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By L. B. Cebik, W4RNL

Building a Medium-Gain, Wide-Band, 2 Meter Yagi

Raid your local hardware store and build this transportable VHF Yagi. Easily duplicated using common materials, it's inexpensive—and ideal for Field Day or emergency use.

Practical Yagis for the 2 meter band abound. What makes this one a bit different is the selection of materials. The elements are high-grade aluminum. The boom, however, is PVC, and there are only two #6 nut/bolt sets and two #8 sheet metal screws in the entire antenna. The remaining fasteners are all hitch-pin clips. The result is a very durable 6 element Yagi that you can disassemble easily for transport.

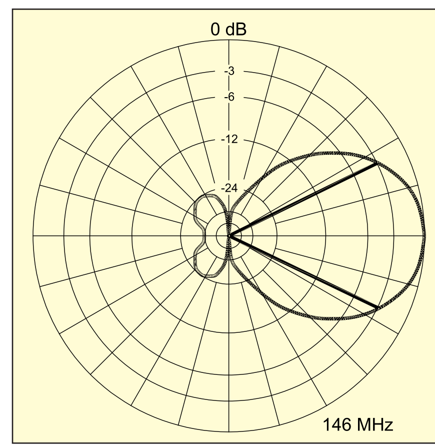

Figure 2—E-plane (horizontal azimuth) pattern in free space of the 2 meter, 6 element OWA Yagi at mid-band—146 MHz. The antenna exhibits a gain of about 10.2 dBi, consistent across the 2 meter band.

The Basic Antenna Design

Every antenna begins with a basic design. The 6 element Yagi presented here is a derivative of the "optimized wide-band antenna" (OWA) designs developed for HF use by NW3Z and WA4FET.[1] Figure 1 shows the general outline. The reflector and first director largely set the impedance. The next two directors contribute to setting the operating bandwidth. The final director (director 4) sets the gain. This account is oversimplified, since every element plays a role in every facet of Yagi performance. The notes, however, give some idea of which elements are most sensitive in adjusting the performance figures.

Designed on *NEC-4*, the antenna uses 6 elements on a 56 inch boom. Table 1 gives the specific dimensions for the version described in these notes. The parasitic elements are all 3/16 inch aluminum rods, while the driver—for reasons of construction—uses 1/2 inch aluminum tubing. Do not alter the element diameters without referring to a source, such as *The VHF/UHF DX Book* (RSGB), edited by Ian White, G3SEK (Chapter 7), for information on how to recalculate element lengths.

The driver is the simplest element to

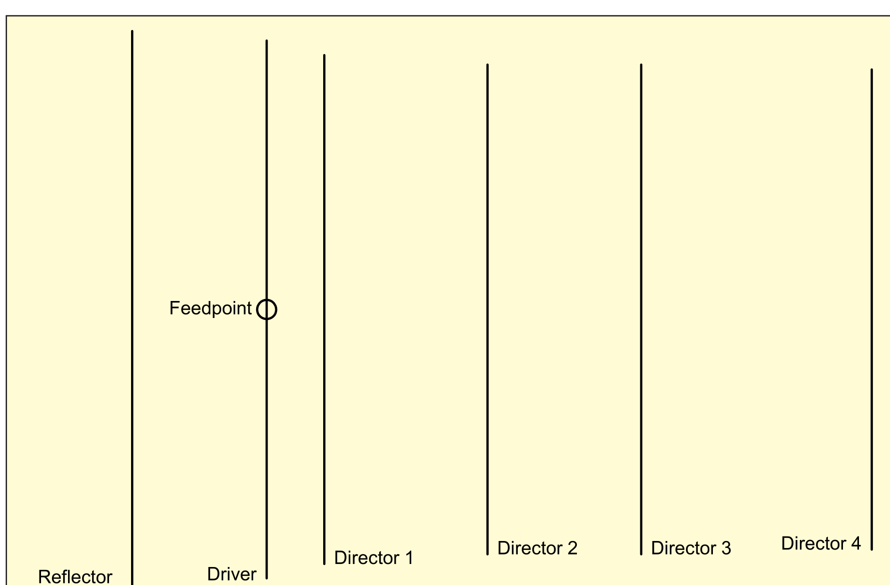

Figure 1—The general outline of the 2 meter, 6 element optimized wide-band antenna (OWA) Yagi. See Table 1 for dimensions.

