High Performance 2 Meter Yagi

Improve your signal with this compact design.

by Bill Robertson W3HMI

It never ceases to amaze me that with 40 milliwatts of RF power into a yagi antenna, I could bring up a 2 meter repeater 30 miles away. But it happened. The report I got was of a "... raspy background but clear copy." Another incident that proves there is no substitute for a good antenna.

2 Meter Yagi Design

The antenna shown in Figure 1 has the characteristics listed in Table 1, which were taken from my old engineering notebook.

It is interesting to note that on the hand-drawn pattern of Figure 3, the E-plane pattern is skewed about 5 degrees off center. This skew is caused by the gamma matching element. The side of the radiator with the gamma element tends to be the side of the positive skew. Reversing the gamma element reverses the skew. When mounting the yagi vertically, it is best to have the gamma element on the upward side so the pattern will tend to point 5 degrees upward.

Super Portability

Transmitter hunters will find this antenna an asset because of its size, weight, mounting and operation ease. It can be mounted either horizontally or vertically.

After a look at Figure 1, it is evident that this yagi appears to be a little different from run-of-the-mill yagi antennas. The driven element is close to the reflector, and the reflector itself looks considerably longer than normal. The full size boom length is just under one wavelength.

The gain measured in the lab on a 20 to 1 model using a standard gain horn was 13.8 to 14.1 dBi over a 3 percent bandwidth. The beamwidth at the half power point is about 37 degrees in the E-plane (vertical plane, with the antenna mounted vertically), and about 42 degrees in the H-plane (horizontal plane). The VSWR (Voltage Standing Wave Ratio) with the gamma set as shown in Figure 2 is 1.5:1 or less at 145—148 MHz. You can get a larger bandwidth by changing some components in the gamma matching element. I have found that the combination shown fits my needs.

I always refer to this antenna as the "Stu Henderson Yagi," after the guru who developed all of its basic parameters, which he based on his original design for a folded dipole TV antenna. Stu spent many hours experimenting with this antenna design. My part in the design consists of the matching device and the construction technique.

Even though the antenna described here is for 2 meters, the same parameters work just as well for any frequency. See Table 2.

Wood or Metal?

The antenna and supporting mast are all metal with the tolerances held as close to within 1/16 of an inch as possible. Using metal for all the antenna parts does *not* affect the performance.

In several articles I have read lately, the beam antennas have wooden booms and masts. However, in most cases, the added protection of all-metal mast elements is worth more than the minor benefits of insulated booms and masts.

One of the things I measured in the lab on the models was the effect of metal with the antenna, vertically or horizontally polarized, mounted on the supporting mast. No measurable difference could be detected on the patterns or gain when comparing wood versus metal mast and boom element.

Making the Boom

The first and most important task is to correctly drill all the holes in the boom. See Figure 1. Getting this right is very important because it affects the accuracy as well as the appearance of the antenna. The boom requires 72-1/4 inches center-to-center from the reflector element to director number 3. Therefore, I had to purchase two booms because they only came in 72-inch lengths. See Table 3.

At the same store, I purchased a 1-inch diameter wooden dowel. A 3-inch long section of the dowel was wrapped with one layer of aluminum foil, and forced 1-1/2 inches in-

