• Beginner and Novice

Choosing An Antenna

BY LEWIS G. McCOY,* W1ICP

As the title indicates, this article is written to help the newcomer decide on the kind of antenna to select for his station. Naturally, it would be impossible in a short article to discuss all the different antennas that could be used, as the number is large. However, several types are more common than others, and these are the ones that will be treated. Constructionally, antennas can be divided into two categories, horizontal and vertical. Let's talk about horizontal antennas first.

As the name implies, a horizontal antenna is one that is more or less parallel to the ground. The commonest form of antenna is a dipole. In amateur radio we usually think of a dipole as being a half wavelength long and fed in the center. Such an antenna is shown at Fig. 1A. It is not planned to overwhelm the reader with math, but there is one simple formula, for the length of a half-wave antenna, that every beginner should know. This is:

$$L\text{ (feet)} = \frac{468}{f\text{ (Mc.)}}.$$

In words, the length of a half-wave antenna in feet is equal to 468 divided by the frequency in megacycles. This formula is used for wire antennas at frequencies up to 30 Mc. For v.h.f. work, the factor generally used is 5540, which gives the answer in inches. That is,

$$L\text{ (inches)} = \frac{5540}{f\text{ (Mc.)}}.$$

The radiation pattern of a half-wave antenna is similar to a figure 8, as shown in Fig. 1B. The maximum radiation is broadside to the axis of the wire, with minimum radiation off the ends of the wire.

Antenna Impedance

There is one more point of importance about a half-wave antenna and that is what the impedance of the antenna is at the feed point. Before going further, let's explain the term "impedance" as it applies to antennas. The feed point of an antenna is where you attach the feeder. This point has certain properties which we have to take into consideration when we wish to put power into the antenna. These properties consist of the following:

1) *Ohmic resistance.* When r.f. energy is fed to an antenna, a certain amount is lost as heat in the wire itself and in any dielectric material in the antenna, such as insulators. This heat loss is due to the ohmic resistance.

2) *Radiation resistance.* This resistance accounts for the r.f. energy that is radiated from the antenna.

3) *Reactance.* Reactance can be expressed as an opposition to the flow of r.f. currents, but without loss of power. It is expressed in ohms, even though you cannot dissipate power in reactance as you can in resistance. These are the properties that go together to make up the impedance of an antenna. In a half-wave antenna the proportion of ohmic resistance to radiation resistance is usually very small, and any losses from ohmic resistance are negligible. If the antenna is resonant or "tuned" to the operating frequency, there will be no reactance present. If an antenna is too long or too short for the frequency, then it will have reactance.

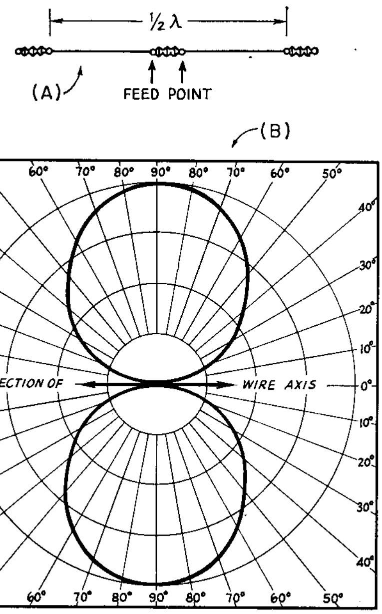

Fig. 1—(A) Diagram of a half-wave antenna. At (B) is the pattern of radiation from a half-wave antenna. The two lobes of radiation are broadside to the antenna axis.

The impedance of a half-wave dipole is approximately 70 ohms. This figure will vary, depending on the height of the antenna above ground. For single-band operation the antenna can be fed with either 50- or 70-ohm coaxial cable or 70-ohm Twin-Lead. Such an antenna is shown in Fig. 2A.

