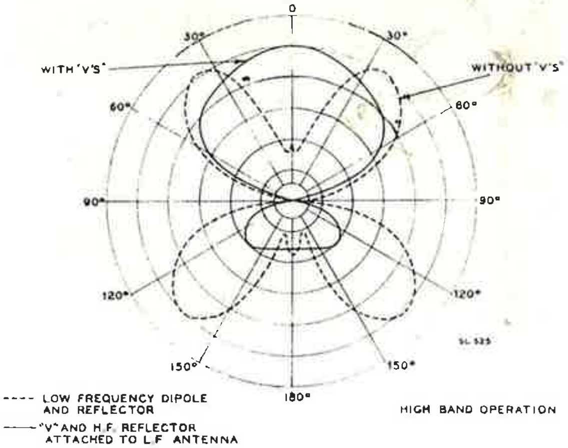


Fig. 28—Effect of "V" Attachments

Conical Antennas

The term conical antenna has been loosely applied and may be construed to mean a group of types. The types considered under this heading have been called V-dipoles, fan antennas and X-type.

The original or older designs (see figure 29) were made as actual cones from sheet metal or in some cases, radial wire or wire mesh cages. Broad band characteristics are inherent in their design.

Later forms of conical antennas have gained wide usage. The forward X elements may or may not be tilted forward. Good gain characteristics may be obtained by the use of reflectors—either a single straight rod or an X reflector placed behind the forward elements.

The directivity characteristics of the conical antenna resemble those of the simple half-wave dipole until the second harmonic is reached. Operation from this point to higher frequencies provides individual characteristics.

One of the conical antenna's distinguishing features lies in the manner with which the conical elements are placed in respect to each other. The cross-sectional area of the conical elements continually increases out to the ends whereas the simple straight-rod dipole's cross-sectional area remains constant. An antenna with a uniform cross-sectional area tends to exhibit higher surge impedance at successive points from the feed point out to the ends. The progressive increase in cross-sectional area of the conical antenna tends to keep the surge impedance constant at each successive point. This provides improved matching stability.

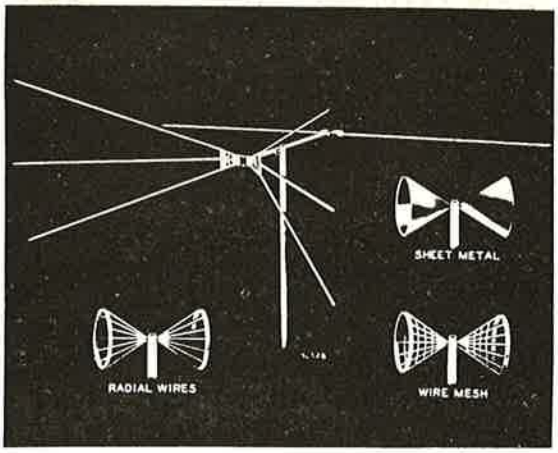


Fig. 29—Conical Antennas

Yagi Antennas

The Yagi antenna is a multiple parasitic element type antenna. The driven element may be either a straight dipole or a folded dipole. This antenna has high front-to-back ratio and has been used as a high gain antenna for fringe area reception.

Its use is generally limited to single channel reception since its frequency response is quite narrow.

The impedance of the Yagi antenna, because of its many parasitic elements, may be lower than 50 ohms. When matching to a 300 ohm line, a quarter wave phasing stub may be used. An alternate method of matching a Yagi to a 300 ohm line is to purposely increase the impedance of the antenna by using a folded dipole driven element with the top section of the folded dipole made of larger diameter tubing than the lower section. The antenna shown in figure 30 illustrates this point. This compensates for the characteristic of low impedance caused by the presence of the additional elements

Reference to this point is made under the heading "Television Antenna Principles"

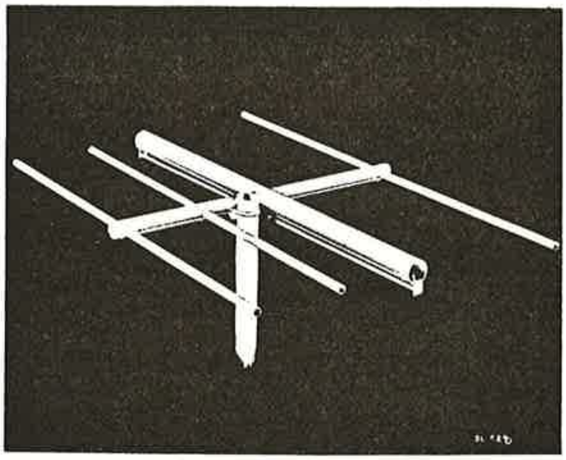


Fig. 30—Yagi Antenna

Stacked Arrays

The stacked array is most useful in fringe areas or where signal strength is at a minimum and increased gain is desired. Where signal strength is adequate, the stacked array becomes an extravagant installation since its mechanical requirements are exacting and the cost is high.

Practically any of the general antenna types discussed in this section can be used as stacked arrays. Some interesting examples are shown in figures 31 and 32.

To show the effectiveness of a stacked array, an assumed condition is illustrated—using the simple dipole as a reference antenna. (See figure 33.)

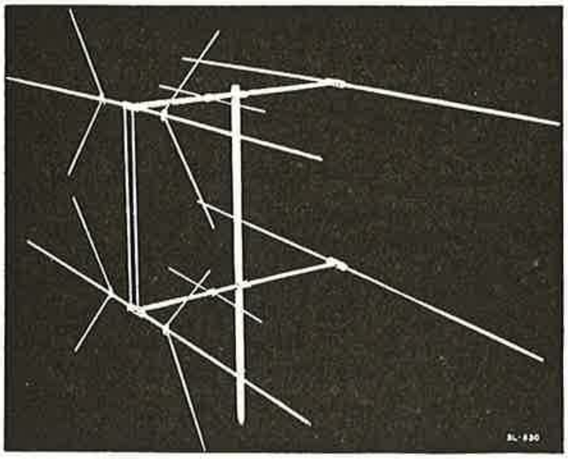


Fig. 31—Stacked Array

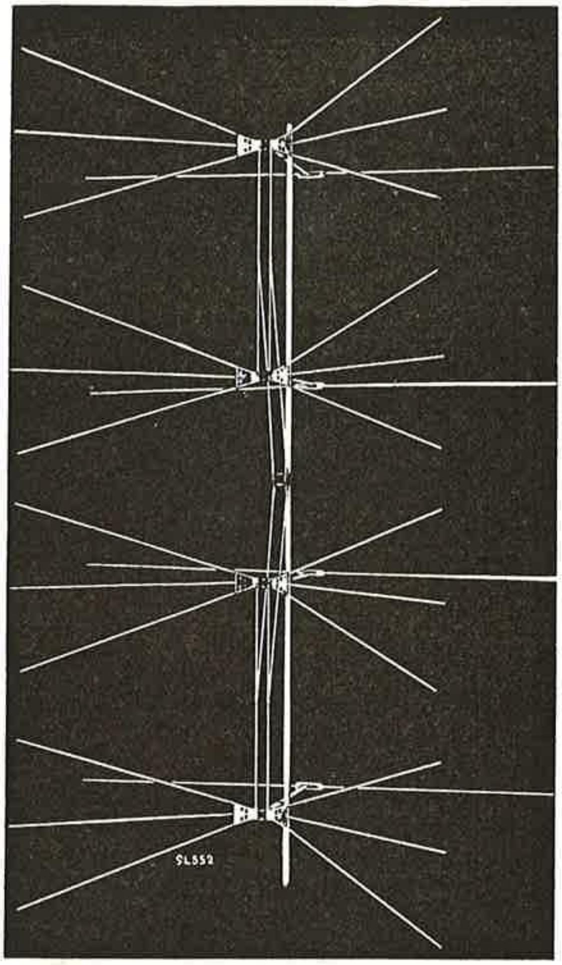
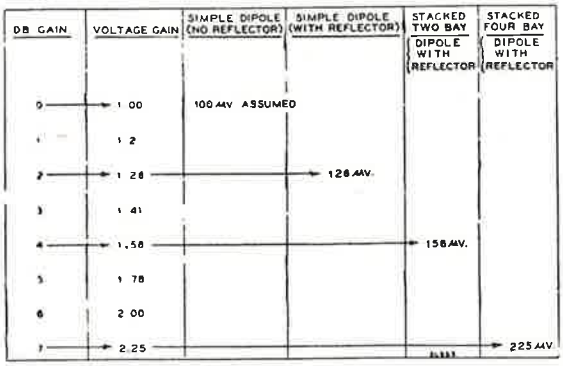


Fig. 32—Four Bay Conical Stacked Array

Suppose a simple dipole with no reflector were erected 25 miles distant from a television transmitter. The dipole's length is correct for the frequency involved, it has ample height, proper orientation and the voltage developed on the antenna is 100 microvolts. The db gain is zero.