[1]L. Cebik, "Notes on the OWA Yagi," *QEX*, Jul/Aug 2002, pp 22-34.

Table 1
2 Meter OWA Yagi Dimensions (in inches)

Element	*Element Length*	*Reflector Spacing*	*Element Diameter*
Version Presented in Text:			
Reflector	40.52	—	0.1875
Driver	39.70	10.13	0.5000
Alternate Driver	*39.96*	*10.13*	*0.1875*
Director 1	37.36	14.32	0.1875
Director 2	36.32	25.93	0.1875
Director 3	36.32	37.28	0.1875
Director 4	34.96	54.22	0.1875

Element	*Element Length*	*Reflector Spacing*	*Element Diameter*
1/8" Diameter Version:			
Reflector	40.80	—	0.125
Driver	40.10	10.20	0.125
Director 1	37.63	14.27	0.125
Director 2	36.56	25.95	0.125
Director 3	36.56	37.39	0.125
Director 4	35.20	54.44	0.125

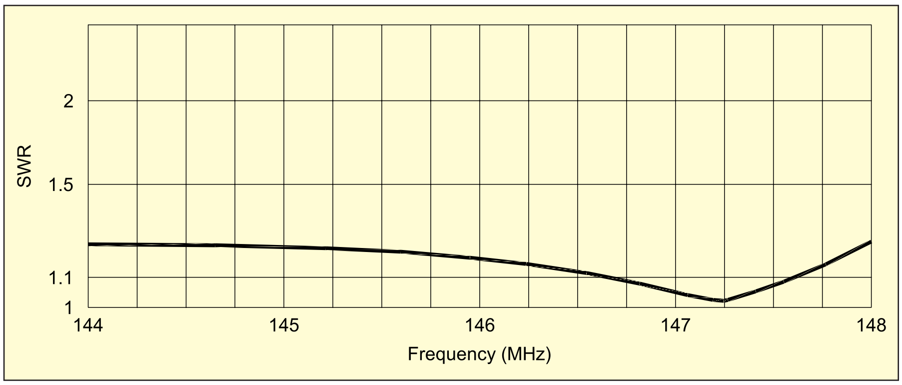

Figure 3—A 50 Ω SWR curve, as modeled on *NEC-4* for the 2 meter, 6 element OWA Yagi from 144 to 148 MHz.

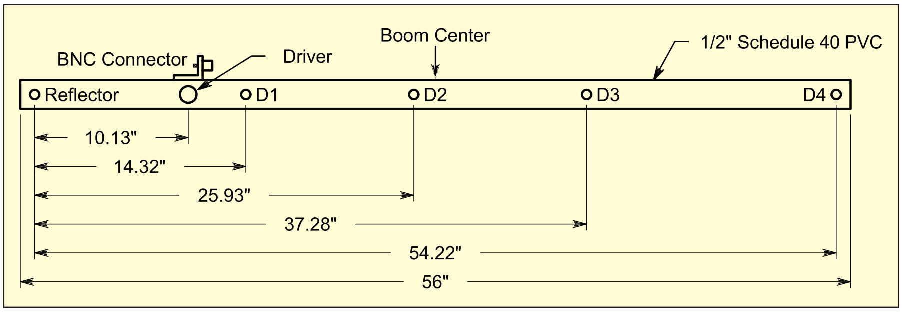

Figure 4—General layout of elements along the PVC boom for the 2 meter Yagi, showing the placement of the BNC connector and the boom center. See the text for element sizes, element to boom mounting and other details.

readjust. Table 1 shows an alternative driver using 3/16 inch diameter material. The driver is, perhaps, the only element that you can extrapolate a reasonable length for other diameters from the given lengths and diameters. The parasitic elements, however, may require more work than merely substituting one diameter and length for another. The right portion of Table 1 shows the design adjusted for 1/8 inch elements throughout. Not all element lengths change by the same amount using any single formula.