Note the statement above — "for single-band

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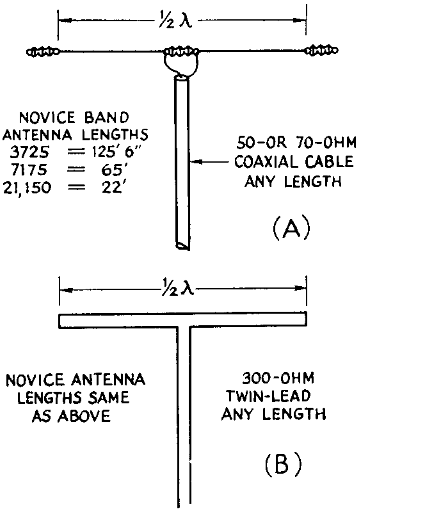


Fig. 2—(A) This drawing shows a coax-fed half-wave antenna. The lengths given are for typical Novice installations. The same lengths apply to (B), the folded dipole antenna. As explained in the text, the folded dipole can be made from 300-ohm Twin-Lead.

operation." When a half-wave antenna is fed with coax, the antenna impedance matches the impedance of the coax fairly well. However, let's see what happens to this antenna when it is operated at twice the frequency. Suppose for a moment that we have a half-wave antenna cut for the 80-meter band. The impedance of the antenna is about 70 ohms. Instead of using the antenna on 80, what happens when we feed a 40-meter signal to it? The antenna is not a half-wave on 40; it is "two half-waves in phase," and the feed-point impedance becomes several thousand ohms. This means that we will have a very bad mismatch between the coax cable and the antenna, which also means that it may prove very difficult to load the amplifier in the transmitter and get power into the antenna.

Standing-Wave Ratio

There is one more point here that should be covered before we can actually discuss different types of antenna — the point is "standing-wave ratio."

The standing-wave ratio on a feed line is determined by the ratio of maximum r.f. voltage on the line to minimum voltage, or maximum to minimum current ratios. If a feed line is terminated in a load matching its characteristic impedance, the standing-wave ratio will be 1 to 1. For example, if we feed a 70-ohm half-wave antenna with 70-ohm coax, the s.w.r. will be 1 to 1 because the antenna impedance matches the line impedance.

However, suppose we use the coax to feed our half-wave antenna at twice the frequency, as in the example of an 80-meter dipole used on 40. Here the impedance is several thousand ohms and the mismatch becomes very large; consequently, a very high s.w.r. results.

Depending on the type of feed line used, a high s.w.r. can or cannot be important. If that statement appears confusing, you'll soon see why. Coaxial cable is a type of feed line that should not be used with a high s.w.r. because a considerable amount of your transmitted power can be lost in the line. When coaxial feed line is used in an installation where the s.w.r. is no more than 2 or 3 to 1 it is usually an excellent line to use, at least for frequencies below 30 Mc. For v.h.f. installations, a low-loss line should be used. However, when the s.w.r. is large, coax should not be used simply because coax is not classed as a *low-loss* line.

On the other hand, there are very-low-loss lines that can be operated with a large s.w.r. with only a negligible amount of power lost in the line. Open-wire feed line is such a line.

You can make your own open-wire line or use one of the commercial types that are available. You'll find that open-wire line is usually listed along with television antenna accessories in the parts catalogs. The line used for TV work is very satisfactory for amateur use.

If you want to build your own, there are a couple of methods for getting job done. E. F. Johnson Co. lists feeder insulators in their catalog. These are available for 2-, 4- or 6-inch separation of the feed-line conductors. Either No. 12 or 14 solid copper wire can be used for the conductors. A good choice is a line with 4- or 6-inch separation. The cost of the line goes up if you use 2-inch insulators, as they have to be installed every couple of feet to keep the conductors from twisting together. The 4- or 6-inch insulators can be used every four or five feet, thereby reducing the cost of the line. Another method is to make your own separators from polystyrene or plastic rod. This material is easy to drill and cut and makes good insulators. (Some hams use plastic hair curlers for insulators; so if your XYL isn't watching, you know what to do!)

