

A Five-Element, 2-Meter Yagi for \$20

This antenna is easy on your wallet and easy to build!

In a matter of a few hours, you can easily build a broadband, 2-meter Yagi—complete with mounting hardware—for \$20. The antenna offers a gain of about 10 dB, is lightweight, mechanically strong and rivals the performance of similar commercial antennas.

The antenna's low cost is made possible by modifying a RadioShack FM broadcast receiving antenna (RS 15-2163). For \$19.99, plus tax, you get a 70-inch-long by 1-inch-square boom, a set of six $\frac{3}{8}$ -inch-diameter elements, antenna-mounting hardware and two plastic end caps to seal the boom ends. In addition to RadioShack's antenna, you'll also need some nuts and bolts to remount elements, an 11-inch length of RG-8 (or similar) coax, an SO-239 connector and a 9x1-inch-long aluminum strip. This strip is cut into two pieces to fabricate a strap for the gamma match and a mount for the SO-239 connector. The thickness of the strip is not important as long as it can be bent easily and is strong enough to hold the SO-239 connector firmly in place. To close any unused holes and the tips of the elements, you'll need some noncorrosive sealant, such as RTV. Most amateurs I know have these items on hand. If you don't, you'll spend a few more dollars.

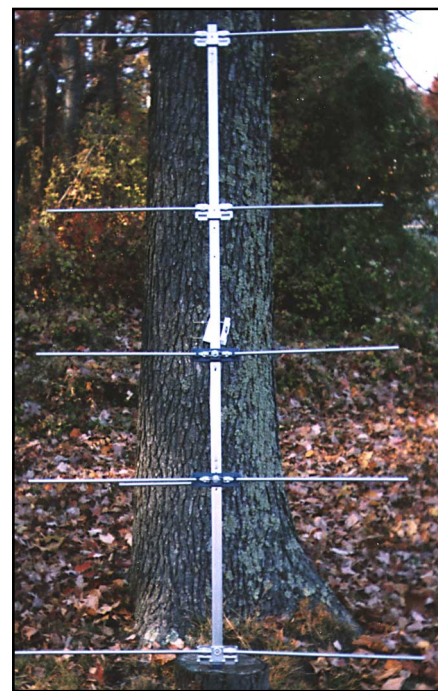
Element Relocation

Refer to the accompanying photo and Figures 1, 2, and 3. First, open all the antenna elements to their fully extended positions. Three of the elements are attached to plastic insulators and are tied together electrically with stiff, crossed, bare-aluminum wires. Each of these three elements looks like a dipole broken in the middle at the plastic insulators. One element measures about 58 inches from end to end, another about 56 inches and the third about 43 inches. You'll not need the 43-inch element.

Cut the wires next to the rivets on the 43-inch element. Drill out the rivet holding the

element to the boom and discard the element. Use a screwdriver and pliers to release one wire from beneath one of the rivets on the 58-inch element. Try not to damage the rivet. Pull the wire out and away from the rivet. Go to the remaining wire on the 58-inch element; its opposite end attaches to another rivet on the 56-inch element. Unwind the end of the wire from beneath the rivet on the 56-inch element and pull it towards the 58-inch element. You now have a single wire on the 58-inch element with one loose end. Pull that wire straight across to the opposite rivet that no longer has a wire under it. Use pliers and whatever force is necessary to loop the wire around and under the rivet head as was the original wire. Seat the wire *fully* beneath the rivet head (see Figures 2 and 3). I was able to get the wire fully seated by pulling hard on the wire with my hand and squeezing the wire under the rivet head using the jaws of Vise Grip pliers. If you cannot get the wire fully wound and seated under the rivet, drill out the rivet and replace it with a bolt and nuts. *Do not* cut the wire off at the rivet. Pull the wire back toward the opposite rivet and cut it off leaving a pigtail about 1½ inches long. You may want to reseat the rivet by hitting it with a hammer. Just be sure to back up the rivet's head with a hard object before striking the rivet's opposite end. Be careful not to damage the plastic insulator. You have now turned a two-piece element into a one-piece element, and this will be the driven element.

