By L. B. Cebik, W4RNL

A 6-Meter Quad-Turnstile

Looking for improved omnidirectional, horizontally polarized performance? This 6-meter turnstile uses the quad loop as a foundation.

Turnstile Principles and Limitations

Figure 1 shows the classic turnstile configuration: Two dipoles at right angles to each other. The main feed line feeds one of the dipoles. A ¼ λ phasing line runs from the first dipole and feeds the second. If the phasing line is exactly ¼ λ long (or 90° electrically) and if the impedance of that line is a match for the resonant impedance of the individual dipoles (70 Ω), then the second dipole will have a current magnitude that is identical to that of the first dipole but the dipole currents will be 90° out of phase. Proper current phasing is required to obtain a nearly circular pattern with no more than about 1 dB gain variation. This ideal condition is called quadrature.

The standard dipole-turnstile has some limitations. The system feedpoint impedance is 35 Ω and requires a matching system if the 1.45:1 SWR level is not satisfactory. Special impedance-based systems that simultaneously obtain proper phasing and a 50-Ω match tend to show distorted patterns because, while they present a good match to the main feed line, they fail to achieve the proper current conditions on the two dipoles. Indeed, the SWR curve for any turnstile is so broad that it is useless as an indicator of proper antenna operation.

The dipole-turnstile has a second limitation: If we operate the antenna too far from the design frequency or if we carelessly construct the antenna or phasing line, then the pattern will no longer be omnidirectional. Instead, it becomes a bidirectional oval with an increasing differential between maximum and minimum gain as we drift from the design frequency. Unfortunately, SWR will give us

An overall view of the quad-turnstile on the assembly and test stand. I took this photo during initial tests before adding the perimeter cord and taping down the phasing line and feed line.

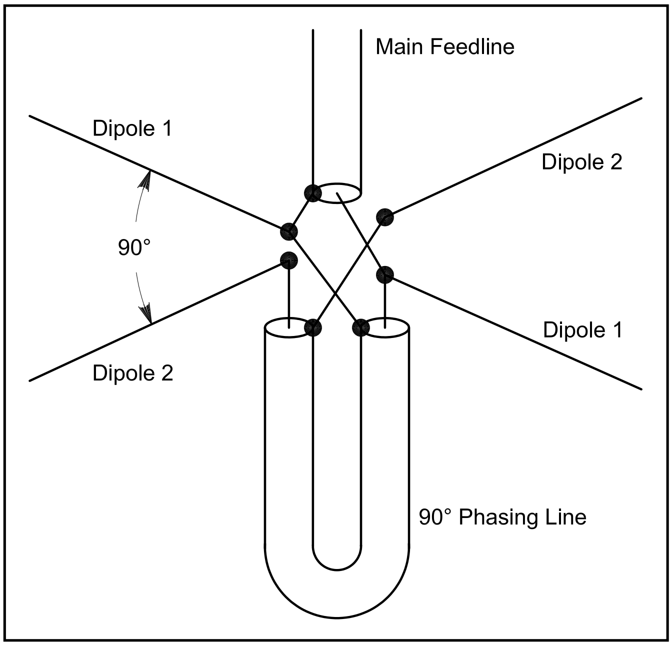

Figure 1—The general outline of a dipole-turnstile. The feedpoint connection scheme also applies to the quad-turnstile described in the text.

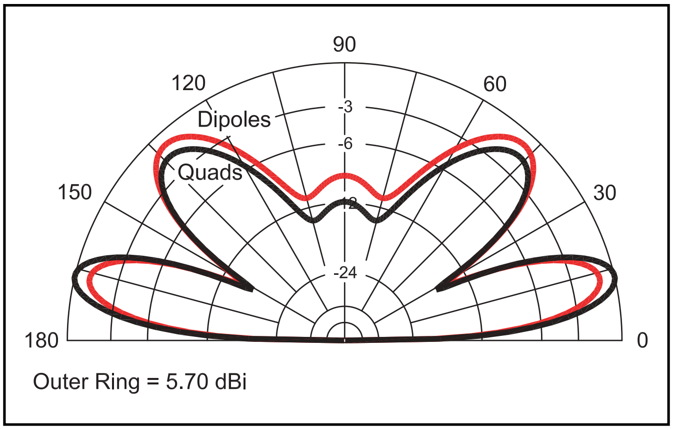

Figure 2—Comparative elevation patterns for a dipole-turnstile and a quad-turnstile when both antennas are 1 λ above ground.

no clue to the drift. Careful design and construction are the keys to effective turnstile operation.