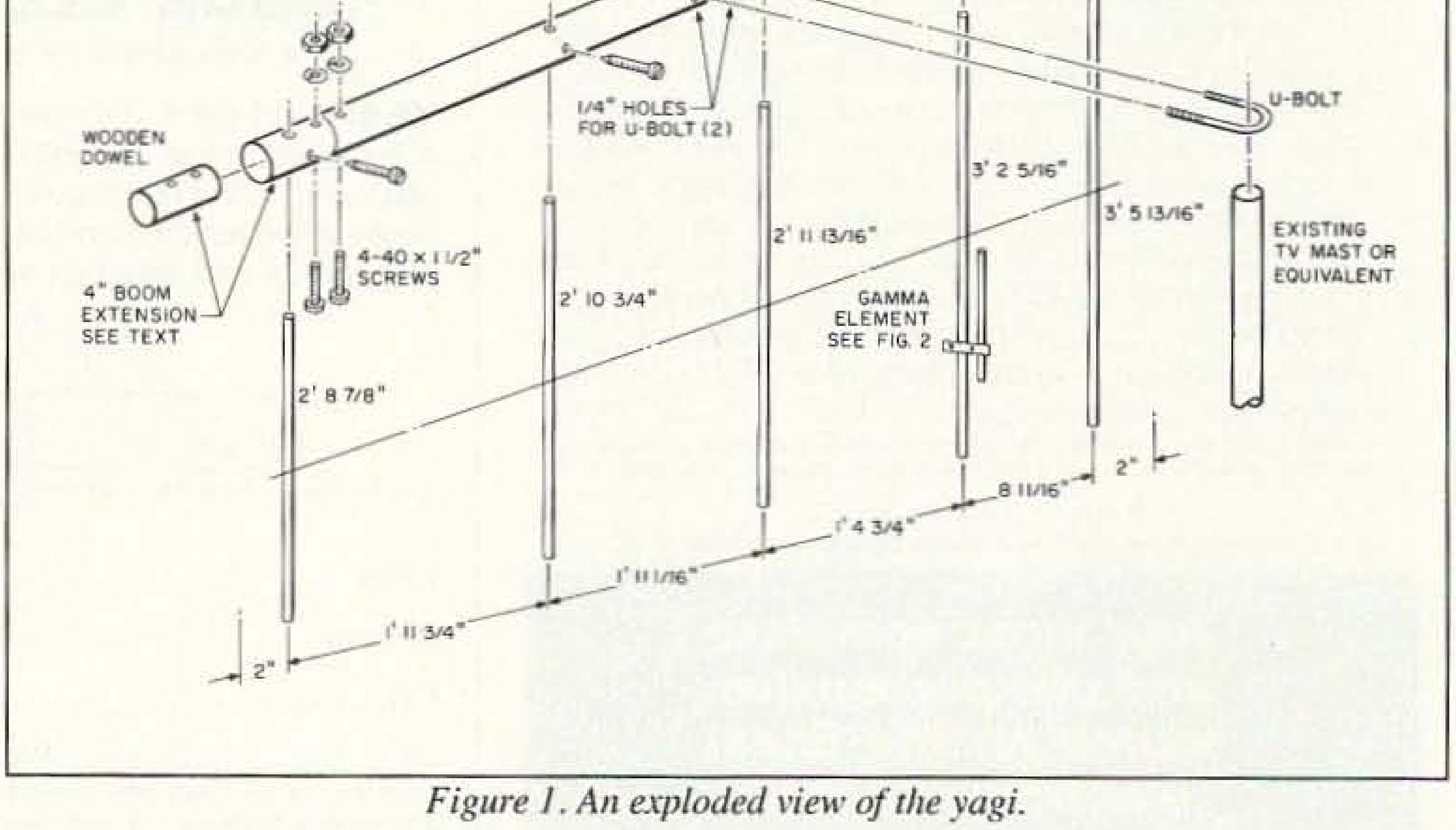

Figure 1. An exploded view of the yagi.

