ROBERT S CAPON WA3ULH

**The author, WA3ULH, with the disassembled 11-ounce vertical strapped to his backpack.**

# Build a Lightweight 20-Meter Vertical

## Could this be the lightest HF vertical in the world?

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Last year I introduced the *walking-stick vertical* (December 1994 *QST*, page 72), a monoband HF antenna ideal for expeditions, Field Day, camping, or as an excellent antenna for new hams. The walking-stick vertical offers performance on par with commercial vertical antennas, except that it only works on a single band, and it's very inexpensive. The antenna is ideal for both low- (QRP) and full-power operation.

The 20-meter version weighs only three pounds and fits into a convenient walking-stick package. I've received a great deal of use and enjoyment from this antenna. I especially relish its location-independent design; because it's free-standing, the vertical is not dependent on nearby trees for support.

Could such a neat antenna be significantly improved? I didn't think so, until I took a fateful excursion to a camping store. While cruising the aisles, I happened across an innovative tent. It was a lightweight shelter intended for backpackers. As I studied its construction, I noticed the collapsible aluminum poles that held it together, and started thinking about antennas. A redesigned walking-stick vertical made of these materials could collapse into an 18-inch bundle of aluminum weighing only 11 ounces!

Using this extremely lightweight aluminum, the redesigned monoband vertical is ideally suited for portable and temporary applications. It can be stowed easily in a backpack, or in an overhead compartment on an airplane.

Because the new antenna is so portable and light, I set up a pair of them fed *in phase* for this year's Field Day station. By feeding the antennas in phase, I created a radiation pattern that concentrated my transmitting power (and reception) into a figure-8 pattern. The result of this focusing effect is approximately 4 dB of gain broadside to the antenna.

I've also experimented with lightweight coax, under the theory that in a true backpacking application, an 11-ounce antenna should not be attached to 10 pounds of feed line! I built a 20-foot feed line that weighs only 3 ounces by using RG-174 coax. More about phasing and coax in a moment.

Before we proceed, please keep in mind the cardinal safety rule when working with vertical antennas: ***Do not allow the antenna to come into contact with a power line or power source of any kind.*** Be especially careful whenever you are in the vicinity of electrical outlets and fixtures, and overhead power lines.

### Quarter-Wavelength Verticals

The quarter-wavelength monoband vertical is a classic design. It consists of a vertical quarter-wavelength radiator and a tuned quarter-wavelength ground-radial system.

The vertical element can be as simple as a quarter wavelength of wire suspended from a tree using nylon rope and an insulator. Three wires trimmed to a quarter wavelength work well for the radial system (Figure 1). You can bury these wires for a permanent installation, or simply lay them on top of the soil. More radials will make the antenna even more efficient, and I've had excellent results with eight quarter-wavelength radials.

To determine the length in feet of a quarter wavelength, choose a frequency that's roughly in the middle of the desired band. Then, use the following formula:

$$\text{Length (in feet)} = \frac{234}{\text{Frequency (MHz)}}$$

This works out to 16.7 feet on 20 meters. When using this formula, you'll notice that the dimensions for the CW and phone portion of each of the bands are only a few inches apart, so the same antenna can be used for different parts of the band without adjustment.

A quarter-wavelength vertical exhibits excellent characteristics for working DX because it has a very low angle of radiation. The antenna also has a low impedance at the feedpoint, is omnidirectional, and exhibits broadband SWR coverage for the band of interest.

### Start with the Base Section

After you've gathered all the materials you'll need (see Table 1), begin by building the sturdy base section. Cut the 3/8-inch diameter tube to a length of 10 inches. Cut the 1/2-inch diameter tube to a length of 15 inches. The aluminum tubing cuts easily with a hacksaw, but please be sure to wear safety glasses and gloves.

Next, cut a 2-inch slot in *one* end of the 1/2-inch diameter aluminum tube. Preparing the 3/8-inch diameter tube is trickier, because a single slot will not compress sufficiently to grip the tent-pole tubing. To work properly, it's necessary to cut *three* 2-inch slots in one end of the 3/8-inch tube. When you look down the length of the tube after slotting, it will look like an asterisk.

To slot the tubes, gently place them in a wooden vise and cut the slots with a hacksaw. Be sure not to make the vise too tight. You might compress the tubing and make it harder to nest them together later. After cutting the aluminum, gently file off the burrs with a fine-grade, curved metal file.