ANTENNA GAIN CHARACTERISTICS

DB GAIN	VOLTAGE GAIN	SIMPLE DIPOLE (NO REFLECTOR)	SIMPLE DIPOLE (WITH REFLECTOR)	STACKED TWO BAY DIPOLE WITH REFLECTOR	STACKED FOUR BAY DIPOLE WITH REFLECTOR
0	1 00	100 μV ASSUMED			
1	1 2				
2	1 26		126 μV.		
3	1 41				
4	1.58			158 μV.	
5	1 78				
6	2 00				
7	2.25				225 μV

Fig. 33—Antenna Gain Characteristics

Note that when a reflector is added, the gain is increased 2 db, which represents a voltage ratio increase of 1.26 or 126 microvolts of signal which is 26 microvolts greater than before the reflector was added.

Stacking the dipole-reflector combination shows that the increase in db gain over the simple dipole (without reflector) is 4 db corresponding to a voltage ratio of 1.58 or 158 microvolts of signal. The two bay stacked array actually provides 32 microvolts increase of signal over the single dipole and reflector combination. The four bay stacked array provides approximately 7 db gain, corresponding to a voltage ratio of 2.25 or 225 microvolts. This represents a gain of 125 microvolts over the simple dipole (without reflector) and 67 microvolts increase over the value for the two bay stacked array.

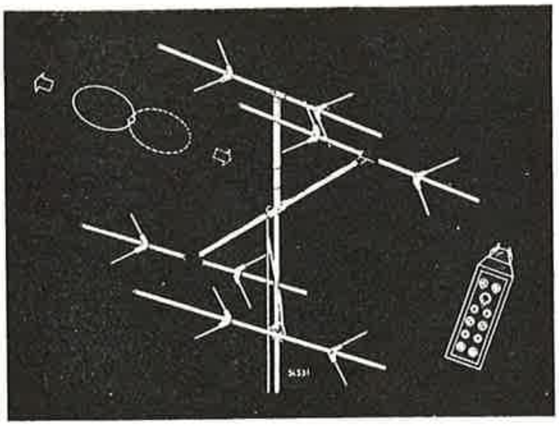


Fig. 34—RCA Reversible-Beam Antenna

The RCA Reversible-Beam Antenna Array

The RCA Reversible-Beam Antenna consists of an array of four eight-foot dipoles—two on a vertical plane and two on a horizontal plane. This antenna type is shown in figure 34.

The array receives signals from only one direction at a time. This feature eliminates co-channel interference where stations are approximately 180 degrees apart. It also eliminates adjacent channel interference where the receiver lacks selectivity. "V" attachments provide uniform directional characteristics for all twelve channels. A high overall front-to-back ratio is achieved through the use of all driven elements. This design provides the unique feature of lobe switching.

A dual transmission line connects the horizontal and vertical dipoles to a diplexing network located at the rear of the receiver. A switch on the diplexer provides directivity selection.

An explanation describing the function of the diplexer will be found under the subject of "Transmission Lines."

Indoor Antennas

In cases where tenants are forbidden the use of a roof for an antenna or some other problem exists to discourage the use of an outdoor antenna, it may be necessary to resort to the use of an indoor system.

There is a great assortment of indoor antennas and many considerations enter into their performance. However, where signal strength is adequate, good results may be obtained.

In selecting an indoor antenna the following considerations should be made.

1. Is the receiver location in a high signal level area?
2. Does the building structure contribute to severe attenuation of the signal?
3. Are room reflections likely to be a problem?
4. Does extending the rods of a telescope type antenna cause a cumbersome, undesirable arrangement?
5. Would the customer prefer a concealed type?

It is possible to conceal an indoor antenna behind a picture or curtain, or beneath a rug or baseboard. The success of these arrangements depends on some of the factors just mentioned.

Concealed types can be made with 300 ohm transmission line in the form of folded dipoles. Some examples of indoor antenna types are shown in figure 35.

They can also be concealed on the back of the television cabinet, cabinet table, or within the cabinet itself. (See instructions for making folded dipole in Appendix.)

Proper dimensions and impedance matching should be taken into consideration when using these types if optimum performance is expected. In orienting an indoor antenna, it may be surprising that the best sig-

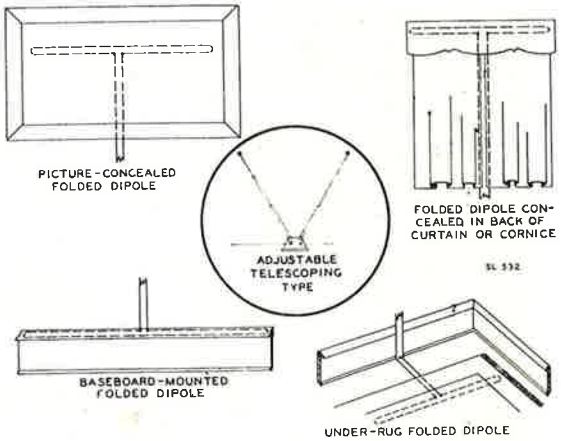


Fig. 35—Indoor Antenna Installations

nal does not necessarily come directly from the direction of the transmitter. Room reflections may contribute to this condition and cause a stronger signal to be intercepted at some unexpected angle. Moving the cabinet-top type of antenna to various positions may establish this fact. In this respect, be careful to locate the antenna away from the location of the high voltage compartment of the receiver. If the antenna is within the field of the high voltage supply, energy may be coupled to the antenna with the possible effect of Barkhausen oscillation appearing on the screen.

Attic Installations

Almost any antenna that will serve as an outdoor antenna will function as an attic installation provided there is adequate space. However, an attic installation may not perform efficiently if the house has a complete metal roof

Methods of mounting depend on the interior construction of the attic, room shape and dimensions.

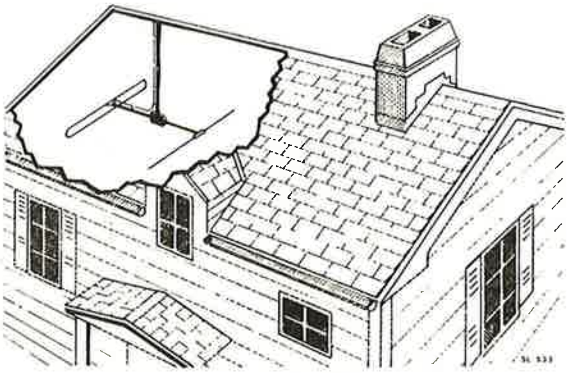


Fig. 36—Attic Antenna

Figure 36 illustrates the use of a folded dipole with reflector. The antenna illustrated in figure 37 is the standard RCA Mallet antenna consisting of two dipole rods held by a plastic insulator. The addition of wings as discussed previously may improve the antenna's operation.

A wood base adapts the antenna for mounting to side wall, attic rafters, joists or cross-members and provides some flexibility for orientation. This type of antenna presents broad band characteristics when connected to 300 ohm transmission line.