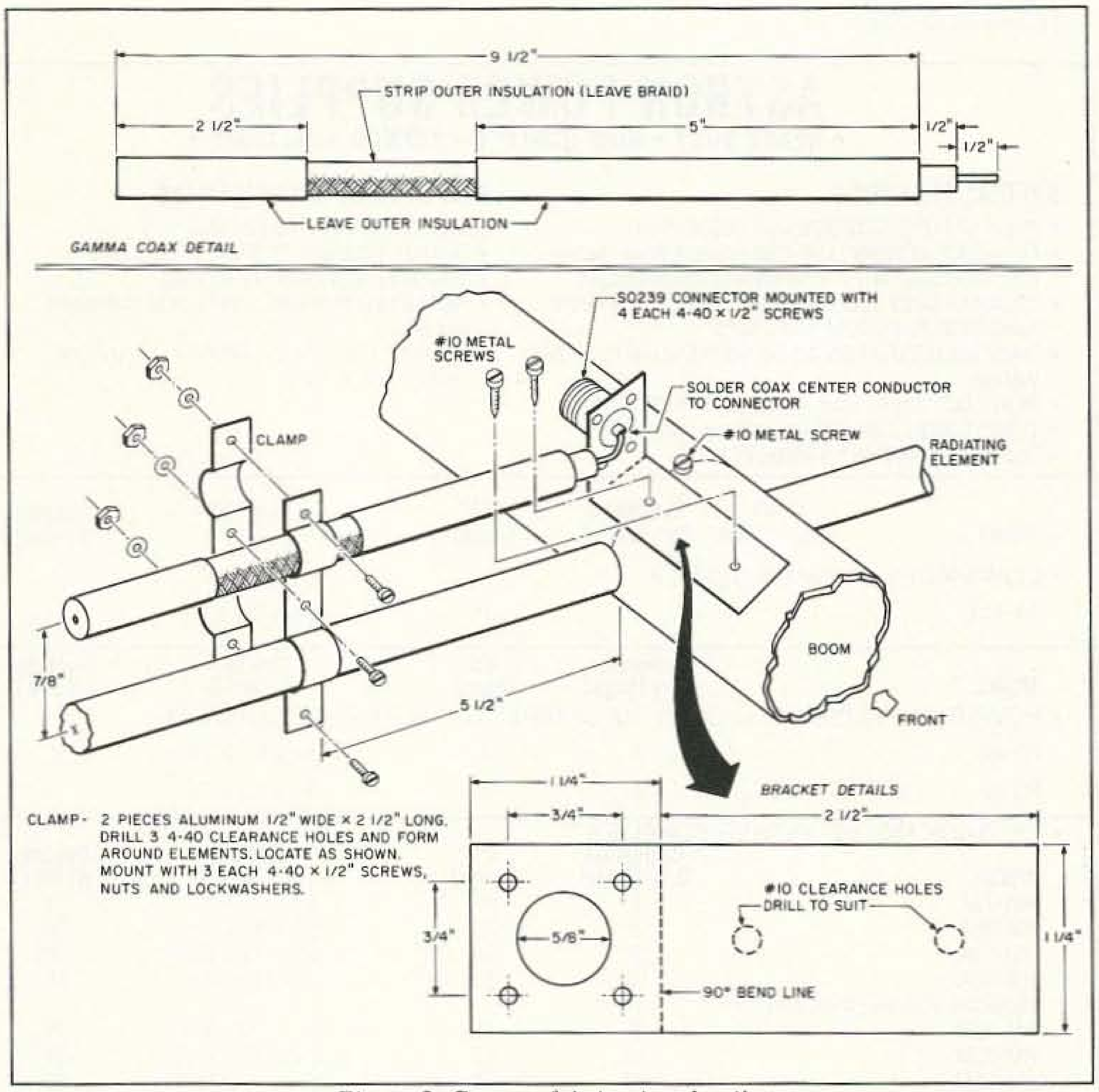

Figure 2. Gamma fabrication details.

side the 1-1/4-inch outside diameter aluminum tubing. This allows an extension to be made to the boom. I added a 4-inch piece, making the total length 76-1/4 inches. Two holes were then drilled through the metal and the wood for the two #4-40 x 1-1/2-inch screws. (Aluminum pipe in longer lengths is available at some stores.)

A bench vice was used to hold the boom in a fixed horizontal position. I used a plumb line to find the top point on both ends of the boom. Then I scribed a line running the length of the boom. Along this line I measured out the element spacing, and center-punched each one. Before punching, however, I double-checked each element spacing for an accuracy of as close to 1/16 of an inch as possible.

At each element measurement, I scribed a line around the boom diameter. If you use a drill press to make the holes, all this will be unnecessary. I used an electric hand drill, so I wanted to find the bottom hole as accurately as possible, and drill from both sides, rather than taking a chance on holding the hand drill straight.

To accomplish this, I cut a strip of paper and wrapped it around the diameter. With this strip of paper marked properly, I could accurately find each 180 degree point for every element measurement.

After marking the paper strip for one boom diameter, you just lay it out flat and measure and mark the halfway point. Then wrap it around the diameter, and the halfway mark will be the 180 degree point. After center-punching them, you can drill the holes. Using a 3/8-inch drill bit on the hand drill, I drilled each element from both sides of the diameter towards the center of the boom.

Next, I drilled the 1/16-inch holes at 90 degrees to the large holes for the #10 metal screws. These holes are for securing the elements once they have been installed. I located the proper 90 degree point with the same paper technique as before.