A third limitation of the dipole-turnstile results from the fact that the strongest radiation is broadside to the pair of dipoles. In free space, the H-plane radiation is stronger than the E-plane radiation. Ground reflections permit the dipole-turnstile to develop a usable pattern. Figure 2 shows the elevation pattern for the dipole-turnstile. At 1 λ above ground the second elevation lobe is actually stronger than the lowest, the lobe we use for point-to-point 6-meter communications. One wavelength is about 20 feet at 6 meters—a typical height for casual operation.

Figure 2 also shows the elevation pattern for a pair of quad loops in a turnstile configuration that partially corrects the radiation pattern problems. This antenna's lower lobe is the strongest and in addition, shows about 1 dB additional gain. Figure 3 compares the azimuth patterns for the two antennas at an elevation angle of 14º. The quad-turnstile not only has more gain, but its pattern is slightly more circular than that of the dipole-turnstile.

For contrast, Figure 4 shows the azimuth patterns of the lower lobes with the antenna operated 5% off-frequency (53.025 MHz). The effect—a radically distorted pattern—is equivalent to cutting the loops 5% too long. The current magnitudes on the elements of both types of antennas are no longer the same, and the current phase angle between elements is no longer 90º. The quad-turnstile may offer a bit more gain, but it is just as susceptible as the dipole-turnstile to both construction and operating errors.

Regardless of important design sensitivities of turnstiles in general, the quad-turnstile has enough advantages over the dipole-turnstile to warrant consideration if you are just beginning to look for an omnidirectional horizontal antenna for 6 meters.

Building a Quad-Turnstile

The photographs will give some perspective views of the basic quad-turnstile, while the sketches of construction details provide dimensions and details. A quad-turnstile will maintain its omnidirectional pattern with about a 1-2% error either in construction or operating frequency. Therefore, the quad-turnstile shown here has been optimized for 50.5 MHz using AWG 14 bare copper wire. Do not use the listed dimensions with insulated wire, since insulation gives antenna wire a velocity factor that ranges from about 0.95 to 0.99, depending upon the thickness and composition of the insulating material. If you choose to use insulated wire, first construct a single quad loop element and bring it to resonance at the design frequency. The dimensions you obtain for this antenna can be copied to the second loop.

Figure 5 shows the dimensions of a quad-turnstile based on a diamond configuration. There is no significant radiation difference between a square quad loop and a diamond-shaped loop. The diamond allowed a very simple form of construction and became the basis for the quad-turnstile. Table 1 is a bill of materials for the antenna.

The Phasing line

A resonant quad loop has a feedpoint impedance of just about 125 Ω. We connect the two loops of the quad-turnstile exactly as we would connect a dipole-turnstile. We need a 90º (¼ λ) phasing line having this characteristic impedance (Z_0). RG-63, carried by the Wireman, is ideal for the job. The resulting antenna feedpoint impedance is 62 Ω, which requires no special matching to a standard 50-Ω main feed line if a 1.25:1 SWR is acceptable. (In practice, the minimum SWR may be about 1.3:1 to 1.4:1, depending upon the reactance introduced by the leads between the loops and the coax connectors.)

A wavelength at 50.5 MHz is 233.72 inches, so a quarter-wavelength is 58.43 inches. However, the listed velocity factor of RG-63 is 0.84. Therefore, 49.1 inches (58.43 × 0.84) will be the correct physical cable length to give a 90º electrical length. When cutting the cable, include the coax connectors in the measurement of total cable length, since they are part of the shielded cable section.