### The Guy Ring

You must guy the antenna securely to keep it upright and to prevent damage from strong winds. To do this, you need to add a guy ring to serve as an attachment point on the antenna for your ropes or strings.

Find a scrap disk of wood or heavy plastic, approximately 2 to 3 inches in diameter. Almost anything will work. I used an item commonly found in hardware stores—a heavy plastic disk designed to hold a closet pole. Drill a 3/8-inch hole in the center of the disk. Then drill three 1/8-inch holes, equally spaced 120° apart, on the perimeter of the disk (Figure 2).

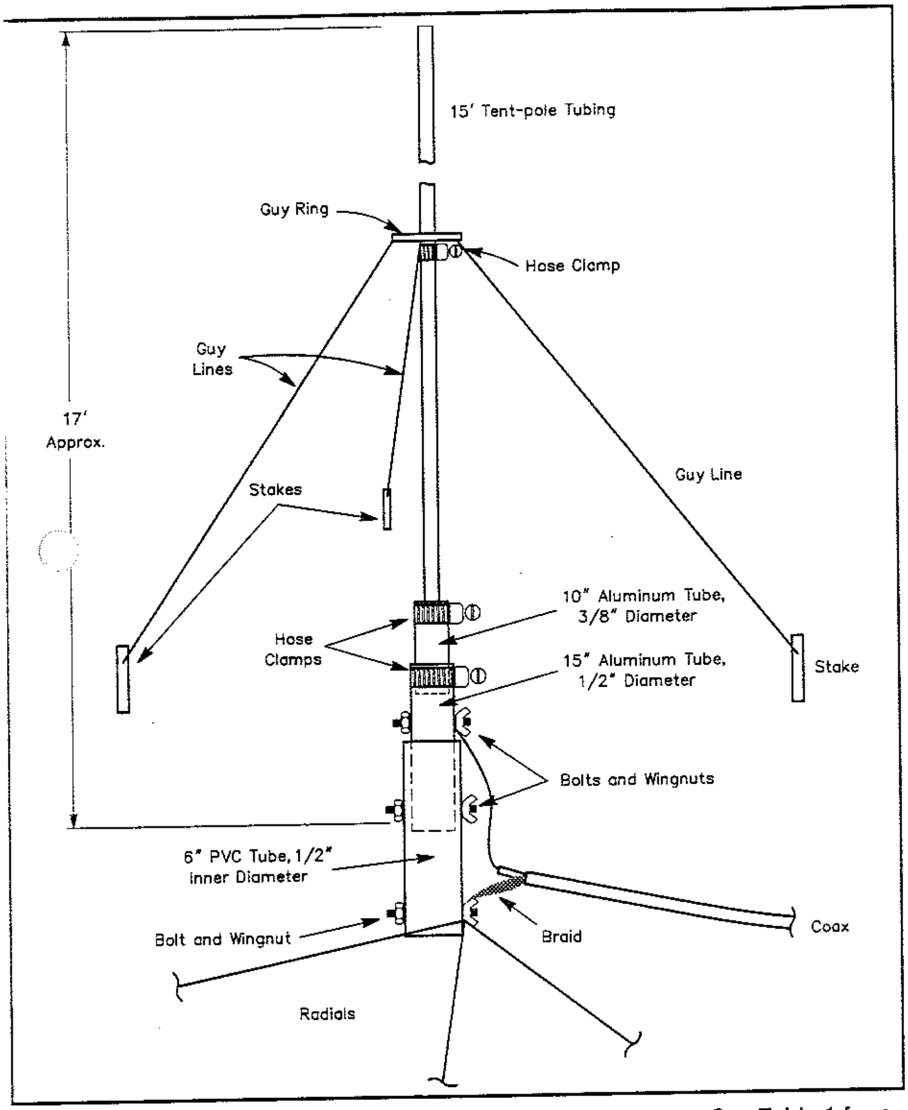


**Figure 1—Construction details of the 11-ounce vertical antenna. See Table 1 for a list of parts and sources.**

**Table 1**

**11-Ounce Vertical Parts List**

All of the parts you'll need are readily available. The total cost of the antenna is about $30.

| | |
|---|---|
| Lightweight, collapsible aluminum tubing:[1] | One 15-foot length |
| Standard aluminum tubing:[2] | One 10-inch length, 3/8 inches in diameter<br>One 15-inch length, 1/2 inches in diameter |
| Guy ring: | A scrap of wood or closet bar hanger |
| Guy rope: | 60 feet of 1/8-inch nylon or braided mason line |
| Tent stakes: | Three lightweight stakes |
| Radial wire: | 150 feet of insulated 22-gauge copper wire (for eight radials) |
| Rubber antenna tip: | Rubber chair tip, from hardware store |
| Ground-radial post: | 1/2-inch diameter PVC or fiberglass tube |
| Radial weights: | Eight heavy hex nuts from the hardware store |
| Hose clamps: | Three small one-inch hose clamps |

[1]Lightweight, collapsible aluminum tubing is available from A&A Engineering, 2521 W. LaPalma, No. K, Anaheim, CA 92801; tel 714-952-2114; fax 714-952-3280.