Now you can locate the U-bolt holes and use the same technique with the paper to center the 1/4-inch clearance holes. Drill from opposite sides again to get the holes straight.

Assemble the elements by cutting them to the correct length, as listed in the design parameters. I found it was easier to center the elements during installation by first measuring each element and marking the center point, then second, measuring from the center point in either direction 5/8 of an inch, and third, scribing a circle around the diameter of the element. Then you can push the elements into the 3/8-inch diameter holes, as shown in Figure 1, until the scribed circle is flush with the boom.

If enough care has been taken drilling the holes, you may be able to drive the elements in and not have to use the #10 screws to hold them in place. If the fit is sloppy, use the screws and tighten them until they touch the elements. (Flatten the screws on the tip with a file before insertion—this makes them fit against the elements a little better than a

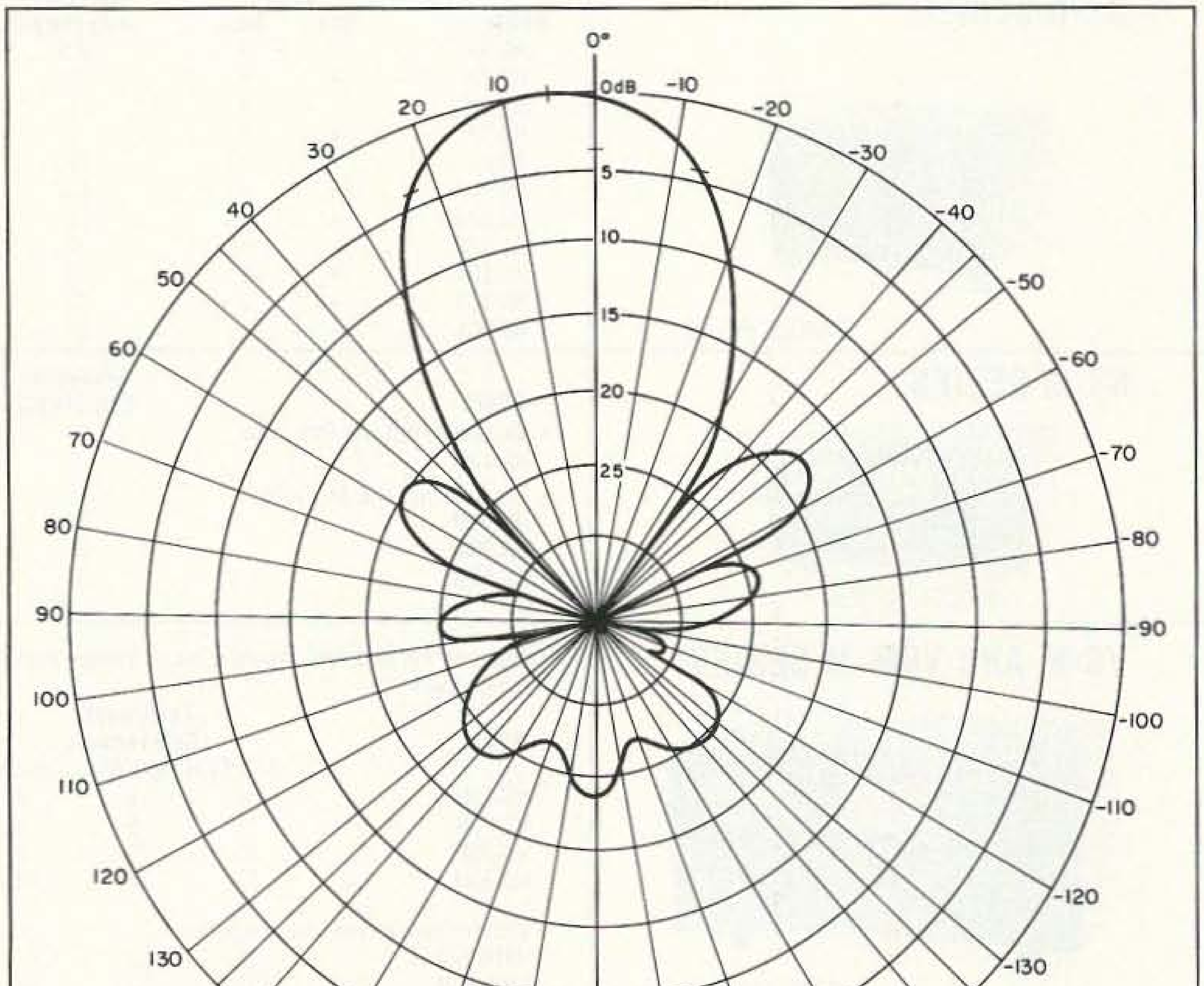

Figure 3. E-plane pattern sketch.