Having prepared the phasing line for

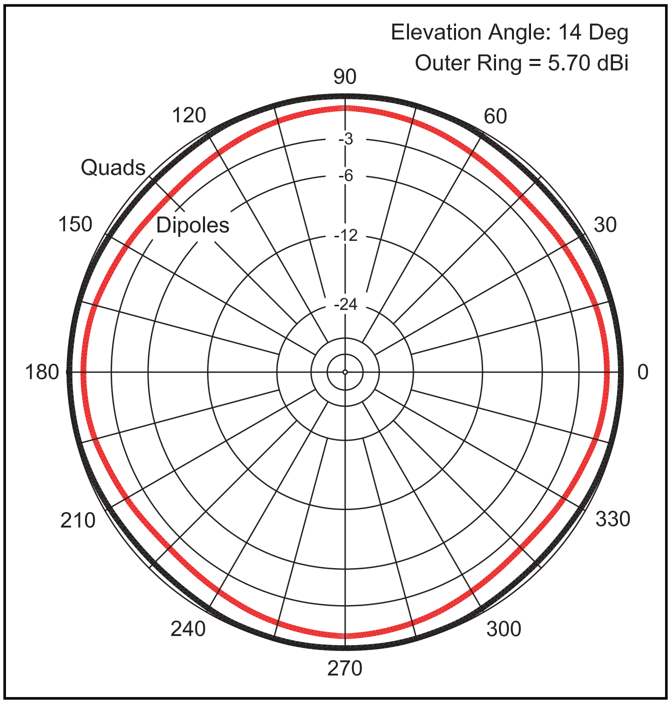

Figure 3—Comparative azimuth patterns for a dipole-turnstile and a quad-turnstile when both antennas are 1 λ above ground. The elevation angle is 14°.

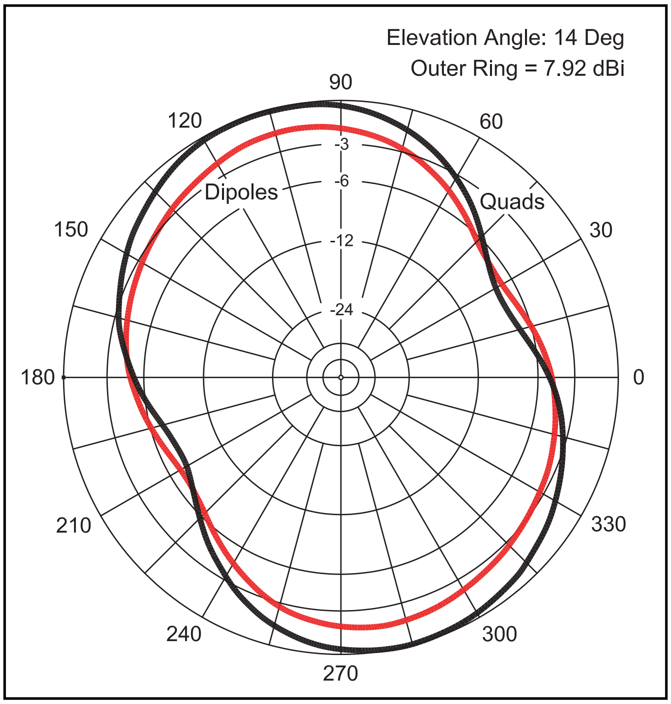

Figure 4—Comparative azimuth patterns for a dipole-turnstile and a quad-turnstile when both antennas are 1 λ above ground at 5% above the design frequency. The elevation angle is 14°.

