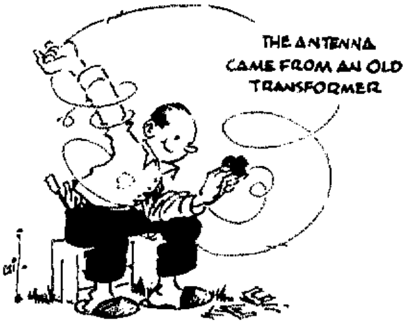
• *Basic Amateur Radio*

Which Antenna to Use?

Many beginners ask the ARRL staff, "What's the best antenna I can put up?" Well, there is no "best" antenna, but here are some pointers for the newcomer.



By Doug DeMaw,* W1FB

"Your *Antenna Book* and the *Handbook* confuse me. They don't tell me which antenna works best," Statements like that are common in letters sent to ARRL Hq. by new amateurs, and understandably so. But, it's a question that has no specific answer because of the many factors that must be considered when making a choice. Generally, the criteria are based on usable property, economics, materials available, operating frequency, attitudes of neighbors, desired communications distance (local or DX) and restrictions and zoning ordinances. All of the foregoing must be considered when selecting an antenna for amateur use. In order to avoid being long-winded in this discussion, let's assume that the following conditions prevail: no restrictions, no problems with neighbors, the house is on a standard city lot, the materials are available locally and we want to work DX and close-in stations. This is a typical scenario for a new radio amateur, and we will key our discussion to this setting of the stage.

Some Basic Requirements

In order for any antenna to perform to the best of its capability it must be as high in the air as possible, and preferably 1/2 wavelength or greater above ground at the chosen operating frequency. Thus, for operation in the 40-meter Novice band (7.1 MHz), our antenna should be 69 feet (21 m) or more above ground. This can be approximated by dividing 492 by the frequency in MHz, or 492/f(MHz), which provides the height in feet. If our 40-meter dipole were only 30 feet (9 m) above ground, it would still work okay, but it would be less useful for DXing. This would be caused by the *angle of radiation* being higher at reduced antenna heights. We can understand this phenomenon by referring to Fig. 1. The outgoing wave from an antenna strikes the ionosphere obliquely and reflects back to earth. This might be compared to a pool shot, where the ball is banked. Therefore, the lower the radiation angle in degrees, the greater distance the ball or signal will travel. Under some conditions of propagation the signal may take two hops (double-hop skip), and the distance covered will be even greater. The radiation angle will, however, still determine the actual distance of the communication. The angle of radiation is shown in simple form versus antenna height in Fig. 2 at B and C.

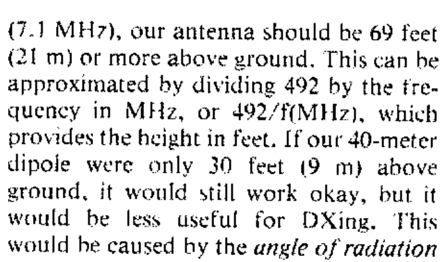


Fig. 1 — Illustration of how radio waves are reflected from the ionosphere. The low radiation angle is preferred for long-distance communications. If high-angle radiation (dashed lines) prevails, the skip distance will be much shorter.

We can see from the foregoing discussion that an antenna which is relatively close to the ground can work in our favor for short-haul contacts. The higher radiation angles will return the signal to earth much closer to the transmitting station than in the case of DX work, and local contacts out to a few hundred miles will be enhanced by virtue of our stronger signals. When antennas are very high above ground (one wavelength or more) it is not uncommon to have "dead zones" a few hundred miles from the transmitter; but, at great distances the signal will be much louder than when the transmitting antenna is close to the ground. Some operators have identical antennas for a given band, with one close to the ground and the other quite high up. The antennas are then chosen for the desired communications distance versus band conditions at a given time. This discussion applies only to high-frequency communications. At vhf and higher the antennas should be as high above ground as possible for *line-of-sight* work. In other words, our discussion deals mainly with signals that are reflected from the ionosphere.