Table 1. Center Design Yagi on 146 MHz

Gain:	14 dBi
Bandwidth for 1.5 to 1 VSWR:	3 MHz
Beamwidth E-plane	37 degrees
Beamwidth H-plane	42 degrees
Front-to-Back Ratio:	Greater than 20 dB
Sidelobes:	Greater than 15 dB down
Length	76-1/4 inches
Weight	Less than 2 pounds

sharp point.) Double-check the fit by pulling and pushing on the elements. Tighten as necessary, but do not over-tighten, as this will distort the element and could tear the thin skin of the boom.

Gamma Construction

Fabricate the gamma parts as shown in Figure 2. The gamma is simple and very effective. The length of coax provides the series capacitance, and the slider provides the inductive adjustment. The combination provides the resistive component. Cut a 10-1/2-inch length of RG-8, RG-9, RG-213, or RG-14 cable. All will work because they naturally have a capacitance of about 29 pF per foot.

Trim two 1/2-inch segments at one end as shown in Figure 2, one all the way down to the center conductor, and the other through the outer insulation and braid. Cut the outer insulation only from a 2-inch section that will be in contact with the gamma slider. The total braid left on the coax piece should be 9-1/2 inches for about 23 pF series capacitance.

Table 2. The "Stu Henderson Yagi" for 146 MHz

Reflector length	= 509/f	3' 5-13/16"
Space #1	= 106/f	8-11/16"
Radiator length	= 466/f	3' 2-5/16"
Space #2	= 204/f	1' 4-3/4"
Director #1 length	= 436/f	2' 11-13/16"
Space #3	= 280/f	1' 11-1/16"
Director #2 length	= 423/f	2' 10-3/4"
Space #4	= 289/f	1' 11-3/4"
Director #3 length	= 400/f	2' 8-7/8"

Where *f* is in megahertz.

Fabricate the connector bracket and mount the SO-239 connector. Align the bracket on the boom at 45 degrees from the elements, and drill the mounting holes for the #10 metal screws. Solder the coax piece to the connector and mount the remainder of components.

Final Adjustments

Fabricating the antenna to the dimensions specified, and holding the tolerance to 1/16 of an inch, should get you very close to the design parameters. I moved the gamma slider in about 1/4 of an inch, and that is the only adjustment I had to make on the first try.

For the VSWR adjustments, I mounted the yagi on a 10-foot section of TV mast and leaned it against a 4-foot chain link fence. This allowed me to make changes easily. I then mounted the yagi on an existing TV mast and measured the VSWR again. One adjustment of about 1/8 inch was all I needed, and I was close enough on the second try.

Table 3. Materials List for the 2 Meter Yagi

2 booms	1-1/4" dia., 76" long, 0.05" wall thickness
3 elements	3/8" dia., 6-foot long solid or thin wall
1 piece scrap	3" x 4", 1/16" thick

I think the yagi is an easy antenna to build. I have built at least 10 antennas for different frequencies, plus all the models during the design phase in the antenna lab.

The total cost for the antenna, including the connector, U-bolt, and all hardware, is less than $30. If you also buy a 20-foot mast, a roof support bracket, and 50 feet of coax with two connectors, the cost is still less than $70. You can buy the necessary materials, hardware, and connectors at most hardware stores and Radio Shack.

Less expensive methods for mounting the antenna are available. One economical approach is to use two chain link fence rails as masting, and a roof bracket. The rails are 10 feet long, interlock with each other, and are about $6.00 each. The roof bracket can be installed to hold the rails at the roof level. On most houses there will still be adequate antenna space on the mast above roof level.

The yagi described here will work well if fabricated to the specified guidelines. Many variations can be applied, and the results would be just as good or better. Don't hesitate to experiment! 73