Another low-loss line which can be used with a moderately-high s.w.r. is transmitting-type tubular 300-ohm Twin-Lead, such as Amphenol 214-076. This line is also available from most parts distributors. Another type (Amphenol 214-022) has two No. 16 conductors imbedded in a solid polyethylene dielectric with greater width than ordinary TV line. Receiving-type Twin-Lead can be used in low-power installations (75 watts or less). However, be sure when you buy your Twin-Lead that you get a "brand" name. There is some line available at bargain prices, but it is often really no bargain because the dielectric material is made from scrap plastic.

If you do a little thinking about our half-wave antenna you can see that it can be used as a multiband system if you choose the correct type of line. If you are interested in a one-band system with a half-wave antenna, then coax is a good choice. There is one exception where a single coax-fed antenna will work on two bands: A 40-meter half-wave operated on 15 meters will have an impedance close enough to 70 ohms so that the s.w.r. will not be large enough to cause high losses.

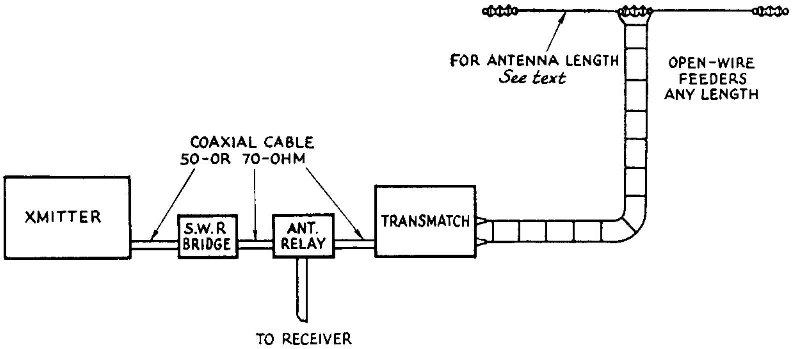


Fig. 3—This drawing shows the complete setup for a multiband antenna installation. The antenna relay or changeover switch should be installed as shown in the drawing, not in the open-wire side of the feeders.

However, for general multiband operation you should use a low-loss line such as the open-wire type.

You can also see that if an open-wire feeder — or any low-loss line — is used to feed a dipole antenna, the impedance of the antenna is no longer of great concern. If we don't have to worry about s.w.r. or matching, then we no longer have to be concerned about having our antenna an exact half-wavelength long. This in turn provides us with a method of making an all-band antenna fit the space available in our location.

A Multiband Antenna

A very simple method for making a multiband antenna is to first measure off the distance between your antenna supports and cut a wire that long. Fold the wire in two, cut it at the center and insert an insulator. Attach open-wire feeders, long enough to reach your shack, at the center. Put insulators on the ends of the antenna and raise it into place.

In order to use the antenna on all bands, you'll need a transmatch[1] at the transmitter. The transmatch is connected to the transmitter via a length of coax line. Such an installation is shown in Fig. 3. With this arrangement, any value of impedance at the transmitter end of the open-wire line can be transformed to 50 or 70 ohms.

Naturally, the reader will ask how short the antenna can be and still be effective on 80 meters, which is the lowest-frequency Novice band and would normally require the longest antenna. The answer is that while the antenna can easily be tuned to 80 meters even if it is very short, the efficiency will be low if the length is much below 60 feet. An antenna approximately 60 feet long will give a good account of itself on 80, and will work even better on the higher bands. Keep in mind, of course, that this is true only if the antenna is fed with open-wire line.

Multiple-Dipole Antenna

For those amateurs that prefer coax feed with multiband operation, a simple antenna is the multiple-dipole type. An antenna of this type is shown in Fig. 4. It consists of two half-wavelength dipoles, one for 80 meters and another for 40. This antenna can be fed with a single length of either 50- or 70-ohm coaxial cable. The system will work on 80, 40, 15 and 10 meters, and no matching network is required. However, it should be pointed out that a Novice should incorporate protection in such a system against radiation of harmonics, particularly the second harmonic, from 80 meters. For details on such protection, see the October, 1961, issue of *QST*.[2]

Folded Dipole

A popular antenna is the "folded dipole." This type is shown in Fig. 2B. There are two basic differences between a folded dipole and an ordinary dipole. First, the feed-point impedance of a half-wave folded dipole is approximately 300 ohms. Second, it has a slightly broader frequency response than a dipole. The folded dipole is a one-band antenna and separate ones are needed for each band.