[2]For standard aluminum tubing, see your local hardware supplier or contact Texas Towers, 1108 Summit Ave, Suite 4, Plano, TX 75074; tel 800-272-3467. Or Metal & Cable Corp, 9241 Ravenna Rd, Twinsburg, OH 44087; tel 216-425-8455.

### The Ground Radial System

Cut three to eight (your choice) ground radials to the same length as the antenna. Figure 1 shows the detail for connecting the ground radials to the antenna. The center conductor of your coax feed line goes to the vertical aluminum tubing, while the coax braid goes to the radials. Attach a small weight, like a heavy hex-nut to the end of each radial, which is helpful to weigh down the radials in the field.

To insulate the ground radials from the center conductor, I used a 6-inch length of 1/2-inch inner diameter PVC plastic tubing mounted with a 1/8-inch bolt to the bottom of the 1/2-inch aluminum tube section. The two pieces fit loosely, so I wrapped a QSL card around the aluminum tube before I twisted it into the PVC pipe. I finished off the PVC section by installing a rubber chair tip on the end.

### Setting Up the Antenna

To set up the antenna in the field, place hose clamps over the slotted ends of each of the standard aluminum tubes that make up the base section. Slide the *unslotted* end of the 3/8-inch tube into the slotted end of the 1/2-inch tube. Tighten the hose clamp for a snug fit.

Slide a hose clamp halfway down the tent-pole section of the antenna, followed by the guy ring. The ring is held in place by the hose clamp.

Tie three 15-foot lengths of nylon string onto the guy ring using a nonslip knot such as a bowline. I used braided mason "snap line" for my guys. The guy ropes work nicely with lightweight tent stakes or pins. My stakes are 6-inch lengths of aluminum with a curved top. (I found them at a trail shop for 50 cents each.) Longer plastic stakes will work fine, too, and are useful for supporting the antenna in extremely loose soil, such as a sandy beach.

Slide the assembled tent-pole tubing into the slotted end of the 3/8-inch tube and tighten the hose clamp. Raise the antenna to the vertical position, then plant your stakes at equidistant points around the base. It helps to have another person perform this task while you hold the antenna. If you're alone, lay the antenna flat and stake the first two guys. Then, erect the antenna and stake the last guy. Attach the coaxial cable as I've already described and you're in business!

### The Joys of Phasing

We usually think of verticals as omnidirectional antennas. That is, they radiate more or less equally in all directions. But if you combine two or more verticals in the proper way, you can create an antenna that has a very *directional* pattern. This technique is known as phasing.

Chapter 8 in the 17th edition of *The ARRL Antenna Book* is all about antenna phasing, and phasing can be tricky stuff. Two factors determine the pattern of gain resulting from the phasing of two vertical

