Antennas For Television*

Part IV—Excellent reception may be had from the simple dipole provided it is made and matched to the line correctly

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A SIMPLE antenna properly cut, positioned, oriented, and matched will equal or surpass in performance many of the elaborate arrays now so prevalent. Elaborate antennas do give additional gain and noise rejection, but the antenna type is not the only important factor in reception.

There are many locations in which a very basic antenna with its simplicity, ease of erection, and lower cost will serve. The simple antenna is much easier to support and it can be mounted high and clear—an increase in antenna height being more effective than the addition of an element.

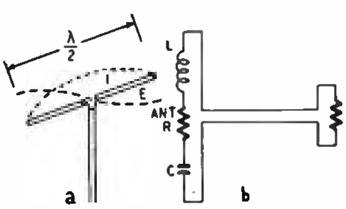

Fig. 1—Actual and equivalent dipole circuits.

For optimum performance from any type of antenna these points must be considered:

1. Correct antenna matching. To obtain maximum transfer of signal, it is vitally important that the transmission line match the receiver input, for it is this point from which reflections might start. Antenna match to transmission line and correct transmission-line length (or addition of lengthening stub) can give considerable improvement to weak stations, regardless of the type of antenna used. Use a low-loss line, remembering that the longer it is, the greater the attenuation. If any mismatch should be present, it will be aggravated by additional length.

2. Antenna positioning and orientation. Ideal performance of any antenna system can be expected only if that antenna is oriented and positioned to obtain peak signal from the weakest stations.

Antenna equivalent circuit

The simple half-wave antenna opened and fed at the center (Fig. 1-a) acts as a series resonant circuit, consisting in effect of an inductor and capacitor plus a resistive component (Fig. 1-b). This is similar to the tuned circuit with which the radio serviceman is familiar. Thus, the antenna has a specific resistance and reactance. It is the resistive component which is matched to the transmission line to convey maximum signal along the line to the receiver input. The net reactance increases as the signal departs from the resonant frequency and introduces mismatch and loss, limiting the bandwidth of the antenna. Because bandwidth is an important consideration in television due to the broad band of frequencies which must be received, the ideal television antenna is one with a rather low Q, that is, a high ratio of resistance to either inductive or capacitive reactance at resonance. This can be obtained by using an antenna with a relatively large surface area or effective surface area (antenna with a number of fanned elements).

A series resonant circuit also has resonant characteristics at harmonic frequencies. For this reason an antenna can also be made sensitive on harmonically related frequencies. For example, an antenna a half-wavelength long and fed at the center at a current maximum can also have sensitivity at the third and higher odd harmonics (Fig. 2). It becomes a three-half-wavelength antenna at the third harmonic, and point of feed is again a current maximum.

Experimental procedure

Extensive tests on both simple and elaborate antennas were undertaken

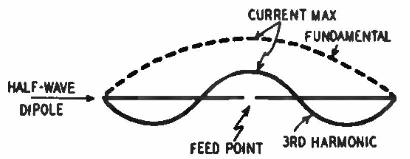

Fig. 2—Reason for third-harmonic reception.

with these considerations in mind. In the tests, the paramount factor was always "How was the picture on the screen of the television receiver affected? Was the change for a given test so small as to be insignificant, or was it worthy of serious consideration because of its effect on performance?"

In making the checks on different types of antennas, accuracy and uniformity were obtained by positioning each antenna in a space loop of the same station. One hundred feet of 300-ohm transmission line was used between antenna and receiver. Much of the research was made at a test site near Trenton, N. J., using the signals from the three Philadelphia television stations approximately 30 air-line miles from Trenton. Thus the checks were made near the fringe area of the stations, where antenna performance is of great significance. At the same time

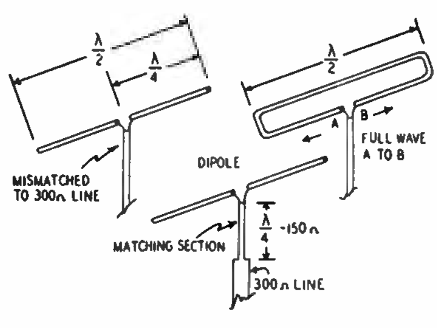

Fig. 3—Two ways of matching to 300-ohm line.

long-range checks were made on the New York stations approximately 60 air-line miles from Trenton. Special checks were also made in many other areas to verify results obtained at the major test site.

In testing antenna performance, a folded dipole was used as a standard antenna because it conveniently matches a 300-ohm line, which in turn matches the 300-ohm input of television receivers.

Simple dipole antenna

A simple dipole (Fig. 3) proved usable at this distance when mismatched to a 300-ohm line. Height of antenna, orientation, and positioning in a space

*From a forthcoming book: "Reference Guide for Television Antennas."

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loop were of major importance, proving more effective in bettering antenna system performance than the addition of a reflector or stacking antenna elements. Of course, the erection of a higher-gain antenna at this optimum position resulted in a further improvement, but not so much.

Fig. 4—Hand-held antenna used for testing.