It is quite easy to make a folded dipole using 300-ohm Twin-Lead for both the antenna and feeders. The antenna length formula is the same as for a dipole. To make one, simply cut a length of Twin-Lead to the antenna length and solder the wires together at both ends. At the center, cut one of the conductors (you must, of course, remove some of the polyethylene insulation) and "skin" back leads for about one inch. Connect your feed line to the two leads, solder, and then tape the joint. You'll need either a transmatch or balun coils to couple the antenna to the transmitter. Balun coils are designed with a 4 to 1 ratio, so using 300-ohm feed line, you would use 70-ohm coax to couple the transmitter to the

[1] McCoy, "A Wide-Range Transmatch," *QST*, November, 1961.

[2] McCoy, "A Novice Three-Band Antenna System," *QST*, October, 1961.

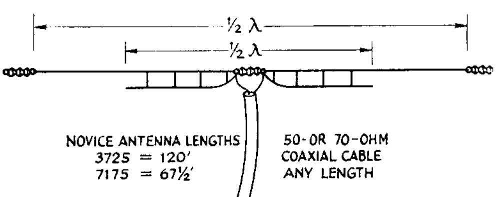


Fig. 4—This sketch shows a coax-fed multiband antenna system. A simple way to make the antenna is to use open-wire feed line of the TV variety. The insulators will keep the two antennas separated so they don't short to each other.

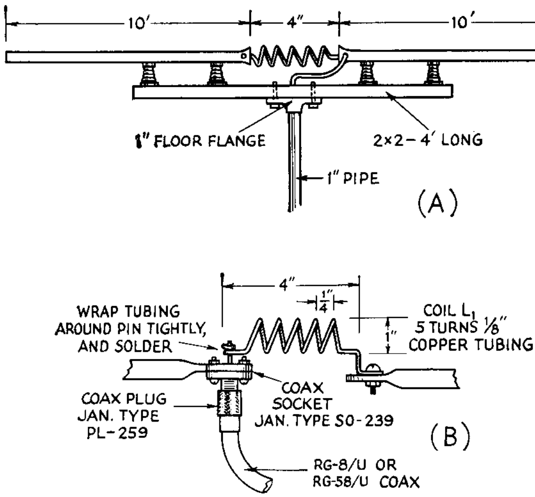


Fig. 5—Here are the constructional details for the 15-meter rotatable dipole, fed with coaxial cable. As shown in the drawing, the coax can be fed either down through the mast pipe, or, if preferred, outside the pipe.

balun. Baluns can be purchased "ready-made." Typical Novice-band antenna lengths are given in Fig. 2.

End-Fed Random Wire

Another popular antenna system is the end-fed wire, which is quite commonly — and often mistakenly — called a "long" wire. This antenna is usually connected directly to the output terminal of the transmitter and no feed line is used. The length of the wire will, of course, depend on the space the user has available. It is difficult to say what the impedance of a random wire is at the end, and in many cases loading of the amplifier in the transmitter may be difficult. If a random-length wire is to be used, it is a good idea also to use a transmatch to provide both matching at the transmitter and reduction of harmonic radiation. With a transmatch, this antenna can usually be made to work on any band, although if the antenna is very short, say, under 30 feet, it may prove difficult to operate on 80 meters. Also, a good earth ground should be connected to the transmitter.

Rotatable Dipole

On the higher bands — 20, 15, and 10 — a dipole is short enough so that it can be made from metal tubing. The tubing can be mounted on a mast and the assembly rotated. This gives you the opportunity to make use of the directivity in such an antenna and you can "beam" your signal in the direction you want. Because the antenna is bidirectional, you only need to rotate it 180 degrees in order to obtain full coverage.

