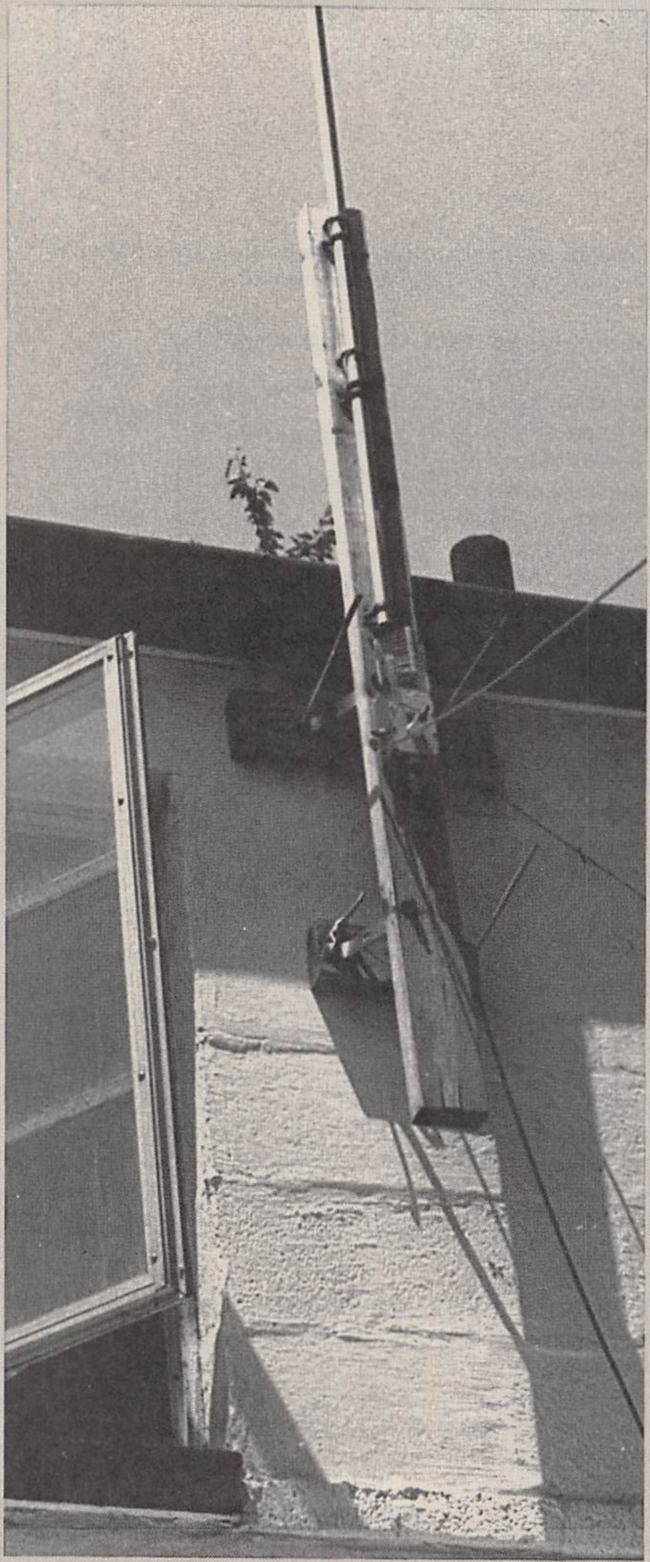
Pipe and Tubing Antennas

Design and build a communications antenna, and save a bundle in the process.

BY JOSEPH J. CARR



Antennas can be made from a variety of materials. The most common materials used in antenna construction are wire and aluminum tubing or copper pipes. In this article, we'll discuss the basic methods used to process aluminum tubing and copper pipes into functioning antenna systems.