The height of an hf antenna has an effect also on the *radiation resistance*, par-

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ticularly with respect to horizontal dipoles. This effect is shown graphically in Fig. 3. For a typical amateur hf-band antenna installation, however, the mismatch will not pose a problem of great consequence unless the feed line is quite long (more than 100 feet or 30.5 m). The longer the feed line (especially coaxial cable), the greater the losses in the line. These losses increase as the operating frequency is made higher. For example, if the feeder caused a 3-dB loss of the rf energy and the transmitter was putting out 50 watts, there would be only 25 watts of power delivered to the antenna. There would be a similar loss during receive. A 3-dB loss is one half an S unit (if they are accurate). The smaller the diameter of the coaxial cable, the greater the losses per foot. For this reason we should try to use RG-8/U or RG-11/U rather than RG-58/U or RG-59/U types of cable at the higher frequencies. Surplus coaxial cable should be avoided, for aging causes contamination of the dielectric material and makes the cable very lossy. It is wise to start with new cable and replace it every few years.

We should strive to keep the radiating portions of our antenna well removed from trees, power lines, phone wires, downspouts or other conductive objects. Close proximity will cause distortion of the radiation pattern and absorption of the signal energy, which will make our antenna less effective than it might be otherwise. Metallic objects that are close to the antenna (a few feet or less) can detune the antenna and cause a mismatch at the feed point. From all of the foregoing we can extract a basic rule: *keep the antenna as high and as in the clear as possible.*

Wire Antennas are Easy

Not many amateurs are willing to invest in towers, rotators and beam antennas at the beginning. We can apply the "crawl before walking" concept, and obtain good results with wire types of antennas. Plenty of DX has been worked with simple antennas, so let's see what options are open to us.

Random-Length Wires: A random length of wire can be used to explore the hf bands, but it represents the least effective of the wire antennas unless it is erected high and has considerable length [1/4 wavelength or greater, derived from 234/f(MHz), which yields the approximate length in feet]. Long spans of wire do not constitute a "long-wire antenna," although they are called that rather frequently. A classical long wire is 1 wavelength or more in electrical dimension.

The "random" antenna is one that is strung from a point near the ham station to some supporting structure a convenient distance away. It will exhibit a variety of feed impedances over the range of hf amateur bands. If it approaches a 1/4-wavelength condition (or odd multiple thereof), the impedance will be low — probably between 15 and 100 ohms, depending on a variety of factors. But, at other frequencies it may be close to 1/2 wavelength or multiple of that electrical length. This being the case, the feed impedance will be very high — 1000 ohms or more. If we are to provide an impedance match between our 50-ohm transmitter/receiver combination and the end of the antenna, it will be necessary to use an antenna-matching device (Transmatch, antenna coupler or antenna tuner, as they