An excellent 15-meter dipole is shown in Fig. 5. Two pieces of electrician's thin-wall steel tubing are used f r the elements. The tubing is ½ inch in diameter, 10 feet long, and is available from any electrical parts house. While a total length of 20 feet is slightly short for 15 meters, the antenna will have an impedance of approximately 50 ohms when tuned to resonance by means of a small loading coil in the center. This antenna offers a good match for 50-ohm coaxial cable, either RG-58/U or RG-8/U.

Fig. 5 is self-explanatory, but just a word about mounting the coax fitting on the antenna. Flatten the element in a vise or with a hammer and this will provide you with a mounting space for the coax fitting. One end of the coil is soldered to inner conductor pin on the coax fitting and the other end of the coil is held in place with a screw and nut. The height of the standoff insulators that support the elements above the 2 × 2 can be 2 to 4 inches, as the dimension is not critical. One convenient method of mounting the antenna is to use TV hardware. Wall stand-offs are available at low cost which will support the mast pipe and antenna. Also, a TV rotator can be used to rotate the antenna.

A Three-Band Rotatable Dipole

If desired, the same element material used in the antenna described above can be used for a

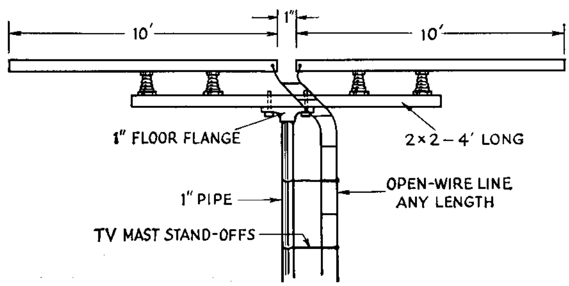
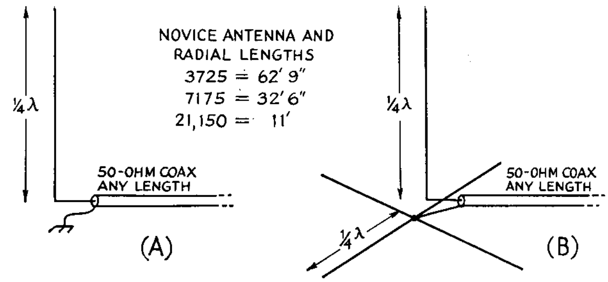


Fig. 6—A rotatable dipole for 20, 15, and 10. Construction details are similar to Fig. 5 with the exception of the feed line and coil at the center of the antenna.

Fig. 7—At (A) is the simplest form of vertical. The ground connection shown at the outer braid should be made to a good earth ground. Shown at (B) is a ground-plane antenna. The four radials are each ¼ wavelength long and connect at the center.



three-band — 20, 15, and 10 meters — rotatable dipole. The entire assembly is the same as Fig. 5 except that the coax feed and coil at the center of the antenna are not used. Open-wire feeders are attached to the dipole as in Fig. 6. The feeders are connected to a transmatch which is used to tune the system to the band in use. Because only 180 degrees rotation is needed for full coverage, there is no problem in keeping the open-wire feeders from shorting to the mast. TV mast stand-offs can be used to hold the open-wire line away from the mast. Leave an extra few feet of feeder length where the line enters the shack. This extra length can be dressed away from the mast so that the line can swing around when the antenna rotates, but doesn't short to the mast.

Incidentally, the feed line can be any length, since all tuning and adjusting is done at the transmatch or antenna coupler. This antenna and its adjustment is essentially the same as the odd-length, center-fed, multiband antenna described earlier (Fig. 3). The main difference here is that you can rotate the dipole, taking advantage of its directivity.

Vertical Antennas

Some amateurs prefer vertical antennas because they take up less space. They have both advantages and disadvantages. On the credit side is the small amount of space required. Also, they are omnidirectional, radiating equally well in all directions. However, a vertical should be mounted in a spot where there are no nearby objects, particularly rain gutters or house wiring, which will detract from their performance. In other words, if you don't have an open field, the antenna should be mounted high, so as to clear nearby objects. Also, a horizontal antenna in its best directions will be better than the omnidirectional radiation from a vertical. A rotatable dipole, for example, can be expected to out-perform a vertical at nearly all times.