Aluminum tubing is available at almost all hardware stores in any diameter. Even small operations carry aluminum tubing in at least three diameters; ½ inch, ¾ inch, and 1 inch. Larger hardware stores may have a substantially more impressive display of aluminum tubing in diameters ranging from ½ to 1½ inches, and in various lengths. While small stores may stock aluminum tubing in six- and eight-foot lengths, larger stores might also carry four-foot and twelve-foot lengths. Specialty metal distributors also have a wide variety of aluminum tubing, but they are a bit harder to find and often require a minimum purchase of $50 to $100.

Regardless of where you obtain the required materials, there's a little secret that you should know about aluminum tubing: adjacent sizes form a slip fit with each other. That is, the smaller outside diameter pipe fits snugly inside larger diameter pipe. When purchasing aluminum-tubing for antenna construction, be sure to buy adjacent sizes, and check them by slipping the smaller pipe into the larger one before leaving the store.

Unfortunately, copper pipe in convenient lengths for antenna construction is quite expensive! Although copper pipe is available in sizes ranging up to two inches in diameter, ½-inch and 1-inch diameter pipes are easier to find. Copper solders well (aluminum doesn't solder with plain solder at all) and is easy to work with ordinary tools (as is aluminum). And although there may be situations where you might prefer copper over aluminum, most of the time aluminum is the way to go. (Copper antennas look great on the day that they are installed, but soon corrode, turning a yucky green in a few months.)

Pipe Joints. Longer lengths of tubing can be made by joining two or more shorter pieces together. There are benefits to working with shorter lengths of pipe or tubing. Because antennas are tuned by adjusting the length, using two sections makes it easier to custom tune the antenna to a specific frequency.

There are several different ways to join sections of tubing. Figure 1 shows four jointing schemes. Figure 1A shows an ordinary slip-joint made by feeding the smaller-diameter tubing six to twelve inches into the larger tubing. The longer the overlap between the two sections, the greater the mechanical strength of the assembly.

Figure 1B shows another jointing scheme, which is used when identical pipe sections are used. The flared end of one section of tubing excepts the non-flared end of the second section of tubing. Note that in that illustration both sections have the same diameter (designated d) for most of their

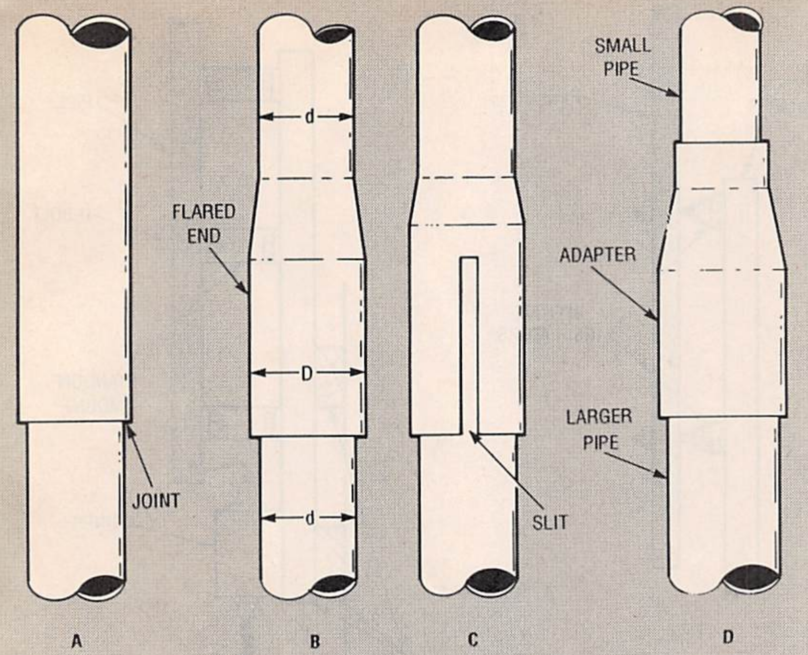


Fig. 1. There are several ways to join lengths of tubing to form an antenna; A shows a slip-fit joint; B is a flanged joint; C is a slotted flanged joint; and D uses a step-down adapter joint.