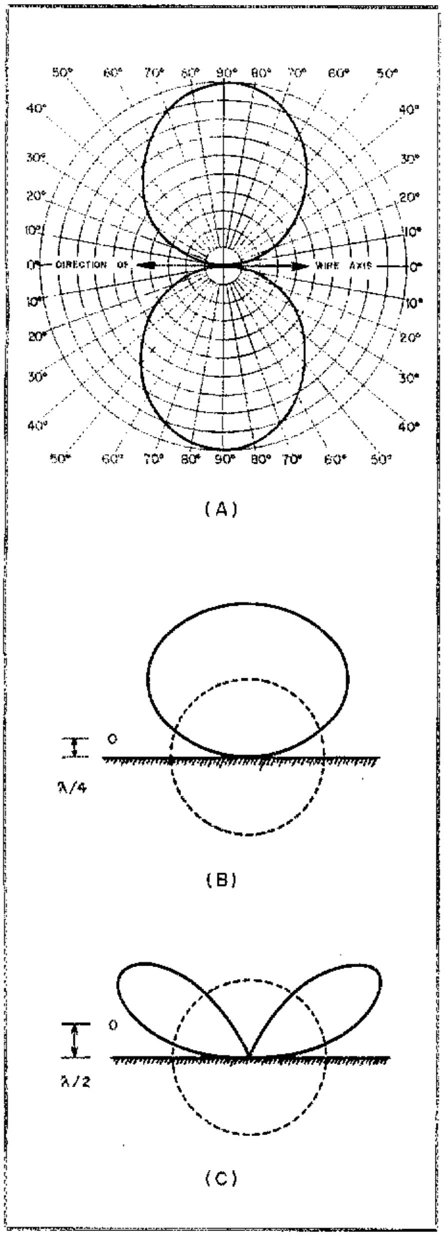

Fig. 2 — If we could rise above our dipole antenna and observe the radiation, we would see the figure-8 pattern at A. This would be seen if the horizontal dipole was 1/2 wavelength or greater above ground. The lobes are off the broadside of the dipole. At B we can see the effect of having the dipole only 1/4 wavelength above ground. There is no apparent directivity, and the radiation angle is very high. At a height of 1/2 wavelength (C), the dipole exhibits two major lobes and has a much lower radiation angle (desired for DX work).

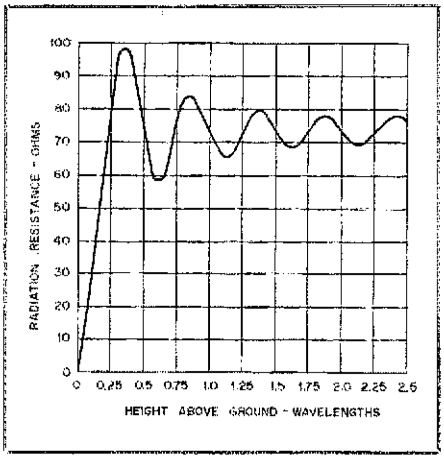

Fig. 3 — The radiation resistance of the antenna feed point varies with the effective height above ground. Here we see the effects of height for a dipole at various elevations above a theoretically perfect ground. At a height of 1/2 wavelength the antenna can be matched nicely with 72-ohm feed line.

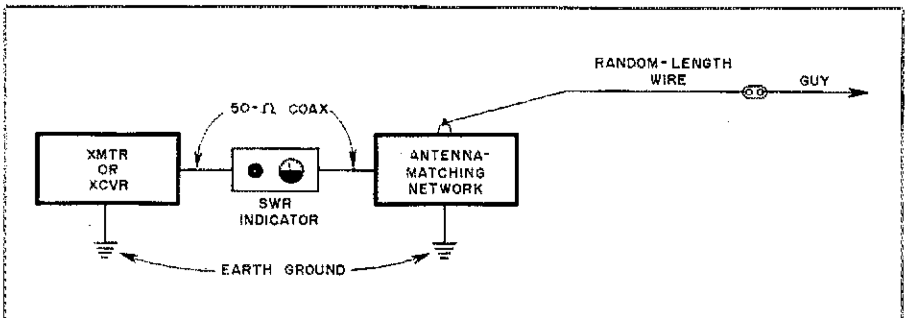

Fig. 4 — Method for using a random-length antenna for multiband operation. The wire is matched to the transmitter by means of a coil and capacitor network (Transmatch). Proper tuning of the network is determined by observing an SWR indicator and adjusting the network for minimum indicated SWR.

are called). This will enable us to change bands and maintain maximum power transfer to the antenna, which will happen when a matched condition exists. Our SWR indicator will show a ratio of 1:1 when the tuner is adjusted correctly. A setup of this kind is shown in Fig. 4.

The shortcoming of this type of antenna system is that rf energy can easily appear on the station equipment. A "hot" key, microphone or transceiver panel will be noted. Also, unwanted rf energy can get into the keyer or the rig and raise havoc. This is most apt to occur when the antenna operates close to a half wavelength or multiple thereof. When the feed impedance is low, rf will probably be absent on the station equipment. In either case, a *short* earth ground is necessary to minimize the hot-chassis problem. The shield braid from a discarded piece of coaxial cable will serve nicely as a ground conductor. It should be as short and direct as possible, running from the chassis of the rig and antenna matcher to a cold-water pipe and/or pipe driven into the ground just outside the shack. Ham shacks that are on the second or third floor of a dwelling are notorious for exhibiting the hot-chassis syndrome. This is because it is difficult to effect a good earth ground from so high up. Sometimes 1/4 wavelength of wire can be laid around the baseboards of the room to serve as a counterpoise ground, and often it will prevent rf from getting on the station equipment.