House wiring should be taken into account when making an attic installation—both from the standpoint of antenna placement and transmission line run. Proximity to the house electrical system should be avoided

In most cases it is preferable to run the transmission line from the attic between the walls or partitions.

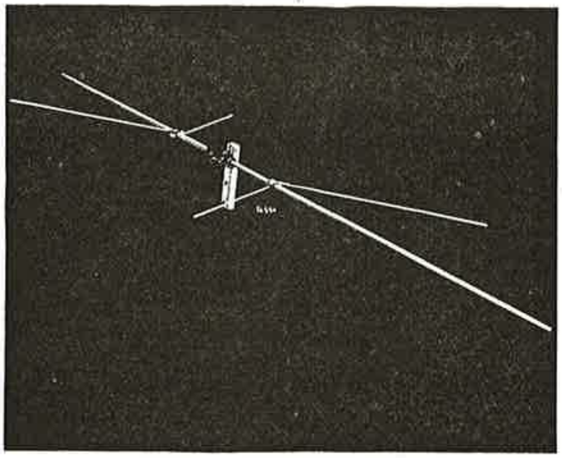


Fig. 37—RCA Mallet Antenna Used for Attic Installation

Frequently, a section between the walls through which the transmission line may be run, can be located from the basement.

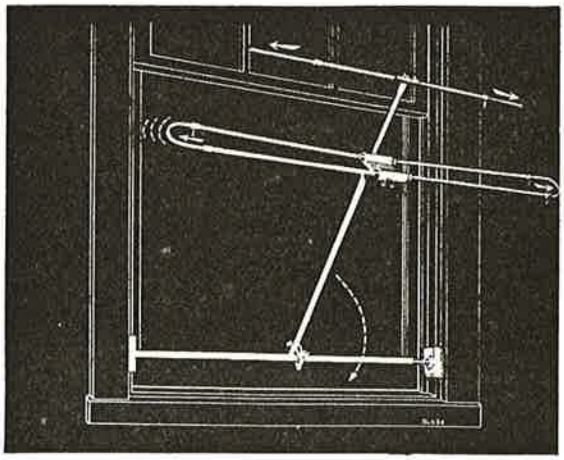
A weighted fish line dropped between the walls from the attic will establish whether the space is clear, and when tied to the transmission line, serves to pull the transmission line up to the attic where it may be connected to the antenna

As far as orientation is concerned, the conditions experienced with indoor antennas, such as room reflections, etc., may also prevail.

Window-Mounted Types

For apartment-house use or where conditions make it necessary, a window-mounted outdoor type may be used. While having some advantages over the indoor types, they too may be subject to some special considerations with regard to reflections, orientation facility, mounting methods, impedance matching, etc. A window-mounted type with adjustable elements is shown in figure 38.

Fig. 38—Window-Mounted Antenna



TRANSMISSION LINES

A transmission line may be defined as a physical device for transferring the energy intercepted by the antenna to the television receiver. It is desirable to transfer this energy with as little loss as possible over the desired frequency ranges. However, at radio frequencies, the power transfer characteristics of the transmission line are essentially dependent upon the match of the television receiver to the transmission line. These characteristics may be changed by the length of the transmission line with respect to the frequency involved. The attenuation of a transmission line increases with frequency so that more power must be supplied to the line at higher frequencies to produce the same input power to the receiver. Some of these points will now be explained.

Transmission Line Theory

The transmission lines commonly used in television consist of two parallel conductors, separated by a distance which is a small fraction of a wavelength. This is the simplest type of transmission line and is known as a balanced transmission line, since neither of the conductors is connected to ground, and are therefore not at ground potential.

When this type of transmission line is considered, it is reasonable to assume that a certain amount of inductance and resistance exist in a transmission line for each short length we consider. It is well known that when the conventional tuned circuit is used at VHF, the inductance required may be nothing more than a short piece of straight wire. This short piece of straight wire will also have its resistance increased by "skin effect" which will be one of the factors determining the "Q" of the circuit.

In like fashion, a certain amount of capacitance will also be present between the conductors, and under certain conditions, there may be leakage between these two conductors. A transmission line may therefore be considered to be composed of a large number of inductances and capacitances, plus any resistances present. In the types of line used in ordinary radio work, these resistances are of such low value that they can often be neglected, except where the transmission line is long. The transmission line is considered to be composed of only inductive and capacitive elements and is then known as a lossless transmission line. A schematic diagram of a lossless line is shown in figure 39A.

When practical transmission lines are considered, certain values of capacitance and inductance must exist along the line. These values will depend mainly upon the diameter and spacing of the conductors. Also, in dealing with VHF, series resistance enters the picture, as shown in figure 39B. Where the transmission line conductors are separated by a dielectric, as in the ordinary 300 ohm line that we are most familiar with, this must also be taken into consideration as the dielectric will add shunt resistance, as shown in figure 39C.

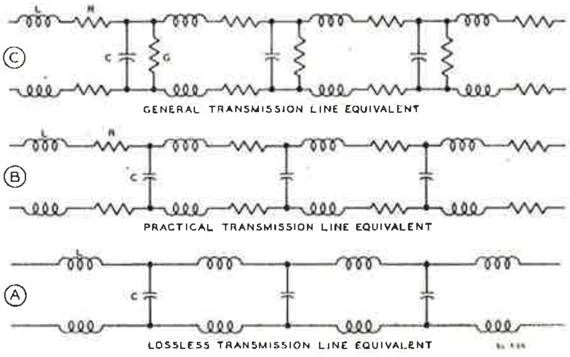


Fig. 39—Transmission Line Electrical Equivalents

It has been determined that if the ratio of the inductance to capacitance in a transmission line is fixed, the square root of this ratio will give us a factor which we call the characteristic impedance of the transmission line. Expressed in the form of an equation:

$$Z_c = \sqrt{\frac{L}{C}}$$

where Z_c is the characteristic impedance, L the inductance, and C the capacitance.

This value is extremely important and the transmission line is generally known by its characteristic impedance, such as 600 ohm, 300 ohm, 72 ohm, and so forth. The diameter of the conductors, the spacing between conductors, and the dielectric material are the main contributing elements in determining the characteristic impedance.

The characteristic impedance of a particular type of transmission line is a property of the line itself and does not depend on the length of the line. The characteristic impedance of a twelve inch length of line is exactly the same as that for a twelve mile length.

Propagation Constant

Another very important factor used when dealing with transmission line is its propagation constant. This may be determined by taking the square root of the product of the inductance and capacitance. Expressing this in the form of an equation:

$$K = \sqrt{LC}$$

The value of "K" above is often referred to as the propagation constant, and determines the relative values of voltage and current that exist on the line and the amount of attenuation in the line for each unit length. By means of this constant the transmission line length for a wavelength, and the amount of attenuation that takes place, can be determined.

The practical effect of propagation constant is shown in figure 40. This same concept can also be applied to antennas. Briefly, when an electromagnetic wave travels through a medium with a density different from that of air or vacuum, its velocity of propagation is decreased, which means that a wavelength as measured on a conductor or other material will be different from that in air. Generally, this difference is expressed as a fraction of the wavelength in air. For transmission lines, of course, this depends upon the conductor size and spacing. For antennas, the difference is mainly dependent upon the ratio of length to diameter. The lower this ratio, the shorter the antenna need be for self-resonance. Figure 40 therefore indicates that the propagation constant must be considered when it is desired to determine the length of a half wavelength antenna or a stub.

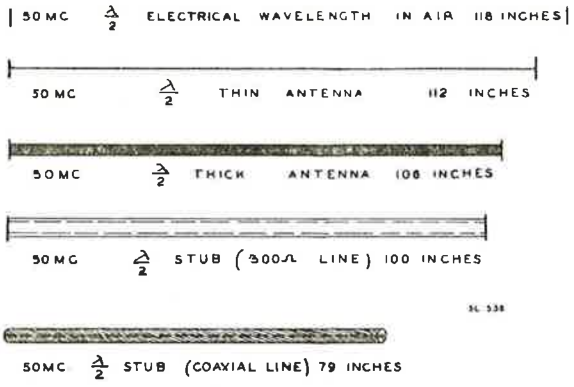


Fig. 40—Propagation Velocity Effects

A coaxial stub for the same frequency will be shorter in length than a 300 ohm balanced stub. Care should therefore be exercised in making stubs to insure that the correct length is obtained. A discussion on stubs appears later.