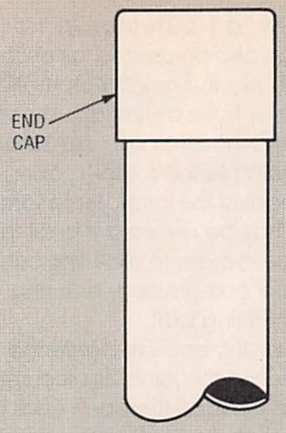


Fig. 3. Once the antenna has been completed, end caps should be placed on the tubing or pipe ends to prevent rain and insects from entering the antenna.

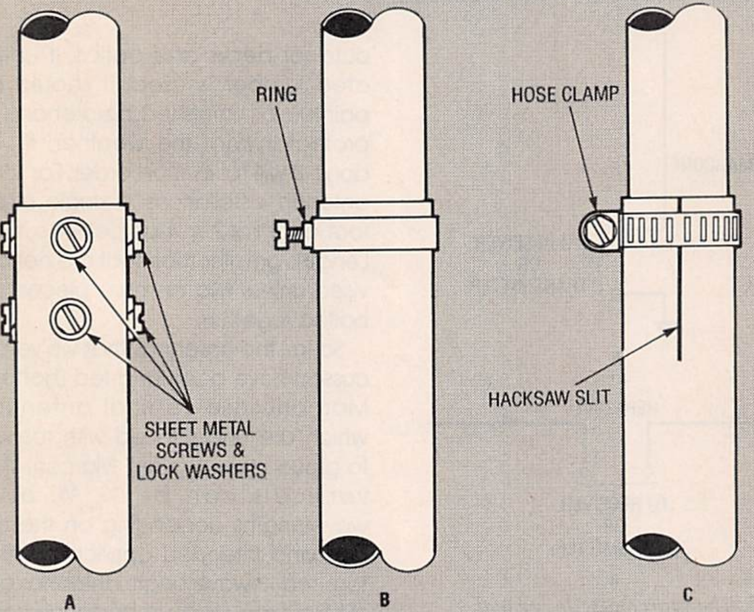


Fig. 2. Putting two pieces of pipe or tubing together is one thing, keeping them together is quite another. Several approaches can be used to secure a joint: in A, several sets of sheet metal screws are used; in B a ring collar with a set screw is used; and in C an automotive hose clamp keeps the joint secure.

length, but flare to a larger diameter (designated D) at one end. In some cases, the small end must be pinched a little bit in order to permit the two sections to be joined. That type of construction is used for steel TV-antenna masts.

Another flared joint is shown in Fig. 1C. In that case, a slot is cut into the flared end to permit an easier slip-fit between the two sections. Some people also use that method for joining two identical diameter pipes, but that scheme considerably weakens the joint.

Figure 1D shows a scheme wherein a reducing (graduated) adapter is used to bridge the two different diameter sections. That scheme might be used to join 1-inch pipe with a ½-inch pipe. Such adapters are very difficult to find for aluminum tubing, but are readily available for most sizes of copper pipe. Sweat soldering the ends of the pipes to the adapter produces an excellent bond between the two sections.

Putting two pieces of pipe or tubing together is one thing, keeping them together is quite another. Figure 2 shows three methods that can be used to secure the joints. In Fig. 2A several sets of sheet-metal screws (use #8, #10 or #12 screws) are used to anchor the joint. The number of screw sets used to secure the joint depends on the size of tubing. It is best to use at least two sets of three or four screws. Unfortunately, sheet-metal screws have one less-than-endearing quality; wind and vibration can cause them to work loose. Unless the antenna is supported above and below the joint, it is probably best to use one of the other methods.

The ring and set-screw assembly, shown in Fig. 2B, is used by some commercial antenna makers. In that method, a special ring collar with a #10 or #12 machine screw is slipped over the joint and then the screw is tightened. That method is reliable, but such ring-collar assemblies are hard to find. In addition, tightening the set screw puts a "dimple" in the metal, making it difficult to disassemble for maintenance or adjustment. In such installations, it is best not to tighten the screw until you are finished tuning, since the antenna is tuned by adjusting the physical length of the element.