The OWA design provides about 10.2 dBi of free-space gain with better than a 20 dB front-to-back (or front-to-rear) ratio across the entire 2 meter band. Figure 2 shows a free-space azimuth (or E-plane) pattern at mid-band—146 MHz. The antenna is consistent in performance across the 2 meter band. The beamwidth will be considerably wider if we turn the antenna on edge for vertical polarization.

One significant feature of the OWA design is its direct 50 Ω feed-point impedance that requires no matching network. Of course, a common-mode choke to suppress any currents on the feed line is desirable, and a simple bead-choke of W2DU design works well in this application. The SWR, shown in Figure 3, is very flat across the band and never reaches 1.3:1. The SWR and the pattern consistency together create a very useful utility antenna for 2 meters, whether installed vertically or horizontally. The only question that remains is how to build the beam effectively in the average home shop.

Beam Materials

The first step in building the beam is acquiring the materials. Let's begin with the boom and then attack the elements. The boom is schedule 40, 1/2 inch PVC. I prefer using insulated booms for test antennas—they do not require refiguring the element lengths due to the effects of a metal boom. This is true whether or not we connect the parasitic elements directly to the boom material.

If the white plumbing material in your region is not well protected from the effects of ultraviolet (UV) radiation in sunlight, you may wish to use the gray electrical conduit version. White PVC stands up for a decade of exposure in Tennessee, but apparently does not do as well in every part of the US. If you use any other material for your boom, be sure that it is UV protected.

Figure 4 shows the element layout along the 56 inch boom. Centering the first element hole 1 inch from the rear end of the boom results in a succession of holes for the 3/16 inch pass-through parasitic elements. Only the driver requires special treatment. We will use a 3/8 inch hole to carry a short length of fiberglass rod that will support the two sides of the driver element. Note that I used a BNC connector mounted on a small plate, which we will meet along the way.

The boom is actually a more complex structure than initially meets the eye. We'll not only need a support for the elements, but a means of connecting the boom to the mast, as well. If we break the boom in the middle to install a T connector for the mast junction, we come very close to the second director. Figure 5 shows how to avoid this predicament.

Before we attack the boom with a drill, let's build it up from common schedule 40, 1/2 inch PVC fittings and linking lengths of PVC pipe. The figure shows

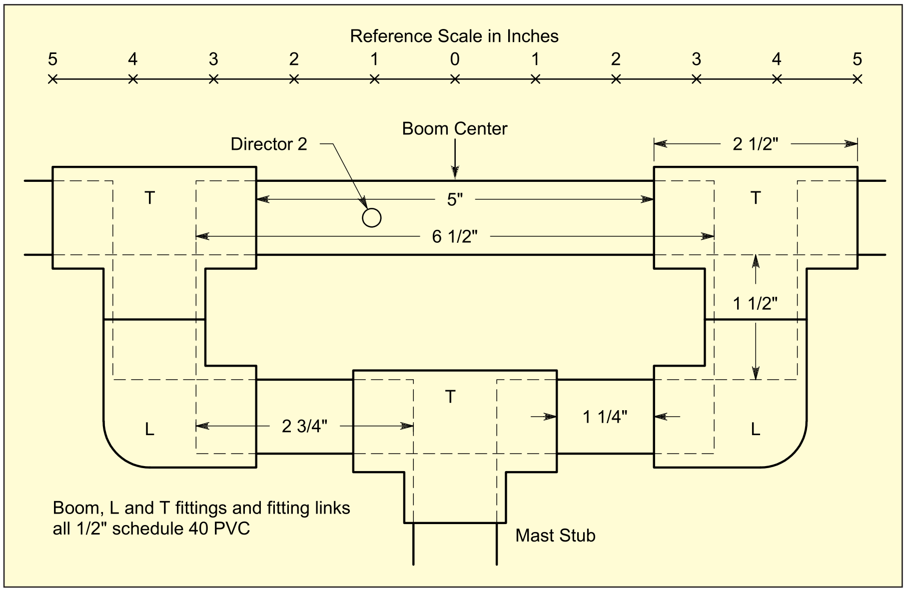

Figure 5—Details of a parallel PVC pipe structure for the Yagi boom and mount.