Matching Transmission Lines

If a transmission line is connected to a source of voltage, and a load equal to the characteristic impedance is placed at the other end, power from the generator will be absorbed by the load. In this case, the voltage and current on the transmission line will vary smoothly and the line is said to be terminated in its characteristic impedance. Transmission lines operated in this manner are known as non-resonant lines and are often called "flat" lines.

In the case of television receivers, the antenna can be regarded as the generator and the television receiver as the load. This analogy is shown in figure 41. In the special case where the source of voltage has an impedance or resistance equal to the characteristic impedance, a maximum amount of power will be transferred. This is important when it is desired to obtain the maximum signal at the receiver from the antenna. Other conditions will exist when the transmission line is not terminated in its characteristic impedance.

As an example, consider a 300 ohm transmission line terminated by a 100 ohm resistor. It has been found that the resistor will not absorb all of the energy being transferred by the line, and this excess energy will be reflected back to the generator. This reflected energy then affects the voltage and current on the line so that between the generator and load, several voltage and current maximums and minimums will exist, depending upon the length of the line. These variations, when plotted on a graph, appear very much like sine waveforms and are known as standing waves. These variations lead to a greater loss in the line itself and also cause a poor transfer of power, except at certain critical lengths of transmission line. It is for this reason that some television antenna installations give better results when the transmission line is cut to a certain length. However, this critical length varies with frequency and at some frequencies, little or no power may be transferred.

The effective transmission line lead length can also be altered by "tuning" the line. This can be done in a practical manner by sliding a piece of tinfoil along the line until a point is found where the voltage developed for a particular station is a maximum. This may be a simple method of improving results on a weak station. This method is shown in figure 42. The fact that a point can be found where the voltage is increased indicates that the line is not terminated in its characteristic impedance.

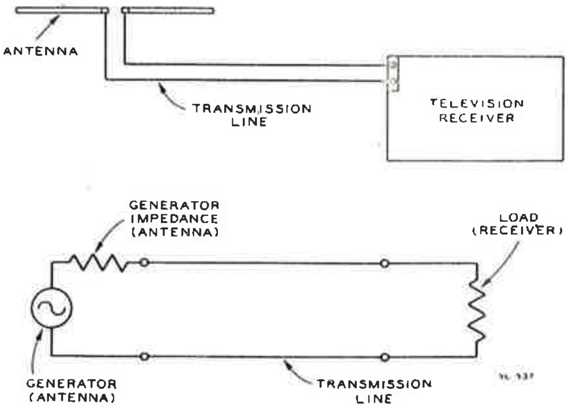


Fig. 41—Generator and Load Analogy

There is another desirable reason for matching transmission lines, especially at the receiver. It is known that if the receiver is poorly matched, transmission line reflections may result and appear as ghosts in the picture. If the receiver does not match the line either capacitive or inductive reactance will be reflected back to the antenna. The effect would be

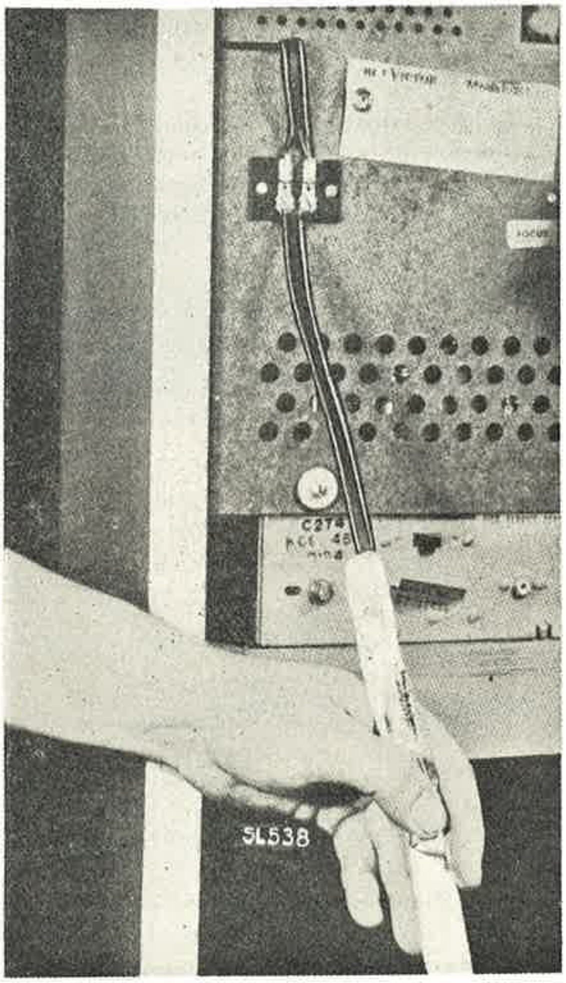


Fig. 42—"Tuning" Transmission Line

to detune the antenna which would be serious for a single band high gain antenna but there would be little effect on a broad band type. Optimum performance of the antenna will be attained when the receiver is matched to the line.

Types of Transmission Line

There are four major types of transmission line now in use, as shown in figure 43. It may be found that one type of transmission line is better suited to a specific application than another. These four types of transmission line will be discussed separately.

RCA Bright Picture Wire (300 ohm Balanced Line)

This type is the most commonly used television transmission line, and has proved very suitable for the majority of installations. The conductors are generally made of stranded copper wire, and are spaced approximately ⅜″ apart. These conductors are molded in a flexible plastic, giving the entire line convenient flexibility. The light weight of this line makes it easy to support. The characteristic impedance is 288 ohms, although it is generally referred to as 300 ohm line.

The choice of 300 ohms for a standard transmission line was made after a study of many factors including the characteristics of the common dipole antenna. It has been said before that the impedance of a simple dipole varies with frequency. 300 ohms is approximately a mean value of impedance of a dipole antenna over its normal operating range. Actually there are four points at which the impedance reaches 300 ohms between 50 and 200 megacycles. See figure 12. This termination of a simple dipole antenna permits a wide bandwidth to be obtained.

When using a folded dipole this line is almost an exact match at fundamental resonance. In using the 300 ohm line with a folded dipole, it is expected that while more gain will be obtained, over some television channels, the bandwidth of this antenna will be poorer than that of the simple dipole.

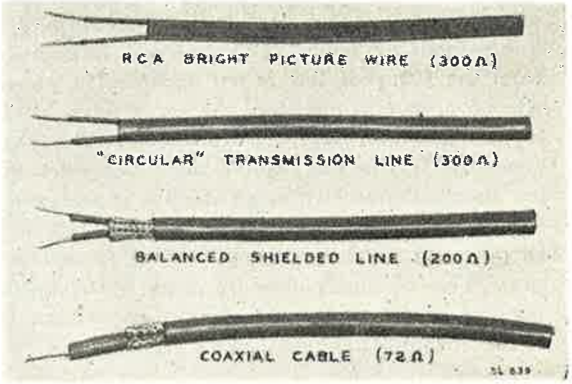


Fig. 43—Transmission Line Types

RCA Bright Picture wire has a low attenuation value and should be used on all installations, except where extra shielding from noise pickup is required.

A table is shown in the Appendix that includes the average attenuation values for the various types of transmission lines. It will be found that 300 ohm balanced line has the lowest attenuation value of the commonly used lines.

Heavy Duty and Special Twin Lead Types

In some applications, and especially where the line may be exposed to mechanical damage, transmission lines similar to the above type, but with thicker dielectric are used. The same characteristic impedance is maintained, and the line is electrically the same as the line mentioned previously. This heavy duty line usually has decreased losses because larger diameter conductors are used. It is more expensive and has less flexibility in handling than the standard 300 ohm line. Its use, therefore, is usually limited to special installations.