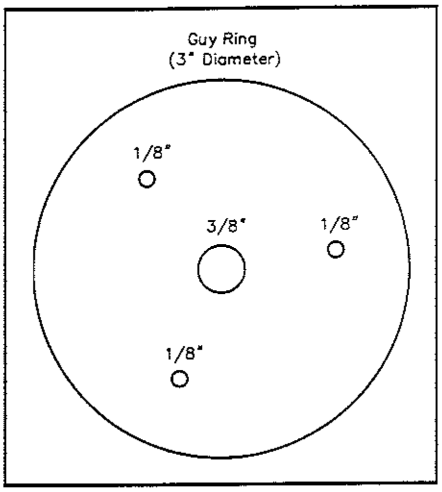


**Figure 2—Guy ring construction.**

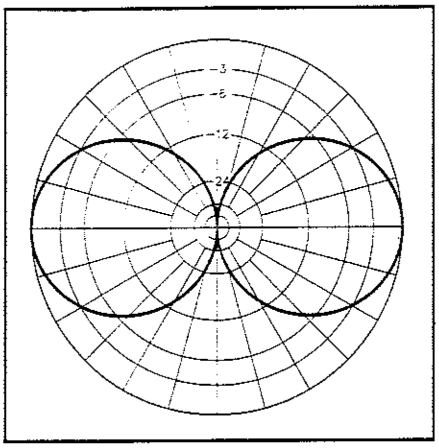


**Figure 3—A figure-8 gain pattern results when two verticals fed at a 0° phase angle and separated by ½ wavelength.**

**Table 2**
**Coax Lengths and Separation Distances**
(Figures for the 11-ounce, 20-meter vertical are highlighted.)

| *Band (meters)* | *Separation Distance (feet)* | *Coax Lengths (feet)* |
|---|---|---|
| 10 | 16.6 | 9.8 ft |
| 12 | 18.8 | 11.1 |
| 15 | 22.2 | 13.1 |
| 17 | 25.8 | 15.1 |
| **20** | **33.4** | **19.7** |
| 30 | 46.2 | 27.0 |
| 40 | 66.6 | 39.3 |

antennas: (1) the distance between the antennas, and (2) the *phase angle* of the current driving the antennas.

Practical distances generally vary from ⅛ wavelength to 1 wavelength. Phase angles vary from 0° to 180°.

Figure 10 in Chapter 8 shows a comprehensive set of gain patterns resulting from combinations and permutations of antenna distance and phase angle. But one particular case of vertical antenna phasing is of interest to beginners: The case of antenna separation of ½ wavelength when the phase angle is 0°. (When the phase angle is 0°, we say the antennas are "in phase.")

This case is important for *two* reasons: (1) The resulting antenna gain pattern is extremely useful, and (2) achieving a phase angle of 0° with two identical elements is very easy.

The resulting gain pattern is a figure-8 pattern broadside (perpendicular) to the axis of the antennas (that is, perpendicular to the line connecting the antennas). The pattern has broad lobes with a peak gain of 4 dB over a single vertical antenna (Figure 3). I used such a configuration at Field Day with the axis connecting the antennas pointing northwest to southeast, so that my gain would lie in the direction of southwest to northeast. The implications of this arrangement are that a pair of 11-ounce antennas that are easily set up by a single person, can provide gain in two fixed directions.

Simply feed each vertical antenna with *equal* lengths of coax and bring them into a coaxial **T** connector (Figure 4). While the lengths will not alter the phase angle (as long as they are the same), they *will* impact the impedance and SWR of the antenna system. The feed line from the **T** connector to the transmitter may be of any length, however.

Table 2 provides the approximate lengths of coax needed to minimize the SWR for this antenna system. They are valid only if you use RG-8, RG-58 or RG-174 coax with *solid* (not foam) dielectric. You may need to adjust the lengths to obtain the best SWR but remember to keep the two cable lengths equal. Once you've successfully tackled two antennas fed in phase, consult *The ARRL Antenna Book* to experiment with other combinations of phased verticals.

## Lightweight Feed Lines

Reducing weight and bulk is not usually critical in camping situations like Field Day. You can bring along the ice chest, hibachi, coals, and plenty of RG-8 coax. I'm a big fan of high-performance coax, and I use it whenever I can.

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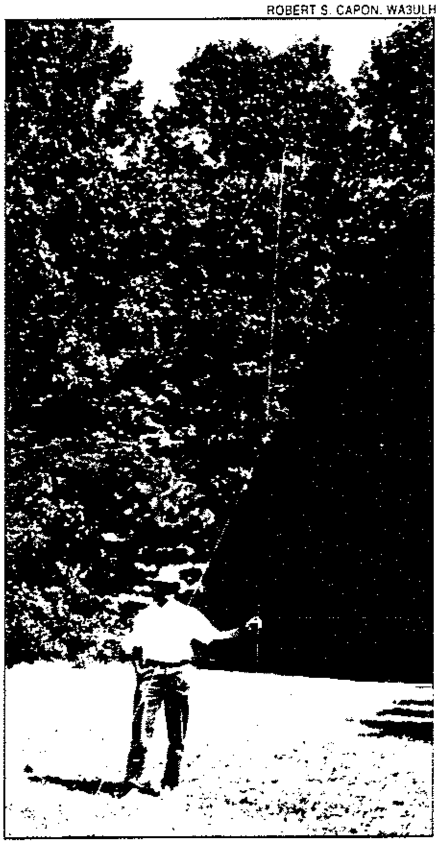


**All set up and ready for action!**

But backpacking is a demanding situation in which weight and bulk must be pared to the bone. It's not at all unusual for backpackers to hack off the handles of their toothbrushes and to tear out unneeded sections of guide books to reduce weight!