Similarly, an automotive hose clamp can also be used to fasten the joint, as shown in Fig. 2C. Automotive hose clamps have a wide adjustment range, and hose-clamp set screw does not dimple the metal, making it easy to readjust the joint later. In some cases, it may be necessary to slit the larger pipe in order to allow the outer pipe to be compressed, ensuring a good tight-fitting joint.

In any event, once the antenna is complete and the joints are secured, it is wise to close off the open ends of the pipe(s) to prevent water, debris, and insects from getting into the antenna system. Figure 3 shows an end-cap placed over the open end of the antenna. For copper pipes, metal caps can be sweat soldered in place. Alternatively slip-fit or plastic caps can be used, or you can simply wrap the end with black electrical or nylon-filament tape. But if tape is used, be prepared to replace the tape once in a while—tape takes a beating (cracks and looses adhesion) when left to the elements.

Mounting Pipe/Tubing Antennas. The typical method for mounting a pipe antenna is, as shown in Fig. 4A, with beehive insulators. The base of each insulator is mounted to a wall or to a piece of lumber (2 × 4 studding stock, for instance). The top of each insulator is outfitted with a bolt that excepts a hex nut or designed to except a machine screw. The insulator selected should have a ¼–20 bolt, as smaller sizes will shear off in the wind; over time, even gentle breezes can shear smaller bolts.

Unfortunately, though once commonplace in electronic parts and radio stores only a couple of decades ago, beehive insulators, especially in sizes appropriate for vertical antennas are becoming hard to find. Your best bet is to try some highly specialized stores, or at hamfests and other tailgating events. And, if you manage to locate a dealer, don't be shocked at the price!

An alternate method for mounting the antenna is shown in Fig. 4B. In that scheme, the antenna is mounted to 6- or 8-inch TV-antenna standoffs that are, in turn, mounted to a wall or attached to piece of 2 × 4 lumber, which is, in turn, mounted to the wall. If an antenna tuner or broadband transformer is used in your antenna system, it should be mounted with the antenna on the 2 × 4.

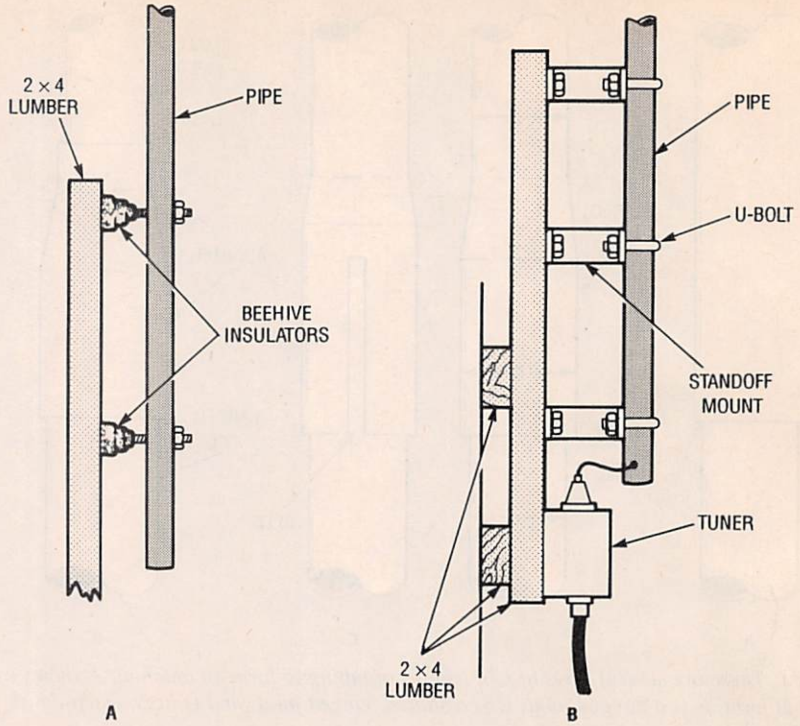


Fig. 4. The antenna should be mounted with beehive stand-off/insulators, as shown in A or using TV stand-off mounts as shown in B.