Another type of line that has been used in special applications is the "circular" twin lead transmission line. The dielectric is molded in the form of a hollow tube, with the conductors embedded in opposite sides of the tube. Deposits of salt or soot may affect the performance of ordinary line by increasing the dielectric loss between the conductors. Circular line is somewhat free from this type of trouble because of the effective air spacing between the conductors.

A precaution that must be observed when using this type of transmission line is the sealing of the line at the antenna end. This can be done by applying heat to the plastic dielectric until a good seal is obtained. If this is not done, the hollow tubing will allow rain to enter, increasing the attenuation losses.

Balanced Shielded Transmission Line

This type of line is now in wide use. This line has two parallel conductors which are surrounded by a braided shield, thus making the line less susceptible to noise pickup. The characteristic impedance of this line is about 200 ohms. This difference in impedance from the 300 ohm line is not apparent in practical television installations since the variation in receiver input impedance may be of this order. This line is somewhat heavier and requires more care when making an installation. Although the line is protected by an outer covering, it is open at the ends and should be protected from moisture by sealing or taping the ends. This is usually done by using water repellent plastic tape. A suggested method of sealing this type of line is shown in figure 2 in the Appendix.

This line may be used with the average television receiver of 300 ohm input impedance without requiring the use of matching transformers. This greatly simplifies the installation compared to a coaxial line installation. The attenuation is increased somewhat compared to 300 ohm balanced line.

Coaxial Line

This type of line has only one inner conductor which is completely enclosed by the shield, or outer conductor. This is the major difference between coaxial line and the balanced shielded line. The coaxial line carries signal currents on the outer surface of the inner conductor and on the inner surface of the outer conductor, or shield. More care therefore must be used when working with the braided shield of coaxial lines than with the braided shield of the balanced shielded line.

A wide variety of coaxial cables is available, differing in both mechanical and electrical properties. Coaxial lines are generally available in impedances of 50 to 100 ohms. The 72 ohm coaxial line is commonly used in television applications. The nominal attenuation characteristics of different types of coaxial line are shown in the Appendix. Coaxial lines have greater attenuation than other types of lines discussed.

Trifilar Matching Transformers

One disadvantage of coaxial cable for television application is the fact that it is an unbalanced line. Most television receiver inputs are balanced, and for proper operation, a dipole antenna also requires a balanced feed system.

A balanced condition can be obtained by the use of a trifilar matching transformer. A transformer of this type is shown in figure 44. Trifilars have three windings which are interwound on the same core, which is important to obtain proper balance of the output voltages. The windings and turns are so arranged that a match is obtained between a 75 ohm unbalanced line and a 300 ohm balanced line. These transformers can be used at the receiver terminals to match the coaxial line to the receiver, or can be used at the antenna to provide a 300 ohm balanced input which purposely mismatches the antenna to provide wide band characteristics.

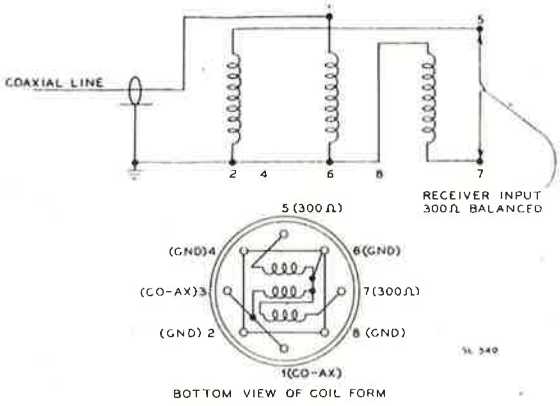


Fig. 44—Schematic of Trifilar Transformer

Antenna Transformer

Current RCA Victor television receivers incorporate an antenna input circuit that will properly match a 72 or 300 ohm transmission line. The signal is fed to the receiver through the antenna transformer, sometimes referred to as the elevator transformer. Although the name transformer describes the action that takes place, an elevator transformer can be considered to consist of two 150 ohm transmission lines, each line coiled up on a separate form. Actually, to obtain either a 72 or 300 ohm input, the coils in the transformer are connected in "series" or "parallel". The change of connections is made in the antenna input plug. The transformer is shown in figure 45, the schematic and plug connections in figure 46.

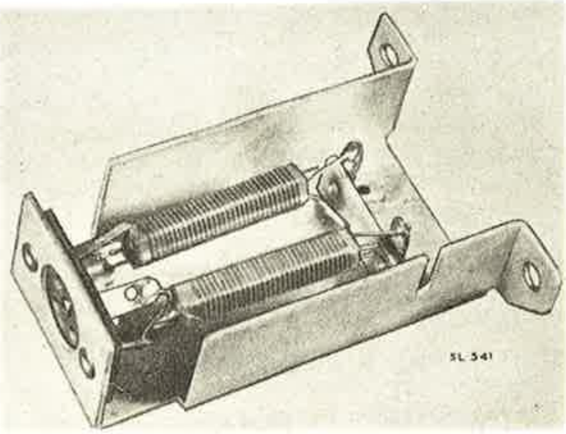


Fig. 45—Elevator Transformer

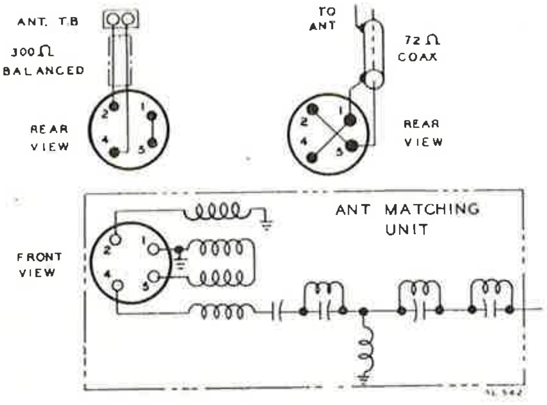


Fig 46—Antenna Input Connections—RCA Victor Receivers

Stubs for Attenuation, Phasing and Impedance Matching

Short lengths of transmission line are often used for special purposes such as matching the impedances of a transmission line and antenna, suppressing interference by tuned stubs, and many other purposes. Generally, these lengths of transmission line need be only a half wavelength long, or less, since a transmission line repeats its characteristics every half wavelength.

Half-Wavelength Stubs

A half wavelength section of transmission line is often used in attenuator stub applications. The length of the transmission line stub is determined mainly by the frequency at which it is to be used and the propagation factor of the line. Practically, the influence of surrounding objects may make a slight difference in the exact length used.

If one end of the half wavelength stub is shorted, a "short" is reflected to the other end of the line at the frequency for which the stub was cut. In effect, a series resonant circuit is present which can be placed across another transmission line and thus attenuate signals at the undesired frequency. This type of stub is valuable for R-F interference suppression purposes.

When the half wavelength transmission line stub is terminated in an impedance, this same impedance is reflected to the transmission line input terminals at the stub frequency, as shown in figure 47 "A" and "B".

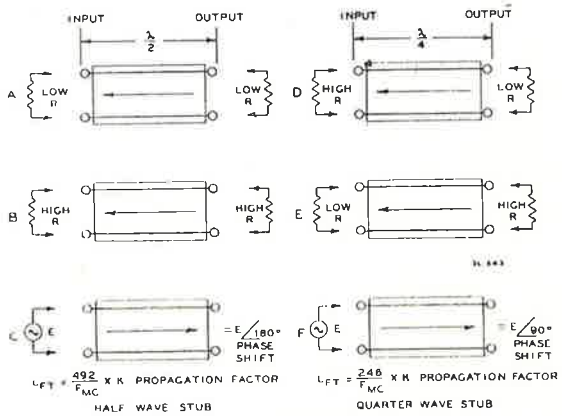


Fig. 47—Matching and Phasing Stubs

Thus, if a 100 ohm resistor were placed across one end of a half wavelength stub which was cut to 50 mc., the stub input impedance would appear as 100 ohms at 50 mc. and also at multiples of 50 mc. in frequency where an even number of half wavelengths would be present.