If you're planning to backpack, you may want to experiment with RG-174 coax. RG-174 is only 0.1 inch in diameter and extremely lightweight. A 20-foot length fitted with connectors weighs only three ounces, making it the perfect companion for the 11-ounce vertical.

The trade-off with RG-174 is loss. This makes RG-174 impractical for VHF and UHF applications, but somewhat more acceptable for HF work, especially below 20 meters. Figure 24.22 in *The ARRL Antenna Book* depicts the relationship between loss (in dB per 100 feet of cable) and frequency for different types of coax. The following data was extracted:

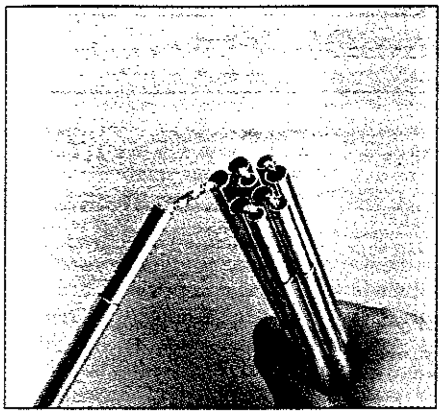
| | *Loss (in dB per 100 feet)* | | |
|---|---|---|---|
| *Coax* | *7 MHz* | *14 MHz* | *144 MHz* |
| RG-8 | 0.55 | 0.8 | 3.0 |
| RG-174 | 3.3 | 4.5 | >10 |

Therefore, a 20-foot length of RG-174 loses only 0.9 dB of our RF on 14 MHz. Remember that the data is for 100 feet of coax and we're only using 20 feet. Divide the 4.5-dB loss figure by 100, then multiply the result by 20.

## Operating Results

A pair of my 11-ounce verticals was put into service for Field Day 1995. Both antennas were set up in about 30 minutes, including eight ground radials and RG-8 coax for each antenna. Using my Autek RF-1 antenna analyst, it was easy to adjust the height of each vertical by changing the lengths of the collapsible sections. I eventually achieved an SWR of 1.1:1 at the frequency of interest—14.025 kHz—on both antennas.

I then hooked up the equal lengths of RG-8 feed line to the **T** connector and measured the SWR at the output of the connec-



**An elastic bungee-type cord holds the tent-pole tubing sections together. Just slide the bottom of one tube over the top of the other. Release the tubes and they snap into place! You can assemble the entire vertical section in seconds.**