Figure 6—A close-up view of the parallel PVC boom and mount, the sequence of threaded fittings and the hitch-pin clips used to secure the parasitic elements.

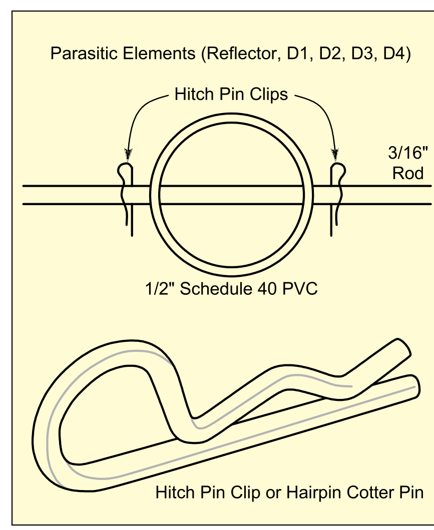

Figure 7—The parasitic element mounting system, showing the general placement of the hitch-pin clips and the shape of the clips.

the dimensions for the center section of the boom assembly. Note that PVC dimensions are always "nominal"; that is, they meet certain minimum size standards. For this reason, you may have to adjust the lengths of the linking pieces slightly to come up with a straight and true boom assembly.

I used scrap lumber to help keep everything aligned while cementing the pieces together. A 1×4 and a 1×6 nailed together along the edges produces a very good platform with a right angle. I assembled the two upper Ts and the Ls below each one first. I dry-fit scrap PVC into the openings, except for the short link that joins the fitting. I aligned them and cemented these in place, using the dry-fit pieces as guides, to keep everything parallel. I then cemented the two short (2 3/4 inch) links into the third T. Next, I cemented one link into its L, using the dry-fit tube in the upper T as an alignment guide.

Before proceeding further, I carefully measured the required length of PVC for the boom section between Ts. How well we measure here will determine whether the boom will be straight or whether it will bow up or down. Then I cemented both the L and the T at the same time, pressing the cemented sections into the two-board jig to ensure alignment.

The final step in the process is to add the 23 inch boom end pieces to the open ends of the upper T. During the brief period when the PVC cement is wet, it's possible to misalign the tubing. I dry-fitted end caps on the boom ends and did the cement work within the two-board jig. By pressing the assembly into the right angle of the boards, I ensured a very true boom. And, it was ready to drill before I had moved the PVC cement back onto its shelf.

Let's pause here to consider the boom-to-mast connection. The lower T in Figure 5 receives a short length of 1/2 inch schedule 40 PVC. This material has an outside diameter of about 7/8 inch, not a useful size for joining to a mast. However, PVC fittings have a handy series of threaded couplers that allow you to screw-fit a series of ever-larger sizes until you reach a more useful size. As Figure 6 shows, I used enough of these fittings to finish off with a 1 1/4 inch threaded female side and a 1 1/4 inch cement-coupling side. To this fitting, I cemented a length of 1 1/4 inch nominal tubing that slides over a length of common TV mast. For a tight fit, I wrap the TV mast with several layers of electrical tape in two places—one near the upper end of the PVC pipe section and the other close to where the PVC pipe ends. You can then use stainless steel through-bolts or setscrews to prevent the PVC assembly from turning.

Incidentally, I find it very useful to keep a graduated set of threaded fittings on hand, replacing those that I use in a project. For each male and female threaded size, I keep a double-threaded version, a threaded male and smooth version, and a female threaded and smooth version. The result is instant coupling capabilities, no matter what the project. The threaded couplings have proven to be exceptionally strong due to the multiple thicknesses of PVC involved. None has ever failed.

Boom and Elements

Before installing the elements, we need to drill the holes in the boom. Here, the temporary two-board jig comes in handy, once again. The key goals in the drilling process are to (a) precisely position the holes, (b) create holes that are a fairly tight fit for the rod elements and (c) keep the elements aligned in a flat plane. For this purpose, a drill press is almost a necessity for all but those with the truest eyes. There are three good sources for drill presses. One is to purchase a good one for the shop. A second is to purchase one of the better smaller substitutes that clamps your hand drill in a vertical position. A third source is a friend whose shop already has any type of drill press.