Half Wavelength Stub Phase Inverters

This application of half wavelength stubs is especially important in stacked antenna arrays. When a voltage is applied to one end of a half wavelength stub, this same voltage appears at the other end, but with its phase changed by 180 degrees. (See figure 47 "C".) Thus the half wavelength line acts much like the phase inverter used in audio amplifier circuits but with the exception that no voltage step-up is obtained. This type of stub finds wide application in stacked in-phase arrays which are fed from one of the dipole elements. Since it is desired to have the adjacent dipole in phase, a half wavelength of transmission line is used which is given a half twist mechanically and is then connected to the adjacent dipole. Thus, the transmission line is now effectively at a phase angle of 360 degrees, which gives the same result as if a full wavelength line were used. The physical length of half wavelength stubs for television applications are given in chart form in the Appendix.

Quarter Wavelength Stubs

Quarter wavelength stubs can also be used for interference suppression and attenuating purposes. In this case, the stubs are only half as long as those previously mentioned. The stub is left open at one end and the terminals of the other end are connected to the circuit where it will be used. A series resonant circuit is effectively formed by the stub, thus shorting the undesired signal. However, the stub must be carefully "pruned" to exactly the right length for maximum attenuation of the undesired signal while it is in the exact physical position it will finally occupy. Otherwise, the best result may not be obtained because of subsequent detuning of the stub in mounting it.

Quarter Wavelength Impedance Inverting Stubs

The quarter wavelength section of transmission line can also be used to match impedances. It is used very commonly between a parasitic array and transmission line where a maximum transfer of power is required at one frequency. The impedance inverting action of a quarter wave stub is expressed by the following formula:

$$Z_s = \sqrt{Z_1 Z_2}$$

where Z_s = stub impedance
Z_1 = input impedance
Z_2 = output impedance

For example, to determine the correct impedance of a matching section between a 75 ohm antenna and a 300 ohm line

$$Z_s = \sqrt{75 \times 300} = \sqrt{22500} = 150 \text{ ohms}$$

A stub for this purpose can be made by paralleling two quarter wave sections of 300 ohm line.

The quarter wave stub can therefore be used to match antenna and transmission lines. If an impedance less than the characteristic impedance of the line is connected to one end of a quarter wavelength stub, a higher impedance than the characteristic impedance will appear at the opposite end of the line. Conversely, if an impedance higher than the characteristic impedance is connected at one end, a lower impedance than the characteristic impedance will appear at the opposite end. This is shown in figure 47 "D" and "E".

When quarter wave stubs are used for impedance matching it should be realized that these conditions hold only for the frequency for which the stubs are cut. The length of quarter wave stubs for various television frequencies is shown in chart form in the Appendix.

Shorted Stubs

A quarter wave section of transmission line at resonance acts as a parallel tuned circuit. At frequencies below resonance, it acts as an inductance and at higher frequencies it acts as a capacity up to where it appears as a half wave section. It then acts as a series tuned circuit. This is shown in figure 48.

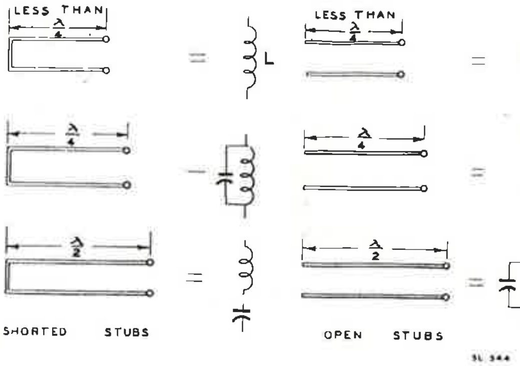


Fig. 48—Transmission Line Stubs

Open Stubs

A quarter wave open stub acts as a series tuned circuit at resonance. At a lower frequency it appears as a capacity. It appears as an inductance as the frequency is increased until at twice the quarter wave frequency, the section acts as a parallel tuned circuit.

Practical Applications of Matching and Phasing Stubs RCA High-Low Antenna

In figure 49 is shown the schematic diagram of the coupling harness used with the RCA High-Low Antenna. Several stubs are used in decoupling the high band antenna from the low band antenna. If this were not done, one antenna would be effectively loaded by the other antenna. The two antennas, by using these stubs, may be oriented independently without serious interaction between the separate antenna elements.

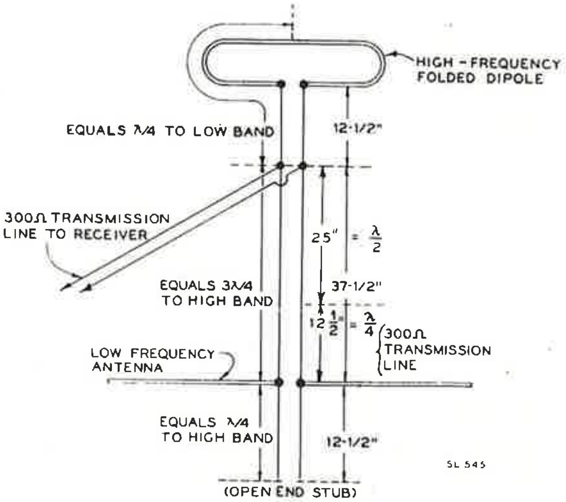


Fig. 49—Stubs in RCA High-Low Antenna

Operation of the high frequency folded dipole will be explained first. It will be seen that a 12½ inch quarter wavelength open stub is connected to the terminals of the low frequency antenna. This stub effectively short circuits the low frequency antenna for the high band frequencies. The effect is as if the low antenna were removed from the system. Another quarter wavelength stub is then connected to the terminals of the low frequency dipole. This then effectively forms a high impedance parallel tuned circuit for the high band. If the high band folded dipole were connected at this point, it would be decoupled satisfactorily by the transmission line, but overall performance would be affected by the close physical proximity of the low band antenna. To maintain the above conditions, and also increase the physical spacing between elements, a half wavelength of line is added to the quarter wavelength mentioned above. This still maintains the parallel tuned circuit effect and represents the equivalent of three quarter wavelengths to the high band. This length of line then becomes 37½ inches and is the point to which the transmission line is connected.

For operation on the low band, the high frequency folded dipole may be considered as a shorted stub. Enough 300 ohm line is added to the high band antenna between the folded dipole and the transmission line connection point to make a quarter wavelength shorted stub broadly resonant in the low band. The additional length of line required is 12½ inches. The high frequency folded dipole is then electrically decoupled when low frequency signals are being received. In effect, the advantages of two separate antennas are obtained with one transmission line. This system of coupling high and low band antennas is an RCA development

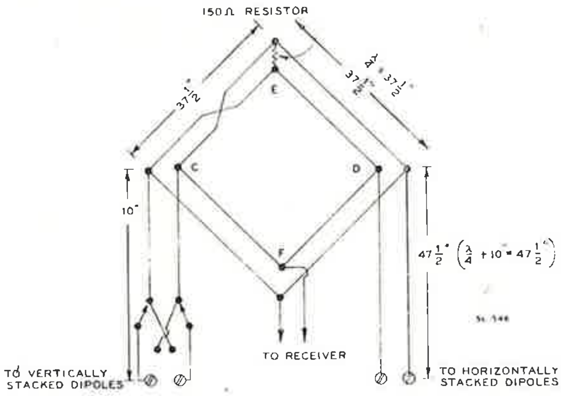


Fig. 50—Reversible-Beam Antenna Diplexer Schematic

Reversible-Beam Diplexer Arrangement

Figure 50 shows a schematic of the diplexer, or mixer arrangement, used with the Reversible-Beam antenna. It is drawn so that its similarity to a bridge is evident. Each leg of the bridge is a quarter wavelength long with the section of line between points "C" and "E" given a half twist physically. The transmission line connected to the horizontally stacked antenna is an extra quarter wavelength long, compared to that used with the vertical stacked antenna.