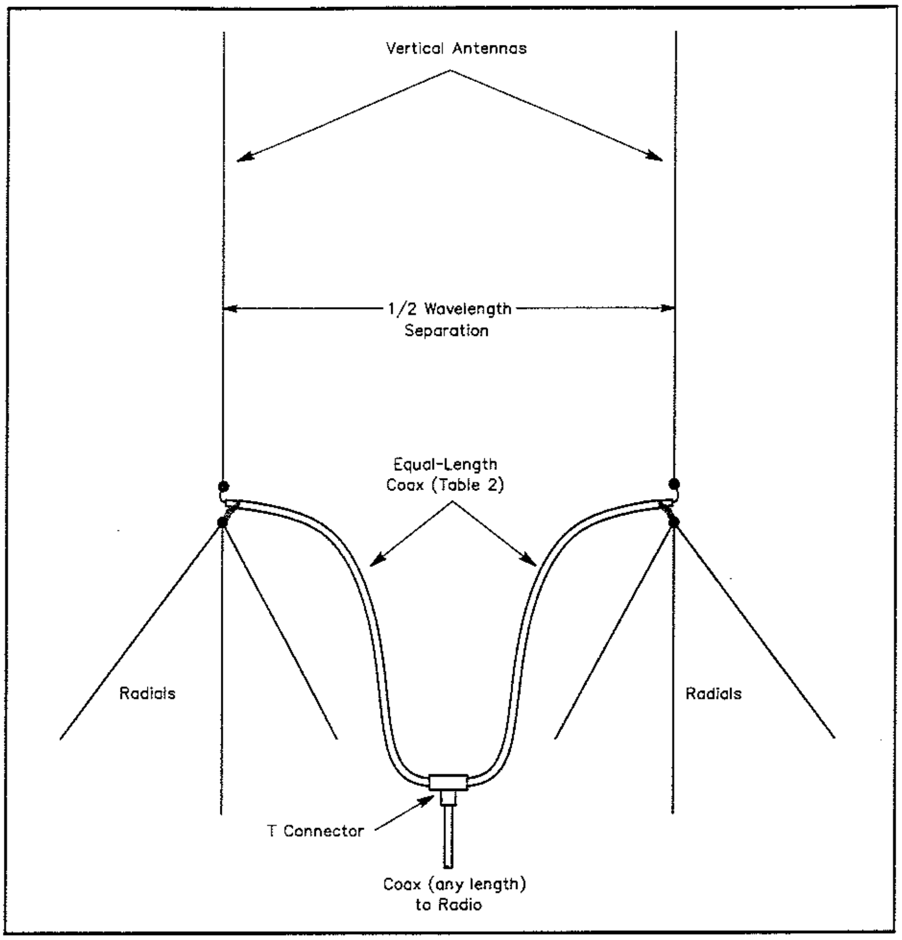



**Figure 4—Phasing isn't as difficult as it seems. It's just a matter of setting up the verticals at the correct distances from each other and using feed lines of equal length.**

tor. It was only 1.6:1. I used a 50-foot run of RG-8 from the output of the **T** connector to the transmitter, and also read an SWR of 1.6:1 at the transmitter.

I was very pleased with the extra gain I was able to achieve. I had good coverage throughout the West, Midwest, Texas, and the Northeast. The nulls in the radiation pattern of the antenna made it difficult to make contacts into 8-land, 9-land, Florida and the Caribbean, but that's to be expected.

With my phased verticals I racked up a respectable 213 contacts on 20-meter CW. The transceiver was an MFJ-9020 running only 4 W and operating on solar-powered batteries.

For Field Day 1996, I plan to set up *two* phased vertical arrays separated by a considerable distance with my station in between. In this manner, I will be able to use an antenna switch to select between North/South and East/West directivity.

### Next Steps

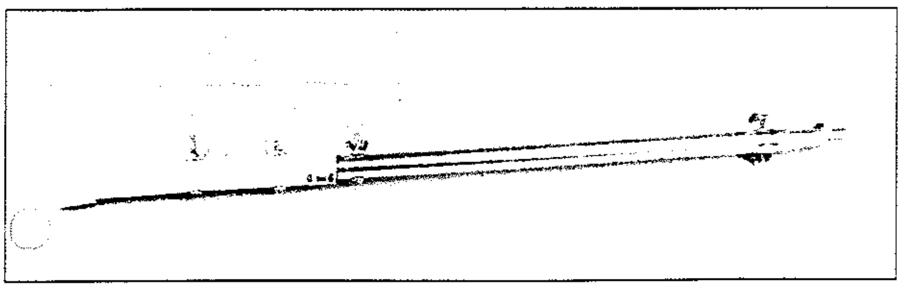
My discussion about phased verticals is intended only as a primer into this rich and complex topic. I encourage you to explore further! Chapter 8 in *The ARRL Antenna Book* deals extensively with phased antennas and includes a lot of the pioneering work of Roy Lewallen, W7EL. Phasing is not at all limited to vertical antennas. My friend Paul, AA4XX, who operated with me during Field Day 1995, set up a pair of phased inverted **V** antennas for 40 meters at a height of 50 feet. Using this interesting antenna design, Paul worked a blistering 325 contacts on low-power 40-meter CW!

*Thanks to my antenna buddy Paul, AA4XX; Ernie, AD4VA; and my son Howard, KE4RUZ (age 8), for helping to field test the antenna and feed lines. Also, special thanks to Roy Lewallen, W7EL, for preparing the table used in this article, and for suggesting the use of RG-174.* QST

## *Radio Tips:* HF Verticals

The vertical is a popular antenna among hams who lack the space for a beam or horizonal dipole. In an electrical sense, a vertical is a dipole with half of its length buried in the ground or "mirrored" in its counterpoise system. Verticals are commonly installed at ground level, although you can also place a vertical on the roof of a building, too.

Vertical antennas take little horizontal space, but they can be quite tall. There is also the space required by all those *radial* wires at the base. The good news is that you don't have to run the radials in straight lines. In fact, you don't even have to run them underground. Depending on the type of soil in your area, you may get away with a few radials, or you may have to install several *dozen*. Some multiband vertical designs do not use radials at all, so they're quite popular for obvious reasons.—*WB8IMY*



**The base section of the 11-ounce vertical is made of standard aluminum tubing (see text). The wingnuts are the attachment points for the center conductor and shield of the coax.**