The simplest vertical antenna, a radiator ¼ wavelength long, is shown at Fig. 7A. The formula for length in feet is 234 divided by the frequency in megacycles. The impedance at the feed point is somewhere near 30 ohms so the vertical can be fed with 50-ohm coaxial cable and a fairly good match will result.

The antenna can be made from wire and suspended from above, but a better system would be to make the radiator from tubing. This can be either guyed or self-supporting, depending on its height. Mount the mast on a base insulator (a coke bottle makes a good insulator), and connect the inner conductor of the coax to the bottom of the antenna. The outer braid of the coax should be connected to a metal stake or ground rod driven into the ground at the base of the antenna. Like a coax-fed horizontal, such a vertical is essentially a one-band system. The exception is a 40-meter vertical, which can also be used on 15 meters.

Ground-Plane Vertical

One of the troubles with a vertical such as just described is that it may not operate very well with poor ground conditions. A way to get around this problem is to install your own ground system under the vertical. Such an antenna is called a "ground plane" and is shown at Fig. 7B. In this antenna the radiator is supported above at least four "radials." The antenna and each of the radials are ¼ wavelength long. The outer shield of the coax is connected to the junction of the radials. A fairly good antenna will result if the entire system is mounted high above the ground and in the clear. One method of doing the job is to mount the vertical on top of a tower or mast and then use four or more guy wires at the top of the mast. The guys can be of wire and should be ¼ wavelength long. Insulators should be used to separate the radial length from the rest of the guy. Even though the radials will slope downwards, the antenna will still work as a ground plane.

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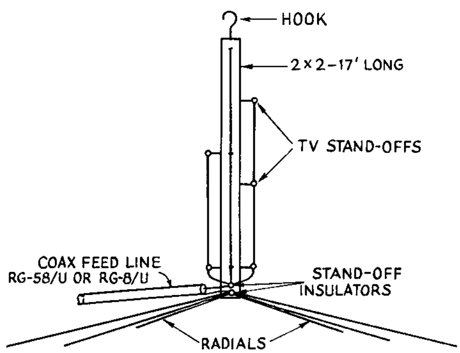

Fig. 8—Drawing of the coax-fed multiband ground plane. As explained in the text the radials are made from four-conductor TV rotator cable. A total of four radials are required for each band. Lengths of the antenna and radials can be determined from the formula given for vertical antennas.

Choosing an Antenna

(*Continued from page 29*)

A Coax-Fed Multiband Ground Plane

Another system that has become quite popular is one described in *QST* by W1TS.[3] This antenna uses a single coax feed line to feed three vertical antennas for 20, 15, and 10 meters, mounted on the sides of a 17-foot long 2 × 2 wood mast. The three wires are connected together at the bottom

[3] Mix, "The Impromptu Ground Plane," *QST*, January, 1959.

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and fed with coax. A hook such as used for clotheslines is screwed into the top of the 2 × 2. The 2 × 2 can then be hung up in a tree or from any overhead support.

In order to make a ground plane for this system you would, of course, need at least four radials for each antenna, or a total of twelve. A simple method of doing the job is to use four-conductor TV rotator cable. Cut four lengths of the cable to a ¼ wavelength on 20 meters (about 16½ feet). Then on each of the cables, strip off enough of each of the conductors to make radials for 15 (11 feet) and 10 (about 8 feet). When completed, you should have a length of cable with a ¼ wavelength radial for 15 and 10 and two wires for 20. The two wires for 20 will provide extra support when you string the radials out. Connect all the wires of all the radials together at the base of the vertical support. This is also where you connect the outer conductor of the coax.

The antennas discussed in this article are just a few of the more common simple types. Multi-element beams and some of the other popular antennas require considerably more discussion than is possible in an article of this type. *The A.R.R.L. Antenna Book* and *The Radio Amateur's Handbook* will give you plenty of additional information. QST