Drill a mounting hole in the boom (for the one-piece element) 17 inches away from the center of the adjacent 66-inch element (reflector). Remove the 58-inch element from its original location and mount it at the new position using a bolt, two washers and a nut. Place one washer directly against the plastic insulator under the wire that connects the two $\frac{3}{8}$ -inch-diameter tubing halves together. Position the other washer on top of the wire so it bears down on the wire when the bolt is tight-



ened. This puts the center of the element at the same electrical potential as the boom. Using the 1½-inch pigtail, bend it and place it between the two washers so there is a piece of wire on each side of the bolt. This prevents the washers from tilting and makes for a cleaner fit. Trim off any excess wire. (All of the foregoing is more difficult to describe than it is to perform! It doesn't take long to do once you understand what is going on.)

The next element (56 inches long; Director 1) is handled similarly to the preceding one. However, this element originally had *two* wires beneath each rivet head. One of those wires has already been removed. At the opposite rivet, unwind one of the two wires so that only one wire remains beneath each rivet. Pull one loose end of a wire straight across to the opposite rivet and force the wire into place under the rivet just as before. Pull the other loose wire end to its opposite rivet and force it into place. The two element halves should now be connected together with two wires. The wires will be parallel to each other and on opposite sides of the rivet that secures the element to the boom.

Next, drill a hole in the boom 13 inches from the center of the 58-inch element (DE). Remove the 56-inch element from (D1) its original location and mount it on the boom at the new hole. Again, place a