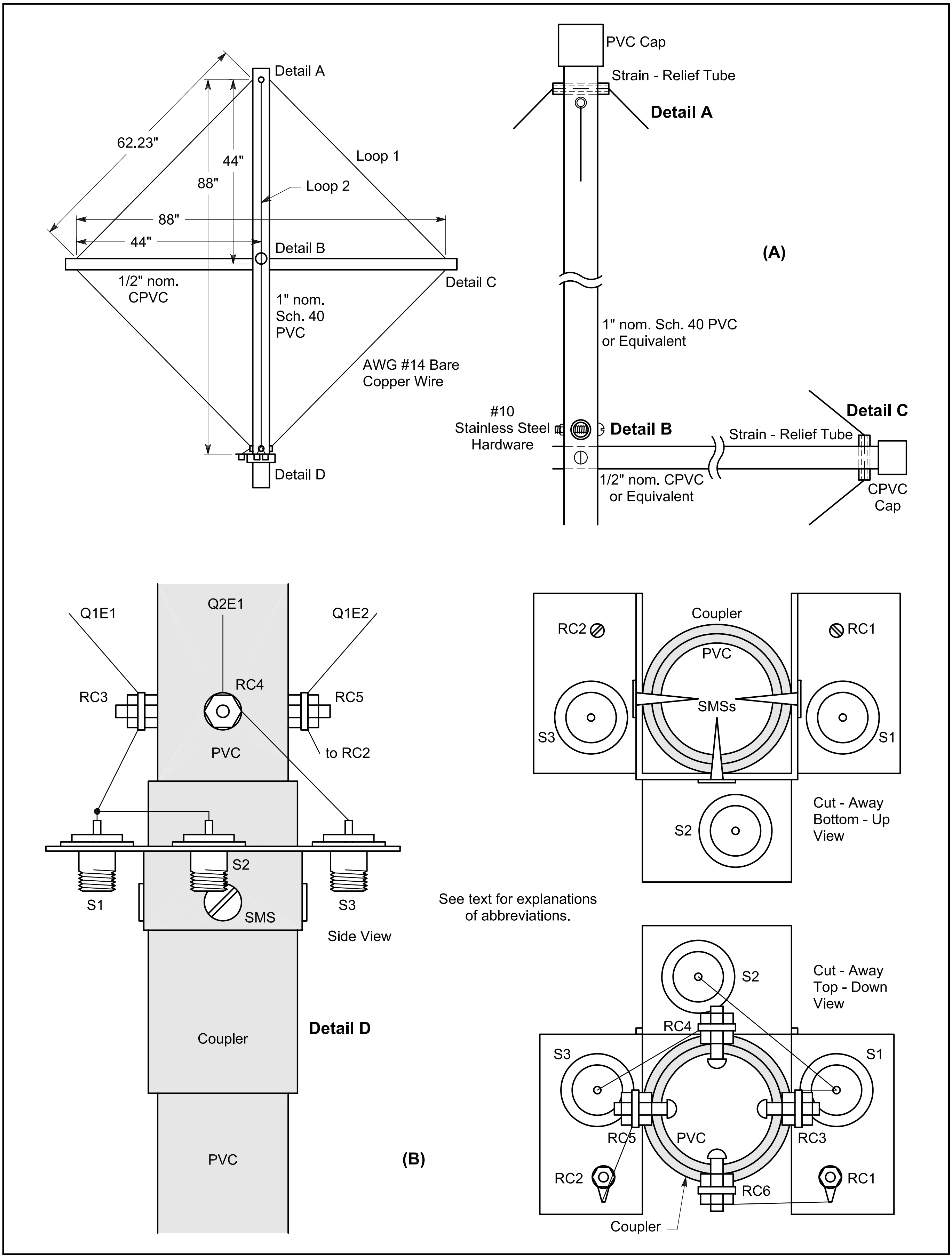

Figure 5—The general outline and dimensions of each quad loop in the quad-turnstile. Details A, B and C show the main post-to-crossarm connection and the slip tubes and end caps at the quad loop corners. Detail D shows several views of the antenna base connections and the coax connector assembly.

A close-up view of the base and connector assemblies. The photo preceded the final waterproofing of all exposed connections.

Table 1
Bill of Materials

Quantity	*Material Description*
43′ min	AWG 14 stranded or solid bare copper wire.
5′	RG-63/U coaxial cable.
2 – 8′ sections	½″ nominal CPVC pipe (gray electrical conduit may be substituted).
1 – 8′ section	1″ nominal Schedule 40 PVC pipe (gray electrical conduit may be substituted).
4	½″ CPVC pipe cap.
1	1″ PVC pipe cap.
1	1″ PVC pipe coupler.
3 to 4″	1″ aluminum L-stock (also called angle stock).
3	SO-239 single-hole connectors.
2	#10 1½″ stainless steel bolt.
6	#10 ¾″ stainless steel bolt.
2	#10 stainless split-O steel lockwasher.
10	#10 stainless steel nut.
8	#10 stainless steel flat washer.
3	#10 stainless steel sheet metal screws.
6 – 2″ pieces	Nylon or plastic tubing (see text).
2	#10 ring terminals.

the quad-turnstile, let's build the antenna itself. My support structure consists of a center pole and two cross arms. The center pole is 1 inch nominal Schedule 40 PVC. In some areas of the country, white PVC is not adequately protected from ultra-violet degradation, so the gray electrical conduit of the same size may be a better choice. The cross arms consist of ½ inch nominal CPVC, which is strong enough to support the wires with minimal weight. The cross arms pass through holes (at right angles to each other) in the center pole. A 1½-inch #10 stainless steel bolt, lock washer and nut secure each cross arm. The cross-arm holes in the main pole should be immediately above and below one another without overlapping.