End-fed Hertz antennas, and some end-fed Zepp antennas, create similar problems with stray rf energy, owing to their relatively high feed impedances (high rf-voltage point). When this problem can't be solved, it is wise to use a coaxial-cable feed system with an appropriate low-impedance antenna, such as a dipole or doublet.

Dipole Antennas: The most common of the beginner antennas is the standard half-wavelength dipole. It is fed at the center by means of low-impedance line, such as coaxial cable, TV Twinlead or open-wire feeders. Some amateurs have even used plastic zip cord (ac line cord) with considerable success! The dipole can be erected horizontally, as a "sloper" or as an "inverted V." The latter was derived from the Quadrant antenna which was used in the early days of radio. Fig. 5 illustrates the various formats for a dipole antenna.

Dipoles are bidirectional (figure-8 pattern) off the broad side of the antenna, but only when the dipole is 1/2 wavelength or more above ground. The closer the antenna is to the earth, the less directional it becomes and the higher the radiation angle will be (Fig. 2). The sloper and inverted-V configurations produce essentially vertical polarization, which is excellent for ground-wave and DX contacts. The sloper, if not mounted on a metallic support, will be omnidirectional in response, as will the inverted V. If either antenna is supported on a steel mast or tower, there will be some directivity (not gain) in the direction of the wire slope.

The advantage of the dipole antenna is its simplicity. The disadvantage is its single-band performance (unless tuned feeders and a Transmatch are used to provide multiband operation, as in Fig. 6). The length of a dipole in feet is determined from 468/f(MHz). Hence, a dipole for 3.7 MHz would be 126 feet, 6 inches (38.5 m) long. Some final adjustment of the leg lengths is usually done to bring the VSWR as close to 1:1 as possible. This can be achieved by inserting a VSWR indicator (sometimes called a "bridge") in the coaxial feed line at a convenient point, then cutting or adding wire in equal amounts to the ends of the dipole until the lowest reflected voltage is noted on the in-

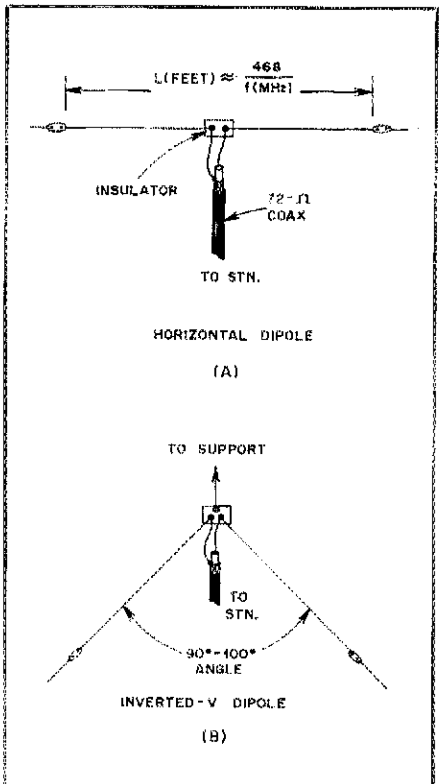

Fig. 5 — Examples of simple but effective wire antennas. A horizontal dipole is shown at A. The legs can be drooped to form an "inverted V," as seen at B. A sloping dipole (sloper) is illustrated at C. The feed line should come away from the sloper at 90° for best results. If the supporting mast is metal, there will be some directivity in the direction of the slope. The antennas at B and C provide vertical polarization and are predominantly omnidirectional if they are supported on a non-metallic mast.