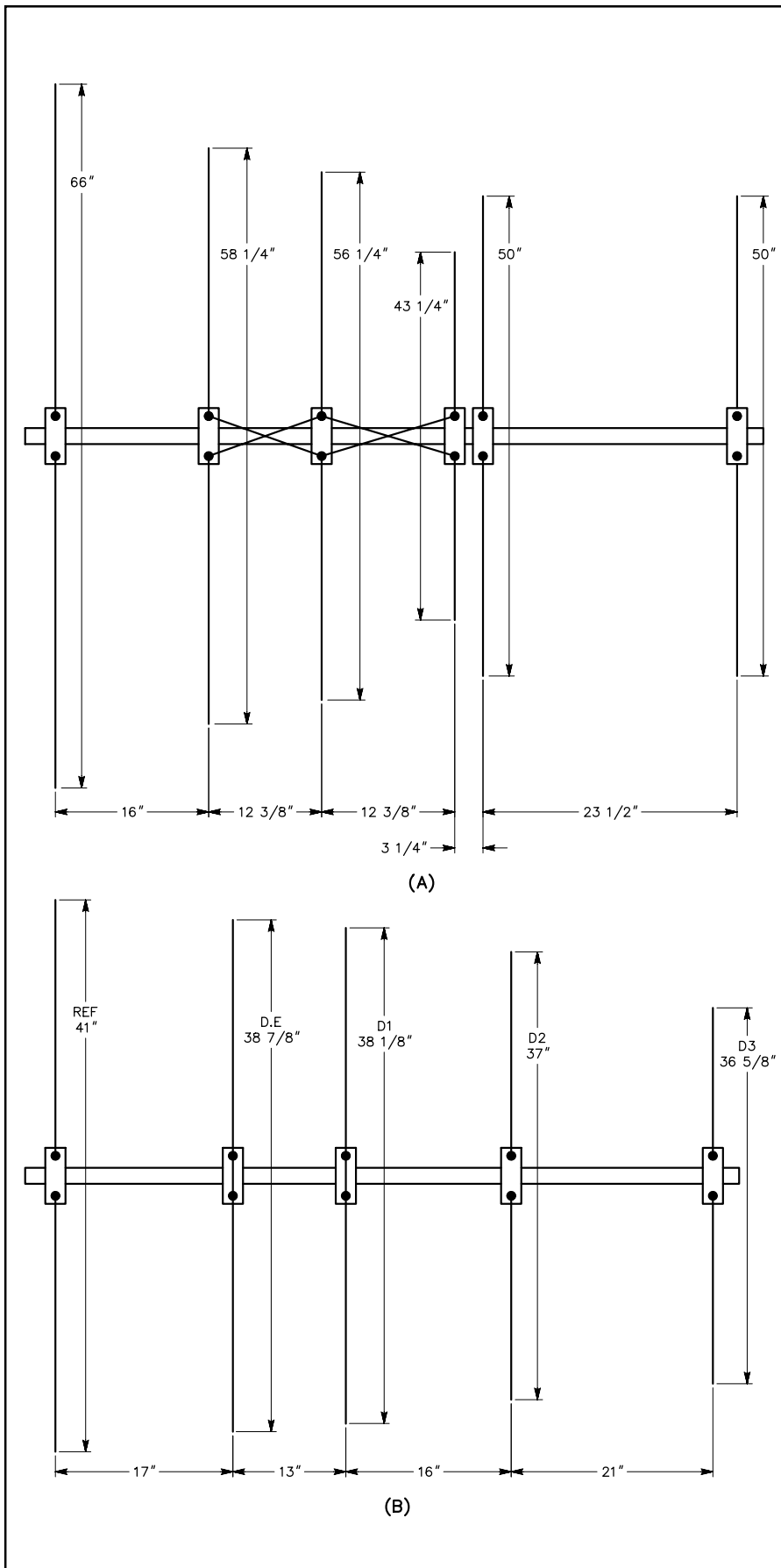


Figure 1—At A, the original configuration of the RadioShack FM receiving antenna. The element lengths and spacings at B are chosen for operation on 144 MHz. For operation on higher frequencies, shorten the elements even more; see text.

washer on opposite sides of the wires so that the washers squeeze against the wires as the bolt and nut tighten the element to the boom.

The remaining three elements (REF, D2 and D3) don't need to be modified; their individual dipole sections are already joined by metal plates. All you need to do is remove two of them from the boom, drill new mounting holes and mount them at their new locations. The first 50-inch element (D2) is placed 16 inches—(center to center)—from the adjacent 56-inch element. The end element (D3)—also 50 inches long—is placed 21 inches (center to center) from the new location of its adjacent 50-inch element. All of the elements are now in place ready to be cut to length for 2-meter operation.^{1, 2}

Element Trimming

For this job, a fine-toothed saw works well. (Caution: During the following steps, be sure that you cut *half the total amount* from each half [ie, each side] of an element.) For operation at the low end of the band (144 MHz), cut the 66-inch element to a total length of 41 inches (see Figure 1B). This element becomes the reflector. Cut the next element in line (the driven element) to a length of $38\frac{7}{8}$ inches. Cut the next three elements (directors D1, D2 and D3) to lengths of $38\frac{1}{8}$, 37 and $36\frac{5}{8}$ inches, respectively. If you want to trim the elements for use at higher frequencies, cut $\frac{1}{4}$ inch off of each element for each 1-MHz frequency increase. For instance, cutting a total of $\frac{1}{2}$ inch from each element tunes and maximizes the antenna for 146 MHz. (Again, cut *half* the total amount from each half of an element section. For 146 MHz, the preceding example, that's $\frac{1}{4}$ inch from each half-element section.)

SO-239 Connector and Mount

Refer to Figures 4 and 5. Attach the SO-239 connector to the bottom of the boom beneath the driven element using an L-shaped piece of aluminum. Fabricate the bracket from a $3\frac{3}{8}$ inch length of aluminum cut from the 9×1 inch strip. Bend it at a right angle so that one side is about $1\frac{1}{4}$ inches long. Make the necessary holes to mount an SO-239 connector on the $1\frac{1}{4}$ inch long section and secure the connector to it. Fasten the bracket to the boom bottom using bolts and nuts, positioning the bracket so that the tip of the SO-239 center pin faces the reflector. Position the tip of the pin about $\frac{3}{16}$ to $\frac{1}{4}$ inch in front of the center of the driven element toward the director side.

Making the Gamma Match

Remove the outer insulation and braid from an 11-inch piece of RG-8 coax, leaving the center conductor and its insulation. Strip off $\frac{1}{2}$ inch of the insulation and solder the center conductor to the SO-239 pin. At the pin, bend the wire at a right angle so that

¹Notes appear on page 37.