As the diameter of the dipole elements was increased, not only was there a perceptible increase in signal strength, but also an increase in bandwidth. This made the dipole antenna cut for the lower-channel stations quite effective for the high-band stations. A minimum recommended diameter for a dipole element is ½ inch.

A dipole antenna mismatched to a 300-ohm line gave inferior performance on all channels compared to a folded dipole. However, with a quarter-wave matching section between the 73-ohm dipole and the 300-ohm line, the signal strength came up to a level not much different from that delivered by the standard folded dipole.

The matching section consists of quarter-wavelength of line attached between antenna and transmission line.

In calculating the necessary impedance Z_m of the line used for the matching section,

$$Z_m = \sqrt{R_a Z_o} \ ,$$

where R_a is the antenna's radiation resistance and Z_o is the impedance of the main transmission line. Thus, to match a 73-ohm dipole to a 300-ohm line requires a quarter-wave section of 150-ohm line. Its length should be slightly shorter than a quarter-wave in free space; it is found by multiplying the free-space figure by the velocity constant of the 150-ohm line, usually available from the manufacturer.

The mismatched dipole does have a low Q and therefore a broad bandwidth. However, it was found that that is not always desirable. It is often helpful to be able to improve sensitivity on one or more stations at a sacrifice in bandwidth. For example, in a specific check a dipole was cut for channel 3 and a quarter-wave matching section was also cut to match this antenna to a 300-ohm line. Reception was appreciably improved on channel 3. The signal was no poorer on channel 6 than with the same dipole mismatched to a 300-ohm line. On channel 10 there was a perceptible improvement compared to the same dipole previously mismatched to a 300-ohm line. Obviously, then, a matching section in conjunction with the dipole will improve performance on a weak station without detracting from the signal of a stronger station.

It is, of course, possible to match a simple dipole to a co-axial line; but as attenuation of co-ax cable line is considerable and it does not match standard receiver inputs, a definitely weaker signal results.

Harmonic relations

A dipole or folded-dipole antenna cut for a specific channel has a certain bandwidth and has appreciable sensitivity at odd harmonics. For example, a folded dipole cut for channel 3 gave satisfactory performance on channel 6. On channel 10 which is approximately the third harmonic of channel 3, sensitivity was excellent, in fact, equal to that which could be obtained from a folded dipole cut for channel 10. Thus it seems sensible and possible in most locations to cut a single antenna for some point

TABLE I

Channel	Channel Limits (mc)	Length (in inches of each half of dipole	Folded dipole (full length, in inches before folding)	¼-wave matching section	3rd harmonic channels:
2	54-60	48.6	207	40	7
3	60-66	44	181	36	8, 9, 10
4	66-72	40	166	33	11, 12, 13
5	76-82	35	145	29	
6	82-88	32.6	134	27	
7	174-180	15.6	64.7	12.9	
8	180-186	15.1	62.6	12.5	
9	186-192	14.6	60.6	12.1	
10	192-198	14.2	58.7	11.7	
11	198-204	13.8	57	11.4	
12	204-210	13.4	55.3	11.1	
13	210-216	13	53.8	10.8	

in the low band and have that same antenna perform very well on the high-frequency channels.

An antenna cut for any of the high-band channels, however, will give definitely inferior performance on the low-frequency channels. In most localities, therefore, a very simple antenna will suffice for reception of all stations if the antenna is properly cut and positioned for best performance on the weakest station. Performance can be further improved for the weak station by adjusting the length of the transmission line, or by the use of a stub across the antenna input terminals.

Space loop check

A simple folded dipole can be used to locate the space loops of the stations to be received. Most TV antennas and their masts are too cumbersome to carry around a roof. A simple channel 13 folded dipole mounted on a light collapsible mast is the ideal tool for locating the loops for all signals to be received. It is shown in Fig. 4. This antenna, although it certainly cannot give good performance on the low-band stations, does give a positive indication of space loops on all channels. Light in weight and easy to handle, it can be held at a level which approximates the height of the antenna to be installed for the customer.

The antenna is made very simply as can be seen in Fig. 5. It consists of the folded dipole attached directly to the top section of the mast without any insulation. This can be done if the mast is joined to the antenna at the exact center of the unbroken side of the folded dipole since this point is a voltage node or ground point. A small metal standoff is used to hold the antenna away from the mast. The radioman can build it in a few minutes with no difficulty.

Antenna dimension table

To assist the serviceman in choosing correct antenna dimensions, Table I is very helpful. Antenna lengths given have been corrected for end effects (capacitive loading at the ends of the antenna), and quarter-wavelength matching sections have been shortened in accordance with the velocity constant of the usual 150-ohm ribbon line.

To help in choosing a low-band antenna which will have good pickup on the high-band channels because of harmonic relations, the chart also indicates those high-band channels which have a harmonic relation to a low-band channel. The third harmonic is the only harmonic which is significant because other harmonics fall outside the TV channels.

As an example, a dipole for channel 3, with a ½-inch separation at the center where transmission line is attached, would have an over-all length of 88.5 inches. According to the last column, this antenna would also be effective on channels 8, 9, and 10.

In the next article performance comparisons will be given for various antennas with respect to propagation characteristics, including the use of reflectors and directors.

Fig. 5—Close-up shows construction details.