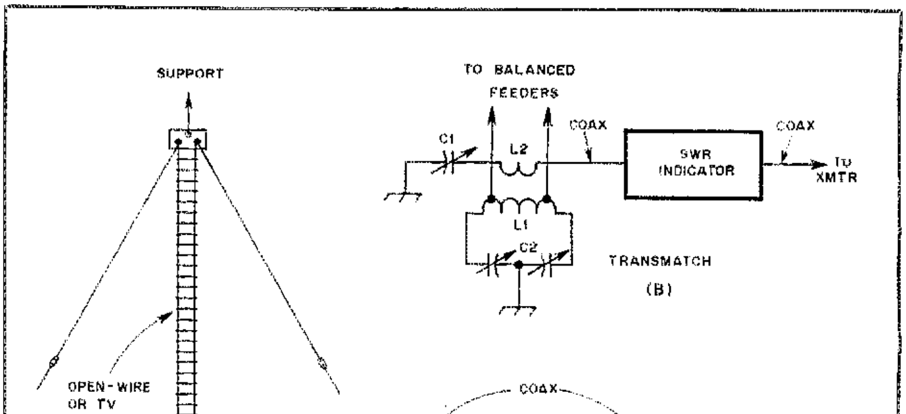

Fig. 6 — Fundamentals of a multiband inverted-V dipole. Balanced, low-loss feeders are recommended (see text). A Transmatch is used to maintain an SWR of 1:1 over the operating range of the antenna. At A we have a balun transformer (to convert from a balanced to unbalanced feed line), a Transmatch and an SWR indicator. Typically, these components are located near the operating position. At B we see the circuit of a Transmatch that is well suited to use with balanced feed lines. The balun at A can be eliminated when using the network at B, and generally the overall system will be more efficient with this style of Transmatch.

dicator. This will usually be a value less than 2:1, in terms of the forward/reflected voltage ratio respective to a half-wavelength dipole that is fed with coaxial cable.

All antennas have a specific useful bandwidth. Dipoles are no exception. The lower the operating frequency, the narrower the antenna bandwidth over a specified VSWR range. Therefore, the antenna should be optimized for the part of the band we use the most. Novices should tune the antenna for the center of the Novice band when using coaxial-cable feed line. At 80 and 40 meters the bandwidth will be especially narrow between the 2:1 VSWR points (Fig. 7), with 100 kHz being typical on 80 meters, and 200 kHz an average expectation on 40 meters. For this reason it is common to hear an amateur say, "I don't work 80-meter cw because my dipole is cut for the ssb portion of the band." In such cases the antenna won't load (accept power) because of the high VSWR in the opposite end of the band. A Transmatch could be utilized to *disguise* the SWR condition, and fair performance would result. But, the mismatched condition at the dipole feed point could not be remedied by that means. A Transmatch merely effects a match between the transmitter and the station end of the feed line — this is important to remember. If it were connected between the antenna feed point and the feed line, it *could* correct the mismatch, but this would be impractical.

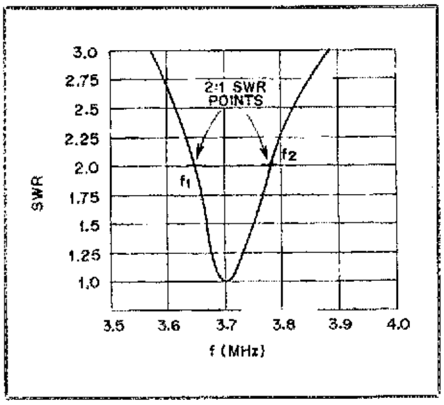

Fig. 7 — Typical SWR curve for an 80-meter dipole with coaxial-cable feed. The antenna should accept the transmitter power quite well when the SWR is less than 2:1 (3650 to 3750 kHz in this example). The bandwidth of an 80-meter dipole may be greater than that indicated here, depending on how it is built.

Multiband Operation

In Fig. 6A we have what is called a multiband inverted-V antenna. It could just as well be a horizontal dipole if the builder preferred that format. Balanced open-wire or TV-ribbon feeders are specified. The open-wire line is preferable, because the losses will be lower than with TV ribbon. The overall length of the dipole is determined by 468/f(MHz) at the lowest intended operating frequency. If it is dimensioned for use on 80 meters, operation will be possible from 80 through 10 meters by using a balun (balanced to unbalanced) transformer and a Transmatch, as illustrated. Some Transmatches come equipped with a built-in balun, which is included for use with balanced feeders.