At each end of the cross arms I drilled a 3/16 inch hole. I epoxied a piece of plastic tubing in the hole to reduce abrasion on the antenna wires. Nylon or other plastics, as well as AWG 12 house wiring insulation, will do the job if the #14 wire passes through smoothly. [US Plastic Corp (tel 1-800-809-4214; **www.usplastic.com**) sells flame-retardant and UV-resistant polyethylene tubing, recommended for this application.—Ed.] For ease of handling, I used tubing pieces that are longer than needed. Once the epoxy had set, I trimmed the tube ends about ¼ inch beyond the cross arm. Figure 5A shows the rough details of the crossarm and main pole end treatments.

The main support pole has two 3/16 inch wire holes near the top, very close to each other and at right angles. These holes align with the cross arms and pass each quad loop while maintaining a small separation. Both holes receive the strain-relief tubing treatment. The cross arms and the main pole top end have about an extra inch of PVC, permitting the addition of caps to keep water out of the support pipes. For true water-tightness, seal the opening in the main support where the cross arms pass through, as well.

The Loop Wires and Connector Assembly

We can prepare the top three corners of the quad loops simply by measuring, drilling, cementing, and bolting. However, let's proceed more slowly with the rest of the antenna. The first step is to measure the wire for each loop. For AWG 14 bare wire (stranded or solid), the loop circumferences are 20.74 feet or 249 inches as close as your tape measure will permit. Leave (and mark) about 2 inches of extra wire on each end for connection leads. Tin—that is, coat with solder—the first and last 3 inches of each wire, whether stranded or solid.

Set the wire aside and examine Figure 5B. In the following notes, the abbreviations used on the drawing appear in parentheses. At the base of the main PVC post a coupler—a short PVC connector designed to join two sections of PVC pipe—will be installed. We shall also construct a bracket to hold the three coax connectors we need—one for each end of the phasing line and one for the main feed line.

The bracket was made from a piece of 1/16 inch thick aluminum L-stock that was 1 inch on a side. I measured the PVC coupler outside diameter and marked the L-stock accordingly. I then drilled 5/8 inch holes in the L-stock top plate for single-hole SO-239 coax connectors (S1, S2, S3). As shown in the drawing, the holes are as close to the open edge of the L-stock as the connector mounting hardware would permit. I also offset them from the center of each section of stock. The offset permits easy installation of the bracket mounting screws, and the near-edge position provides clearance for the male coax connector shell to fit between the SO-239 and bracket. #10 stainless steel hardware provides mounting points for the ring terminals (RC1 and RC2) that will terminate each quad loop on the coax braid side.

Once the drilling is complete, hacksaw through the top plate of the L-stock so that you can bend it around the PVC coupler, making the three-sided bracket. On each side, drill a hole in the L-stock to pass a #10 stainless steel sheet metal screw (SMS). Fit the bracket very close to the top of the coupler and drill smaller holes so that the screws will bite and tap the coupler. Attach the bracket to the coupler with the sheet metal screws. However, do not yet glue the coupler and connector assembly to the main post.

Take one of the loop wires and temporarily clamp or tape it to the post just above the point where you think that you will mount the base assembly. Now thread the wire through the cross arms and main post holes so that both ends approach the base of the main post at the marks you made on the wire indicating the ends of the loop. Mark the post for the four #10 stainless steel bolts and nuts (RC3, RC4, RC5, RC6). From the bolt position, leave enough extra PVC (about $1^{1}/_{8}$ inches) to allow mating with the coupler and then cut off the main post. Drill four holes in the main post and install #10 bolts with a single nut on each one.

Remove the connector bracket from the coupler. Cement the coupler to the main post using good quality PVC cement, maintaining good alignment between the connectors and the cross arm assemblies. Once the PVC cement dries (less than 1 minute), drill through the holes in the coupler into the main post. Reattach the connector bracket. The double thickness of PVC will provide a secure assembly with only three #10 sheet metal screws.