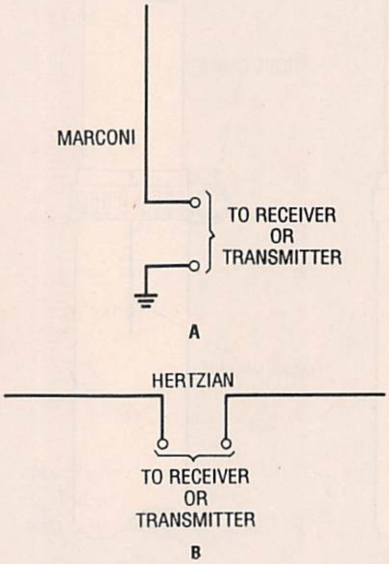


Fig. 5. The Marconi-style vertical antenna (A) is an end-fed (bottom) antenna, and is unbalanced with respect to ground. The Hertzian antenna (B) is balanced with respect to ground: A dipole is a Hertzian antenna regardless of whether it is vertically or horizontally mounted.

The lumber (if that's the type of installation you choose) should be pressure-treated weatherized material, which is the type normally used for outdoor decks and patios. If untreated lumber is used, it should be painted or varnished beforehand to protect it from the weather; if you don't, it will rot in short order. For most antenna installations, a single eight-foot length of 2 × 4 lumber will suffice. Lengths greater than that are not advised unless two or more pieces are bolted together.

So far, the antennas that we've discussed have been end-fed (bottom) Marconi-style vertical antennas, which are unbalanced with respect to ground (see Fig. 5A). Marconi-style verticals can be ¼, ⅝, or ¾ wavelengths depending on the design and intended application. Bottom-fed ½-wavelength antennas also exist, but require an impedance transformation tuner at the feedpoint. For the standard ¼-wavelength antenna, the starting length for tuning is found from:

$$L_{feet} = 234/f_{MHz} \qquad \text{[Eq. 1]}$$

Keep in mind that the length calculated from Eq. 1 is merely an approximation; the actual length will vary a small amount from the calculated value. The antenna is tuned for minimum voltage standing-wave ratio (VSWR) by adjusting the actual physical length of the antenna up or down