A more effective method for matching the transmitter to a balanced feeder system is shown in Fig. 6B. In this example the feeders are brought to the operating position and tapped on L1 of the matching network. The length of L1 (effective inductance) must be changed for each band of operation, and this is possible by means of a switch or clip leads. The feeder tap points on L1 must also be changed in accordance with the band of operation. The E. F. Johnson Matchboxes were based on this kind of matching network.

The shortcoming of a multiband dipole is its declining performance as the operating frequency is increased: an 80-meter antenna of this type will perform rather well on 80 and 40 meters. It will give fair results on 20 meters, and may yield mediocre performance on 15 and 10 meters in terms of DX work. However, the multiband inverted V is a very popular all-around antenna despite the compromises. Once erected, it need not be trimmed. The Transmatch will compensate for the SWR "seen" by the transmitter.

The tuned-feeder concept can be applied to the antennas in Fig. 5 as well. The classic name for a straight dipole with tuned feeders is the "Center-Fed Zepp." The inverted-V format is preferred by many because it requires only one support, is essentially omnidirectional and is vertically polarized. The center should be erected as high as possible above ground for best results.

What Kind of Wire is Best?

There is confusion among beginners about what kind of wire is suitable for the radiator of an antenna. Some have asked, "Can I use wire that has plastic insulation?" Others have wondered, "What size wire must I use?" In both cases there is no particular answer. Bare wire and insulated wire both work fine in the range from 1.8 to 30 MHz. The insulation will not degrade the radiation of the antenna. The wire size can be the largest you can acquire or afford. Generally, 12-, 14- or 16-gauge sizes are used. But, very fine wire, such as nos. 20 through 26, is satisfactory if there is not too much stress on the legs of the antenna. The smaller wire will break easily in wind and ice, and this must be considered when making a choice.

Hard-drawn copper or Copperweld wire is the most rugged, and is not subject to stretching with stress versus time. No. 12 or 14 plastic-coated house wiring is excellent for dipole antennas if it is available. Stranded copper works just as well as solid copper for amateur antennas. Some amateurs use insulated hookup wire and report good results. The primary consideration is that we use strong enough wire to ensure that the antenna stays aloft once it is erected.

The end insulators can be made from any good grade of material such as glass, plastic or phenolic. If you don't want to buy insulators, you can make them from pieces of glass-epoxy pc board (copper removed) or Plexiglas. Some amateurs have used the white, plastic six-pack retainers as strong insulators. Others report fine results with plastic clothespins and hair curlers. The center insulators for dipoles can be fashioned from Plexiglas or similar material. Always be sure to seal the open end of the coax cable with epoxy cement or Silastic compound to keep the dirt and moisture from entering the cable.

Homemade open-wire line can be built easily. The line spacing and wire size aren't important for a multiband dipole. A good compromise is to use no. 16 wire for the two conductors, spaced 3 to 4 inches apart. The spacers can be made from plastic clothespins, hair curlers or even a 1/4-inch (6-mm) diameter wooden dowel rod that has been boiled in paraffin wax. We must be innovative if we are to save money!

Trap Dipoles

"Can't I use a trap dipole?" Sure, if you don't mind buying a commercial product. But, a homemade trap dipole is hard to design and to tune if one is a beginner to radio, so the commercial product might be the best to consider.

A trap dipole permits multiband operation without a Transmatch. It uses a coaxial feed line which can be connected directly to the transmitter and receiver. It can be erected as shown in Fig. 5. The trade-off is in performance. The bandwidth will be narrower than with a full-size dipole, and there will be some losses in the traps. However, in an actual on-the-air situation it may be hard to tell the difference between a trap dipole and a single-band, full-size one. Nearly all multiband antennas represent a compromise between convenience and performance.

The best plan is to try various antennas and learn which one will work best for you. Identical antennas often yield different results at separate locations. This is because of the terrain, conductivity of the earth below the antenna and other factors. It won't take long to determine how effective your antenna is, once you start contacting stations near and far. If the performance is dismal, try another style of antenna. Experimenting is part of what Amateur Radio is all about! QST