Use the jig and a couple of clamps to hold the boom assembly in place. Because the assembly has two parallel sections, laying it flat will present the drill press with the correct angle for drilling through the PVC in one stroke. Drill the holes at pre-marked positions, remembering that the driver hole is 3/8 inch while all the others are 3/16 inch. Clean the holes, taking care not to enlarge them in the process.

The rod and tube stock are dealt with next. For antenna elements, I prefer not to rely on questionable materials that are designed for other applications. Hence, I tend to obtain 6063-T832 tubing and 6061-T6 rods from mail order sources, such as Texas Towers, McMaster-Carr and others. These materials are often not available at local hardware outlets.

We are now ready to mount the elements—with a little preparation. Cut the parasitic elements to length and smooth their ends with a fine file or sandpaper. Find the center of each element and carefully mark a position about 1/16 inch outside, where the element will emerge from each side of the boom. We will drill small holes at these locations. You may want to very lightly file a flatted area where the hole is to go to prevent the drill bit from slipping as you start drilling.

Drill 1/16 inch holes at each marked location all the way through the rod. Deburr the exit ends so that the rod will pass through the boom hole. These holes are the locations for hitch-pin clips. Figure 7 shows the outline of a typical hitch-pin clip. Some suppliers also refer to this as a hairpin cotter pin. Obtain stainless steel pins whose bodies just fit tightly over the rod when they are installed. Initially, install one pin per parasitic element. Slide the element through the correct boom hole and install the second pin. Although the upper part of the drawing shows a bit of room between the boom and pin, that space is shown for clarity only. Install the pins as close to each side of the boom as possible.

Pins designed for a 3/16 inch rod are small enough so that they add no significant size to the element, and antenna tests show that they do not move the performance curve of the antenna. Yet, they have held securely through a series of shock tests that the prototype was subjected to. These pins—in various sizes—offer the home builder a handy fastener that is applicable to many types of portable or field antennas. While we may want to use better fasteners when making permanent metal-to-metal connections, for joining sections of Field Day and similar antennas the hitch-pin clips perform the mechanical function, while the clean tubing sections provide adequate electrical contact for the limited use period.

The Driver and Feed-line Connector

The final construction step is perhaps the one requiring the most attention to detail, as shown in Figure 8. The driver and feed-point assembly consists of a 4 to 6 inch length of 3/8 inch fiberglass or other nonconductive rod, two sections of the driver element made from 1/2 inch aluminum tubing, a BNC connector, a homemade mounting plate, 2 sets of stainless steel #6 nuts, bolts and lockwashers, and 2 stainless steel #8 sheet metal screws. Consult both the upper and lower portions of Figure 8, since some detail has been omitted from each one to show other detail more clearly. For example, the upper part does not show the BNC connector mounting hardware.

First, trial-fit the driver tubing and the fiberglass rod, marking where the rod exits the boom. Now pre-drill 9/64 inch holes through the tubing and the fiberglass rod. Do not use larger hardware, since the resulting hole will weaken the rod to the breaking point. If you use an alternative plastic material, observe the same caution and be certain that the rod remains strong after drilling. Do not use wooden dowels for this application, since they do not have sufficient post-drilling strength. Position the holes about 1/4 inch to 3/8 inch from the tubing end where the element presses against the boom. One hole will receive a solder lug and the other will connect to an extension of the BNC mounting plate.

Second, install the fiberglass rod through the boom. You can leave it loose, since the elements will press against boom and hold it in place. Alternatively, you may glue it in place with a two-part epoxy. Slide the driver element tubes over the rod and test the holes for alignment by placing the #6 bolts in them.