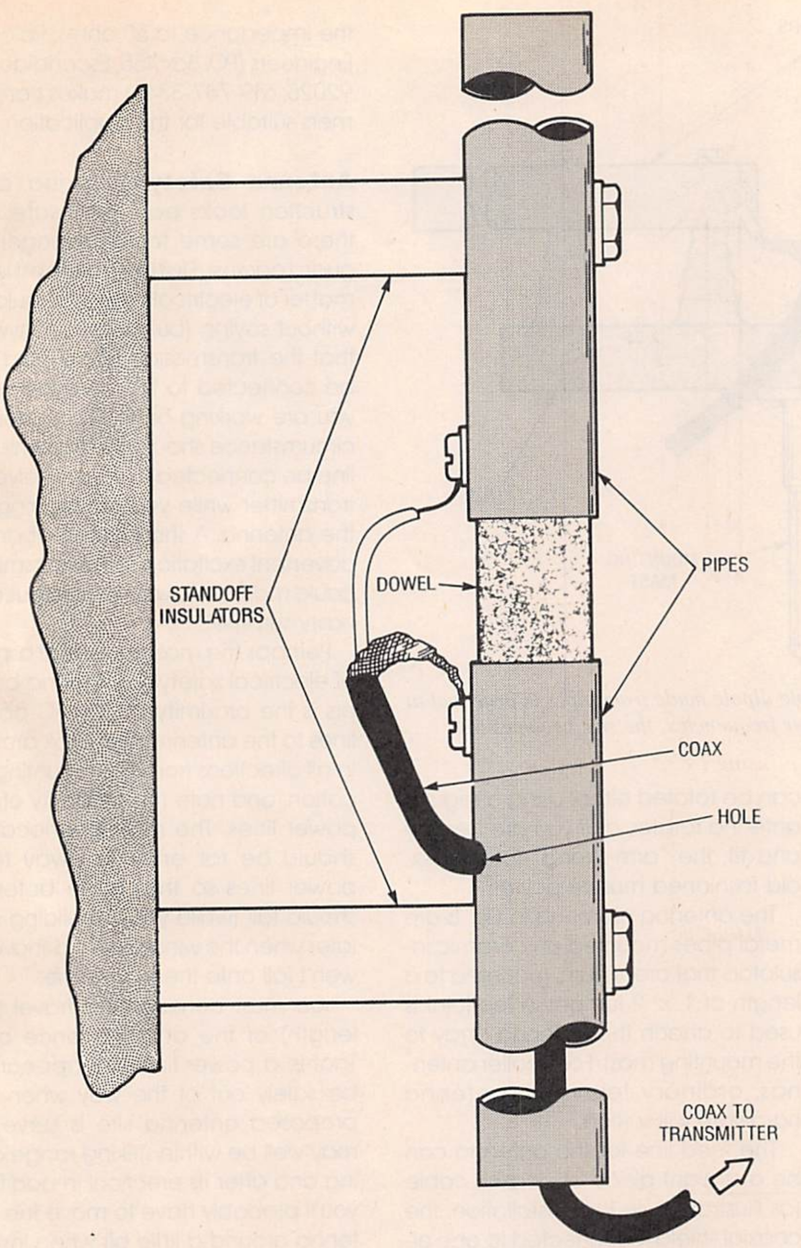


Fig. 6. The transmission line can be connected to the feedpoint of the antenna in the manner shown here. The coaxial cable is routed through the hollow pipe to a hole on the side. That method only works when sufficient standoff insulators are used so that the antenna assembly does not need a long dowel.

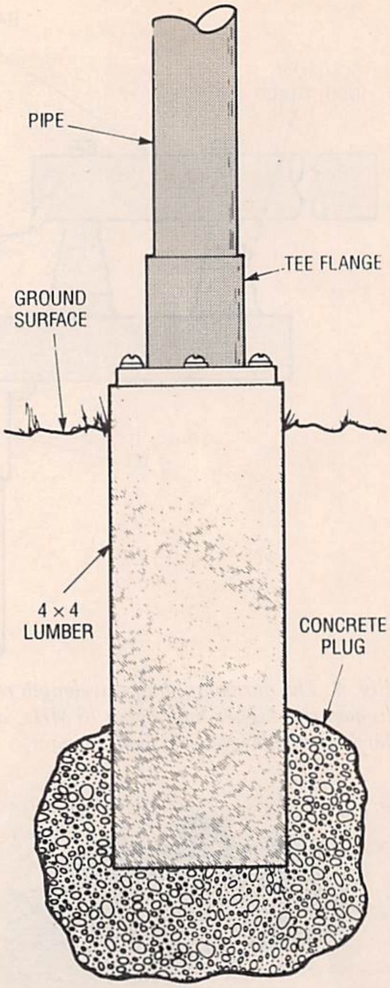


Fig. 7. In this ground mounting system, a tee-flange is mounted to a section of 4 × 4 lumber that is, in turn, mounted in a fence-post hole, and set in concrete.

from the calculated point. The actual length is also a function of mounting style, local conducting objects in the field, and several other factors (hence, the equation can not produce absolute values).

A different form of antenna—a ½-wavelength Hertzian (balanced with respect to ground) dipole—is shown in Fig. 5B. A dipole is a Hertzian antenna regardless of whether it is mounted vertically or horizontally. If mounted horizontally, the two elements (top and bottom) are equal in length. The length of the elements can be found using Eq. 1. That is, the overall length is twice the length derived from Eq. 1, or:

$$L_{feet} = 468/f_{MHz} \quad \text{[Eq. 2]}$$

Each element is mounted to a wall or 2 × 4 lumber using at least one stand-off/insulator per pipe section as shown in Fig, 6, although two or more per section is probably wiser. A wooden, plexiglass, or Lucite dowel is placed in between the two sections when the antenna is self-supporting or when only one insulator per section is used. The pipe sections should be mounted about 3-inches apart with a single dowel (of at least two feet in length) fed in to the ends of the two pipes. The dowel should then be fastened to the two pipe sections with several sets of three or four sheet-metal screws.