The signal arrives at the vertically stacked antenna a quarter wavelength later because of the spacing between the two antennas. The addition of a quarter wavelength of line in the feed line of the horizontally stacked antenna delays the signal sufficiently so that the voltages from each antenna array are in phase when they arrive at the diplexer bridge, at points "C" and "D". These voltages are combined in-phase at point "F", and are fed to the receiver. Because of the half twist in the "C"-"E" leg, the voltages from each antenna arrive out-of-phase at point "E" and therefore cancel. No power is dissipated in the 150 ohm terminating resistor under this condition.

If the receiver input is mismatched, this mismatch will produce undesirable effects on the normal lobe pattern. When a mismatch is present, the diplexer bridge then acts to absorb the reflected power. This is done in the following manner. The reflected power travels to the antenna and then returns to the diplexer bridge. The reflected voltages are now out-of-phase because of the extra quarter wavelength of line in the horizontal leg. These voltages now travel to point "E" where they are in-phase because of the phase reversal caused by the twisted length of transmission line, "C"-"E". The reflected power is then absorbed in the 150 ohm resistor. If reflected power does arrive at the receiver connection it arrives out-of-phase and the voltage components cancel.

The diplexer bridge arms become three quarter wavelengths long during operation of the antenna on the high band. Performance of the bridge is the same as that previously explained for the low bands.

MULTIPLE-RECEIVER ANTENNA SYSTEMS

It is often necessary to use two or more television receivers at the same location. It may be inconvenient to install separate antennas for each receiver under some circumstances, so methods have been developed which permit the connection of two or more television receivers to the same antenna without appreciable interaction. Some of these systems are discussed below.

Non-Amplified Distribution System

This distribution system has found wide use in dealers' showrooms, service benches, and other locations where several receivers may be in use simultaneously. The system shown in figure 51 has the advantage of using only simple resistor networks and can be fabricated at low cost. Usually not more than six receivers are used with this system, since the signal level required then becomes large as the signal must be divided between the receivers. The successful use of this system is therefore restricted to strong signal areas. A schematic of this type of system is shown in figure 52. One junction box is used for the system and one

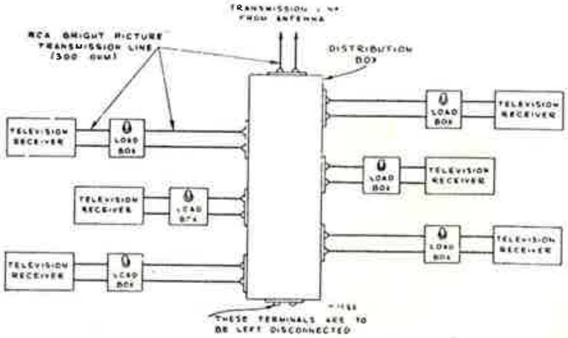
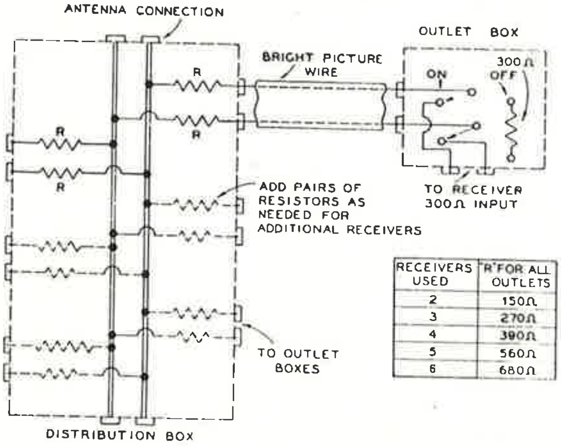


Fig. 51—Non-Amplified Distribution System

outlet box for each television receiver. The antenna lead-in, which should be 300 ohm balanced line, is connected to the junction box. Pairs of resistors up to a maximum of six, are connected to the output terminals. Values of resistors depend on the number of receivers used. Values are given in figure 52. Transmission lines are connected to each of the outlet terminals, and run to the outlet boxes, which should be mounted near the receiver. The transmission line runs from the junction box to the receivers should be separated by a distance of at least six inches.



RECEIVERS USED	'R' FOR ALL OUTLETS
2	150Ω
3	270Ω
4	390Ω
5	560Ω
6	680Ω

Fig. 52—Schematic of Non-Amplified Distribution System

The outlet or load box, as shown in figure 53, contains a D. P. D. T. toggle switch and a 300 ohm resistor. When the receiver is not in use, or is disconnected, the toggle switch should be thrown to the "off" position. This connects the 300 ohm resistor to the line so that it is properly terminated. If this is not done, transmission line reflections may result.

This same system can be also modified so that the toggle switch and 300 ohm resistor are placed in the junction box. This provides a convenient central control for the television receivers where line runs are short.

RCA Antenaplex System

The RCA Antenaplex System, in contrast to the system just mentioned, is capable of supplying a far greater number of receivers with television signals. To do this, amplifiers tuned to each available television channel are used. Amplifiers are also provided for AM and FM reception. The major advantage of the Antenaplex System is that sufficient signal strength can be provided through amplification to supply a large number of receivers.

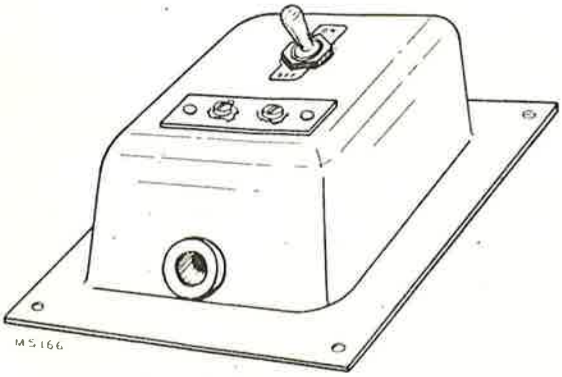


Fig. 53—Outlet or Load Box

A photograph of the RCA SX-8B Antenaplex unit is shown in figure 54. The components are mounted in a cabinet which can be wall mounted, or installed in any other convenient manner. The amplifier units are shown at the top. The power supply is shown mounted in the base of the cabinet.

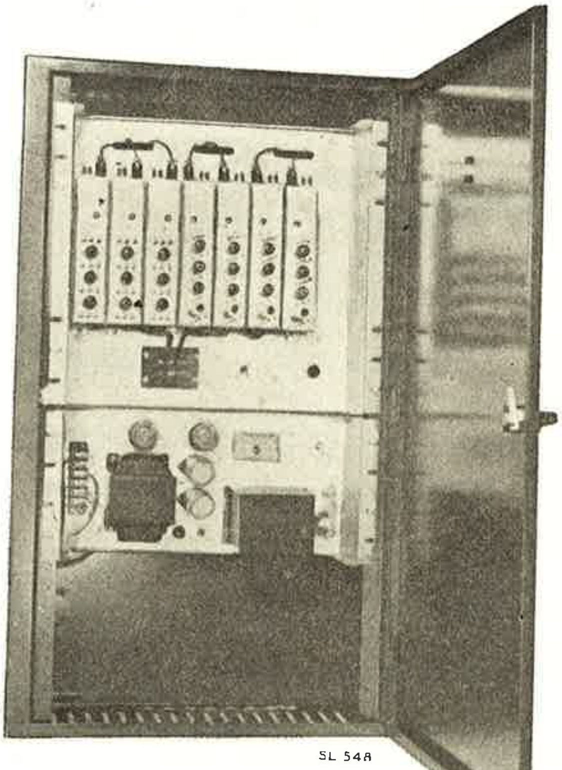


Fig. 54—RCA SX-8B Antenaplex Unit

In order to obtain optimum results, it is evident that each Antenaplex must be a custom built installation, engineered to produce the fullest capabilities of the system. In this sense, each Antenaplex system is a special installation and the particular layout will depend upon many factors, such as: location, distance from the television transmitters, signal-to-noise ratio at the location, number of outlets, building construction, etc. Only the basic elements which enter into such a system will be discussed.