Next, cut and shape the BNC mounting plate from 1/16 inch thick aluminum. I made my fitting from a scrap of L-stock, 1 inch on a side. Before cutting the stock, I drilled the 3/8 inch hole needed for the BNC connector. I then cut the vertical portion. The horizontal portion requires a curved tab that reaches the bolt on one side of the boom. I used a bench vise to

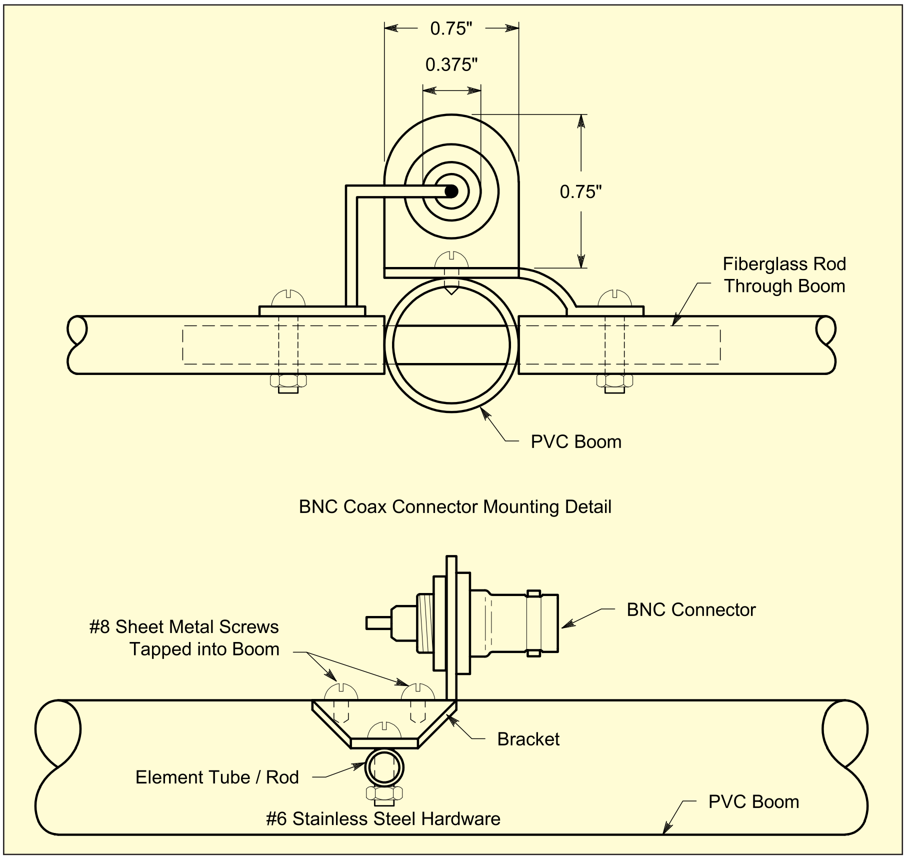

Figure 8—Details of the feed point of the Yagi, showing the BNC connector, the mounting plate and connections to the 1/2 inch driver element halves, which are placed over a central 3/8 inch fiberglass rod.

Figure 9—A photograph of the Yagi feed-point assembly. A study of this view and the drawing of Figure 8 should enable easy duplication of the feed system.

Table 2
Parts List for the 2 Meter OWA Yagi

Note: Sources in parentheses are suggestions only. The builder is encouraged to explore other sources.

17'	0.1875" (3/16") 6061-T6 aluminum rod (Texas Towers)
3.5'	0.5" (1/2") 6063-T832 aluminum tubing (Texas Towers)
7'	Schedule 40, 1/2" PVC pipe (local hardware outlet)
3	Schedule 40, 1/2" PVC T connectors (local hardware outlet)
2	Schedule 40, 1/2" PVC L connectors (local hardware outlet)
2	Schedule 40, 1/2" PVC (boom) end caps (optional) (local hardware outlet)
—	Miscellaneous male/female threaded pipe diameter transition fittings (local hardware outlet)
1	Support mast (RadioShack)
10	Stainless steel hitch-pin clips (hairpin cotter pins), 3/16"-1/4" shaft range, 0.04" "wire" diameter (McMaster-Carr 9239A024)
2	Stainless steel #6 nut/bolt/lockwasher sets, bolt length 1" (local hardware outlet)
2	Stainless steel #8 sheet-metal screws (local hardware outlet)
1	BNC chassis-mount female connector (local electronics outlet)
2"	1/16" thick aluminum L-stock, 1" per side (local hardware outlet)
1	VHF bead balun choke (Wireman, Inc)
7"	Fiberglass or other nonconductive rod, 3/8" diameter