The coaxial transmission line can be connected to the feedpoint of the antenna in the manner shown in Fig. 6. In that system, the coaxial cable is routed through the hollow pipe to a hole on the side. That method only works when enough standoff insulators are used so as not to need a long dowel.

Another mounting scheme—a ground mounting system—is shown in Fig. 7. In that system, a tee-flange is mounted to a pedestal made of 4 × 4 lumber that is, in turn, set in a fence-post hole and surrounded at the base by concrete. The pedestal should be made from the treated lumber of the

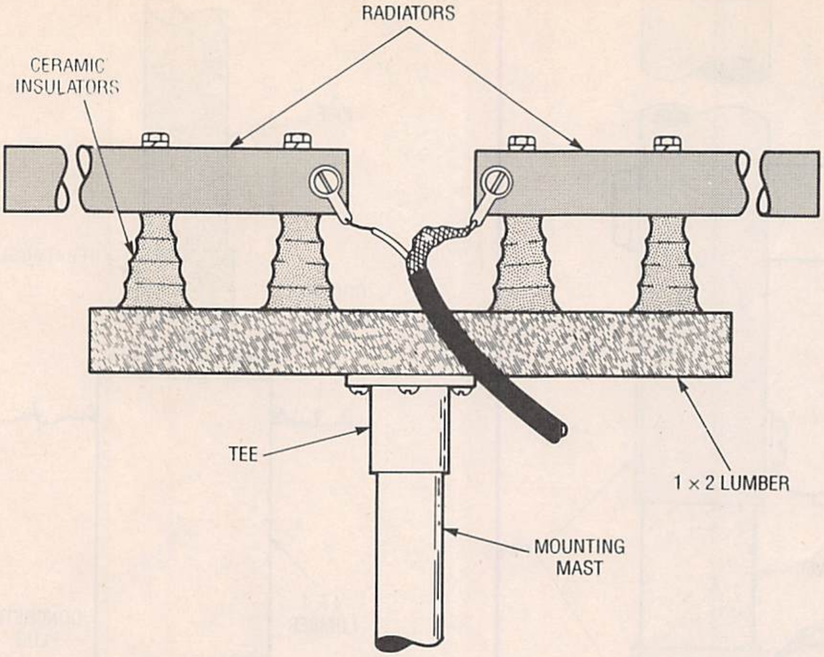
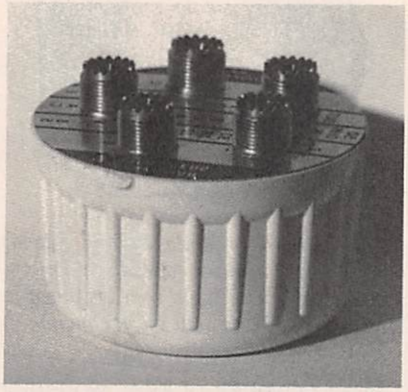


Fig. 8. The horizontal half-wavelength rotatable dipole made from pipes is practical at frequencies higher than about 18 MHz; at lower frequencies, the size becomes too large and bulky for easy construction.



This multi-impedance transformer, which is especially made for vertical antennas, can be placed at the feedpoint of your antenna to transform its impedance to 50 ohms.

type that is use for fence posts; if the treated type is not used, bugs and rot will destroy it very quickly! It is also possible to combine mounting schemes. For instance, you could use a 2 × 4 or 4 × 4 lumber to form the pedestal portion of the mount in Fig. 7, and then attach the antenna using the method outlined in Fig. 4.

Finally, Fig. 8 shows a horizontally mounted dipole antenna. That type of antenna is practical at frequencies higher than about 18 MHz; at lower frequencies, the size becomes too large and bulky for easy construction. The antenna provides a bidirectional receiving or transmitting pattern. It can be rotated either using a regular antenna rotator, or if you are healthy and fit, the "arm-strong" rotator, *i.e.*, old-fashioned muscle power!