Installing the Loops

Start the installation of the first loop. Leaving enough wire to reach the RC1 or RC2 terminal, wrap a single tight turn of the antenna wire around the connector bolt. This relieves strain from the coax and ground connectors on the base assembly. Add a washer and nut and tighten this connection. As an alternative, you may cut the loop wire and use ring connectors on this bolt. Now add (crimping and soldering) the ring connector that attaches to the connector assembly plate, trimming any excess from the wire-end lead.

At the other end of the wire, similarly attach the loop wire to the proper bolt on the main post. Tension the wire enough so that the loop does not flop about, but not so much as to bend the cross arms. Run the loose wire end lead to the appropriate SO-239 terminal (S1 or S3), trim any excess, and solder. Repeat this process for the second loop. Be sure to add a bridge wire from the main feed line connector (S1) to the first phasing line connector (S2).

You can optionally add at each cross arm a thin wire soldered to the loop wire above and below the slip tube and run on the outside of the arm. These wires will tend to keep the cross arms from drooping with time, sun, and wind. For additional resistance to wind effects, you may add a perimeter UV-resistant cord, looping and knotting the cord at the ends of each cross arm. The result is an octahedron with considerable sturdiness, despite the light materials.

Completing the Antenna

When you have finished the basic antenna construction, you should have some leftover 1 inch PVC. Cement one end of this tubing into the bottom of the coupler. To mount the antenna on a standard TV mast, you can cement or bolt a length of this tubing into 1¼ inch nominal Schedule 40 PVC to make a fitting that will slip over the mast. A few wraps of electrical tape around the TV mast will provide a tight fit for the larger PVC, while the 1 inch stock will come to rest on the mast top.

Since coaxial cable tends to be heavy, when you install the main feed line and the phasing line, tape them to the main mast. A pair of tape wraps about 1 foot apart will provide adequate strain relief for the cables, antenna, and fittings. For minimum interactions among lines, place the phasing line on one side of the mast and run the main feed line down the other side. Once you have tested the antenna, waterproof all coax fittings and connections.

Conclusion and the Next Step

I have relied on construction details that will assure an antenna that is close to optimal, because normal ham equipment does not permit very meaningful performance measurements. If you choose to use a different wire or construction scheme, the first step will be to resonate a single quad loop at the design frequency. A single loop will show a 125-Ω resistive impedance with little or no reactance at resonance. You can then use this wire length for both of the quad-turnstile loops. The required wire lengths for bare AWG 18 through AWG 10 are within the recommended 1% tolerance, so you may use the listed dimensions with any of these wire sizes.

The performance expectations that I have shown are based on placing the base of the antenna at a height of 1 λ above ground. Additional height will lower the elevation angle of the lowest lobe and improve performance. There will be a limit to wind survival, however, with the fairly light construction shown.

Beyond the quad-turnstile, for added omnidirectional horizontally polarized gain, we might turn to a pair of dipole turnstiles vertically stacked about $^{1}/_{2}$ λ apart. However, the design of such a stack involves paying close attention to the mutual coupling between the dipoles. That interaction results in the need for a non-standard phasing line Z_0, along with other complexities of in-phase feeding of the arrays. The assembly is also considerably wider and taller than our simple quad-turnstile.

As an intermediate step in the process of improving omnidirectional antenna performance, the quad is a notch better than the dipole. However, the care with which we constructed the quad-turnstile, if applied to a dipole turnstile, can go a long way toward getting the most out of the more elementary antenna. Phase-feeding elements, even in simple-looking arrays like the dipole and quad-turnstiles, requires all the care that we can bring to the shop.

*L. B. Cebik, W4RNL, retired from The University of Tennessee, Knoxville, a few years back to devote his time to research and writing, as well as a Web site primarily focused on antennas (***www.cebik.com***). His articles have appeared in nearly all ARRL periodicals. He has done books on quads and LPDAs, as well as a number of beginning antenna enthusiast volumes. He serves the League as both Technical and Educational Advisor and recently authored the ARRL on-line course on antenna modeling. You can reach the author at 1434 High Mesa Dr, Knoxville, TN 37938-4443;* **cebik@cebik.com**.

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