bend the tab in a curve and then flatten it for the bolt-hole. It takes several tries to get the shape and tab exact, so be patient. When the squared-edge piece found its perfect shape, I took it to a disk sander and rounded the vertical piece to follow the connector shape. I also tapered the top edges to minimize excess material. The last step is to drill the mounting holes that receive the #8 sheet-metal screws.

Mounting the assembly requires loosely attaching both the #6 and #8 hardware and alternatively tightening up all the pieces. Be certain that the side of the BNC connector that receives the coax points toward the mast. Next, mount the BNC connector. The shield side is already connected to one side of the driver. Mount the other side of the driver, placing a solder lug under the bolt head. Connect a short wire as directly as possible from the solder lug to the center pin of the BNC connector. After initial testing, you may coat all exposed connections with Plasti-Dip for weather protection. Figure 9 shows the details.

Tune-Up

Testing and tuning the antenna is a simple process if you've built it carefully. The only significant test you can perform is to ensure that the SWR curve comes close to the one shown in Figure 3. If the SWR is high at 148 MHz but very low at 144 MHz, you will need to shorten the driver ends by a small amount—no more than 1/8 inch per end at a time. I found that shaving the ends with a disk sander was most effective.

Using the antenna with vertical polarization will require good spacing from any support structure with metal vertical portions. One of the easiest ways to devise such a mounting is to create a PVC structure that turns the entire boom by 90°. If you feel the need for added support, you can create an angular brace by placing 45° connectors in both the vertical and horizontal supports and run a length of PVC between them.

As an alternative, you can let the rear part of the boom remain slightly long. To this end you can cement PVC fixtures—including the screw-thread series to enlarge the support pipe size. Create a smooth junction that you attach with a through-bolt instead of cement. By drilling one side of the connection with two sets of holes, 90° apart, you can change the antenna from horizontal to vertical polarization and back in short order.

The 6 element OWA Yagi for 2 meters performs well. It serves as a good utility antenna with more gain and directivity than the usual 3 element "general-use" Yagi. When it is vertically polarized, the added gain confirms the wisdom of using a longer boom and more elements. With a boom length under 5 feet, the antenna is still compact. The ability to disassemble the parts simplifies moving the antenna to various portable sites.

Perhaps the most satisfying feature for me has been the adaptation of some little-used materials, such as hitch-pin clips, to the mechanical needs of the antenna. If I eventually decide that I've found a better design, I can save the costlier parts of the antenna—the elements and the connector—and discard the PVC in favor of a new mount that is custom-made for the new design. If the elements are too short for the new 2 meter design, then I'll likely adapt them to a design for 222 or 432 MHz. For the frugal antenna experimenter, adaptation is the name of the game. This 2 meter OWA Yagi, however, appears to be an antenna that I will keep for a long time to come.

Photos by the author.

*Licensed since 1954, L. B. Cebik, W4RNL, is a prolific writer on the subject of antennas. Since retiring from teaching at the University of Tennessee, LB has hosted a Web site (***www.cebik.com***) discussing antennas—both theoretical and practical. He has written more than 15 books, including the ARRL course on antenna modeling. Serving both as a technical and an educational ARRL advisor, he's also been inducted into both the QRP and QCWA Halls of Fame. LB can be reached at 1434 High Mesa Dr, Knoxville, TN 37938 or at* **cebik@cebik.com**.

FEEDBACK

◊ As a follow-up to the October Feedback item involving the schematic of "A Simple, Well-Behaved Crystal Oscillator" [Technical Correspondence, Sep 2004, p 67], we should also point out that both FET sources connect to resistor R2. Although the text did specify that the oscillator used "…source coupling between stages," some readers were confused because the FET source position was unconventional; it was at the top rather than at the bottom of the FET symbol (when the FET is drawn vertically).