The antenna elements in Fig. 8 are metal pipes mounted on ceramic insulators that are, in turn, mounted to a length of 1 × 2 lumber. A tee-joint is used to attach the antenna array to the mounting mast. For smaller antennas, ordinary television-antenna hardware will suffice.

The feed line for the antenna can be a straight piece of coaxial cable (as illustrated). In that installation, the coaxial shield is connected to one element, while the center conductor is connected to the other. For the best radiation pattern for that installation, connect a 1:1 BALUN transformer to the feedpoint, and connect the coax to the BALUN.

Impedance Transformers. The feedpoint impedance of a vertical is 50 ohms, while for a dipole it is 75 ohms, right? Nope! Some ¼-wave verticals have a feedpoint impedance of 37 ohms, which is a reasonable match to 52 ohm coaxial cable. However, most antennas have a feedpoint impedance that is a lot less, perhaps as low as about 5 ohms. A multi-impedance transformer especially made for vertical antennas can be placed at the feedpoint to transform the impedance to 50 ohms. Palomar Engineers (P.O. Box 455, Escondido, CA 92025; 619-747-3343) makes transformers suitable for this application.

Antenna Safety. Antenna construction looks easy and safe, but there are some terrible dangers to guard against. First and foremost is the matter of electrical safety. It should go without saying (but I'll say it anyway) that the transmission line should not be connected to the antenna while you are working on it. And under no circumstance should the transmission line be connected to your receiver or transmitter while you are working on the antenna. A short circuit, or an inadvertent excitation of the transmitter, could make for a very dangerous and nasty surprise!

Perhaps the most important aspect of electrical safety for antenna builders is the proximity of any AC power lines to the antenna site. Look around in all directions from the mounting location, and note the proximity of the power lines. The mounting location should be far enough away from power lines so that if the antenna should fall (while you're building it or later when the wind gives it a shove), it won't fall onto the power line.

You must consider the travel (the length) of the antenna once built. That is, a power line that appears to be safely out of the way when the proposed antenna site is surveyed may well be within striking range during and after its erection! In addition, you'll probably have to move the antenna around a little bit when installing it. So allow yourself plenty of leeway. Although a power line may be insulated, after a short time out in the weather that insulation becomes weakened and brittle. If the antenna touches it, the insulation may crumble, exposing the current-carrying conductor inside.

Another precaution is to make sure that you are physically able to do the job. Pipe antennas are very light, or so it may seem, but they are also very long. Because of its length, the antenna can put a great physical strain on you, especially if there is a slight breeze (don't build an antenna in a wind!). I've thrown out my back building verticals alone. So get help; it's a two-person job.

(Continued on page 93)

er voltage and polarity on the board. Remember the button-0 input of the game port has a pull-up resistor on it, so there will be +5 volts present on that signal line. If the voltages check out turn the computer off, unplug the interface cable and insert the AD654 and LM324 into their sockets. Plug the interface cable in and turn on the computer. If you have an oscilloscope, check for a square-wave on pin 1 of the AD654. If you do not have a scope, you can use a logic probe or frequency meter. If there is no signal on pin 1 then there is a problem with the board or perhaps the interface cable. Turn the computer off and double check the circuit against the schematic and then check the wiring of the interface cable to find any errors.

If the circuit checks out then run the DVM program. If the program finds a square-wave on the button-0 input, it will begin to display values on the screen. If the signal is not present, the program will display a message and abort.

Once the circuit is functioning correctly you can secure the circuit board in the case and connect the input wires to the terminals. That's all there is to it; your circuit is now ready for use.

Going Further. There are 4 digital inputs on the game port so you can have up to 4 Analog Input Adapters connected at the same time. You can easily construct a circuit board that distributes power and ground to the attached adapters. Remember to connect the signal lines to different button inputs on the port. Refer to the pinouts in Fig. 4 for the proper connections and input addresses for the game sport connector. ■