Antennas

A separate antenna for each channel is used, so that the maximum signal-to-noise ratio can be obtained, thus insuring high quality signals. High directivity is also a desirable factor of the antenna, so that in many cases, Yagi-type arrays of the kind shown in figure 30 are used. In good signal-to-noise ratio areas, a folded dipole with reflector cut for the desired channel is sufficient. In order to avoid noise pickup, coaxial cable is generally used, both for the antenna lead-in and for the receiver distribution wiring. Coaxial cable also has the advantage of being mechanically stronger, less susceptible to moisture, may be installed in conduit, and grounded directly for maximum protection against lightning.

Amplifiers

The antennas are connected to separate amplifier units. As stated before, amplifiers are used for each available channel so that the necessary output can be obtained. In many cases, FM and broadcast outputs are required. Separate antennas and amplifiers are used for these channels. Each amplifier is capable of supplying a number of receivers. The outputs are fed into a mixing arrangement so that the desired signals can be fed over a common cable. A gain control is provided on each amplifier so that the output level can be equalized. The amplifiers used are constructed on a small sub-chassis, which can be inserted or removed from the main chassis.

Distribution Networks

Distribution of the signals may be accomplished in two ways. These methods are known as transformer distribution and bridging distribution. In large installations a combination is used.

In the transformer distribution type, an elevator type transformer is connected to the combined output of the amplifiers which have an output impedance of 72 ohms. The transformer has four 72 ohm outputs. These four outputs are connected to four more elevator transformers, each with four outlets, so that a total of sixteen outputs are now available. This process can be continued to the limit of the amplifier output.

In the bridging system, one elevator transformer is used as described above, but its four outlets are fed to 72 ohm cables. The 72 ohm cables are terminated at their ends, and the desired receiver inputs are bridged across the cable through isolating resistors.

Outlets and Receiver Connections

The outputs of the distribution systems mentioned above are fed to wall boxes, to which the receiver antenna terminals are connected. These wall boxes contain high pass filters, which prevent AM broadcast signals from entering the television receiver. The AM signals are fed to a separate terminal for broadcast band reception. The outputs provided are 72 ohms unbalanced. Television receivers which have this input impedance, or which can be wired to provide this impedance, can be used without additional equipment. However, if the receiver has only a 300 ohm balanced input circuit, a trifilar matching transformer, which was described under "Transmission Lines" in this lecture, is used. Its only purpose is to match the receiver to the Antenaplex outlet network.

From the preceding discussion, it can be seen that satisfactory methods and equipment have been developed which permit the connection of a large number of television receivers to a single antenna for any one channel. The systems described are finding increased application with the growth of television and in most cases, provide the only practical solution to satisfactory reception from a large number of receivers which may be located only a few feet distant such as in large apartment houses, etc.

This article will be concluded in September Radiotronics, when TV receiver installation techniques will be dealt with.

Later issues will give a step-by-step description of a typical TV receiver.

New RCA Releases

The new **Radiotron 7JP1** is a 7-inch cathode-ray tube of the electrostatic focus and deflection type designed to provide exceptional brightness when operated with an anode-No. 2 voltage near the maximum of 6000 volts, and good brightness at anode-No. 2 voltages as low as 1500-2000 volts. Intended for general oscillographic applications, the 7JP1 has a small, brilliant focused spot and high deflection sensitivity for its relatively short length. The screen is of the medium persistence, green-fluorescence type and provides high contrast.

The 7JP1 utilizes an electron gun which has a grid-No. 2 operated at anode-No. 2 potential so that the beam current and grid-No. 1 cutoff voltage will not be affected by focusing adjustment. The gun also has an anode-No. 1 which takes negligible current. As a result of these features, the spot can be sharply focused, on the screen and remains sharp when beam current is varied over a wide range. The very small anode-No. 1 current permits the use of a low-current voltage-divider system.

Other features of the 7JP1 include (1) a bulb face with minimum curvature consistent with bulb-strength requirements, (2) separate base-pin connections for each of the four deflecting electrodes, (3) balanced deflecting-electrode input capacitances, (4) full screen deflection with either pair of deflecting electrodes, and (5) a large diameter neck with medium-shell diheptal base which not only provides the required insulation so that the high-voltage electrodes can have base-pin terminals but also permits reduction and better balancing of capacitances.

The 7JPI is especially suitable for use in balanced electrostatic-deflection circuits and gives best definition when so used. However, the 7JP1 may be used with unbalanced deflection because of design features which minimize spot and pattern distortion, effects characteristic of such operation.

Radiotron 2J50 is a magnetron of the internal-resonant-circuit type intended for pulsed oscillator service, such as radar, at a fixed frequency of 8825 megacycles per second. It has a maximum peak power input rating of 260 kilowatts. When operated with a peak anode voltage of 12000 volts, the 2J50 is capable of giving a peak power output of 45 kilowatts at a duty factor of 0.001.

The output circuit of the 2J50 consists of a loop joined to a coaxial line feeding into a matched junction to a wave guide terminated in a standard wave-guide coupler. This circuit is designed to withstand electrical breakdown at the reduced pressures associated with high-altitude operation. Furthermore, the performance of the circuit is not affected by the small variations in operating frequency from tube to tube and by changes in operating frequency resulting from variations in the load. The wave-guide flange and the mounting flange are made so as to permit use of the 2J50 in applications in which a pressure seal is required.

A new Radiotron 7-inch cathode-ray tube has been introduced particularly for use in portable monitor equipment. Designated as **the 7QP4**, this new tube supersedes the 7CP4 for use in the design of new equipment.

The 7QP4 has a high-efficiency, white fluorescent screen on a relatively flat face. Utilizing magnetic focus and magnetic deflection, this new kinescope provides pictures having high brightness and improved focus over the whole picture area.

A rounded-end picture $6\frac{1}{4}''$ x $4\frac{11}{16}''$ is obtained by utilizing the full-screen diameter; or a rectangular picture $5\frac{3}{8}''$ x $4''$ with rounded corners is obtained within the minimum-useful-screen area.

Other features of the 7QP4 include large screen area in relation to tube diameter; an ion-trap gun requiring only a single-field, external magnet; and a small-shell duodecal 5-pin base.

Radiotron 17CP4 is a new short, directly viewed picture tube of the metal-shell type for use in television receivers. It has a picture area $14\frac{5}{8}''$ x $11''$ with slightly curved sides and rounded corners—a shape that provides a very pleasing frame for the picture.

The rectangular shape, which allows reproduction of the transmitted picture without waste of screen area, permits use of a cabinet having about 20 per cent. less height than is required for a round-face tube having the same picture width. Consequently, the volume as well as the cost of the cabinet can be substantially decreased and its styling can be executed to give a more pleasing frontal area. In addition, the chassis need not be depressed or cut out under the face of the tube and controls can be located as desired beneath the tube.

Use of the metal shell not only makes practical a construction which weighs substantially less than a similar all-glass tube, but also makes practical the use of a higher-quality face plate than is commonly used on all-glass tubes.

The 17CP4 with its design-centre maximum anode-voltage rating of 16 kilovolts, provides pictures having high brightness and good uniformity of focus over the whole picture area. It has a high-efficiency, white fluorescent screen on a relatively flat, high-quality face made of frosted Filterglass to prevent reflection of bright objects in the room and to provide increased picture contrast.

Employing magnetic focus and magnetic deflection, the 17CP4 features an improved design of funnel-to-neck section which facilitates centreing of the yoke on the neck and, in combination with better centreing of the beam inside the neck, contributes to the good uniformity of focus over the entire picture area. The diagonal deflection angle is 70° and the horizontal deflection angle is 66°.

Other features incorporated in the 17CP4 are short overall length and an ion-trap gun which requires only a single-field, external magnet.