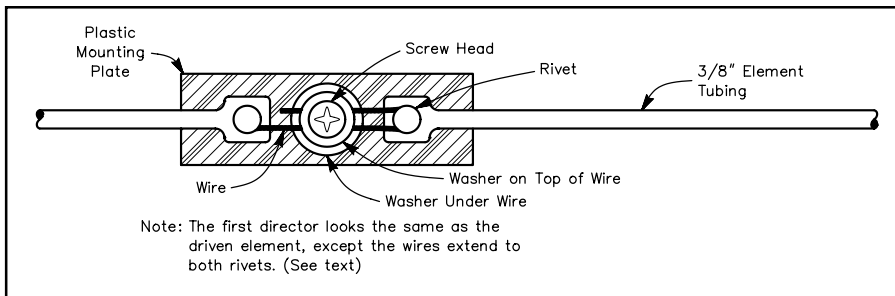


Figure 2—Drawing of the driven-element modification.



Figure 3—Here's the modified driven-element.

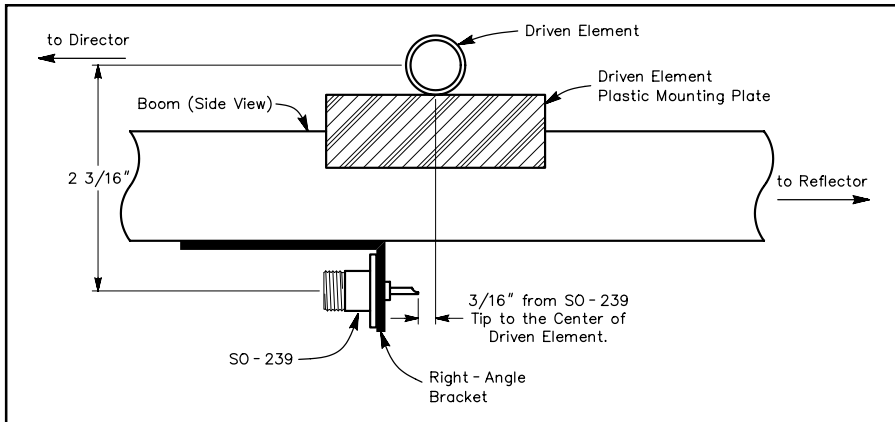


Figure 4—Side view of the driven-element area and SO-239 mounting bracket.

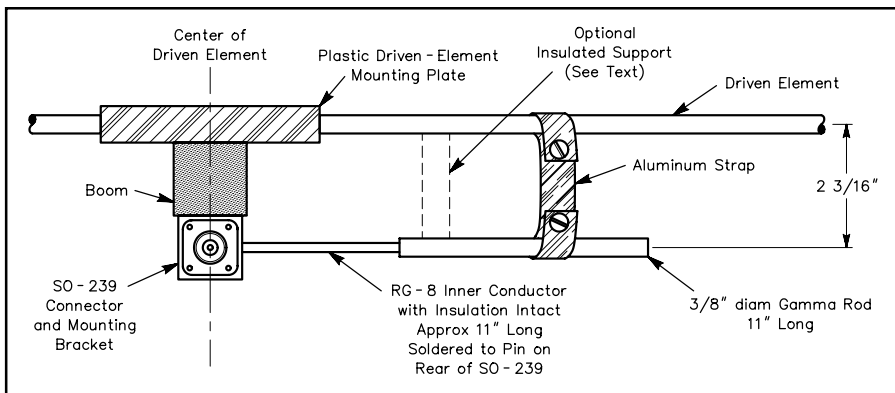


Figure 5—The 2-meter Yagi's gamma match. A piece of RG-8 coax and a length of tubing combine to create an inexpensive and rugged gamma-match capacitor.

the wire is parallel to and about $2\frac{3}{16}$ inches away from the driven element along its length (see Figure 5). This lead forms the inner plate of the gamma capacitor. Next, select a piece of the scrap $\frac{3}{8}$ -inch tubing you cut from one of the antenna elements and cut it to a length of 11 inches. Slip this tubing over the RG-8 inner-conductor insulation to form the outer plate of the gamma capacitor. Position the tube seam so it faces the ground when the antenna is at its operating position; this allows moisture an easy way out. To complete the capacitor construction, wrap the remainder of the 1-inch aluminum strip around the driven element on one side and around the 11-inch tube on the other. Construct the strap so that the centers of the tubing sec-

tions are approximately $2\frac{3}{16}$ inches apart. Leave a tang on each side of the strap to accept a locking screw. Trim away any excess material.

Tuning the Gamma Match

Before applying RF to the antenna, connect an SWR meter to the SO-239 connector *at the antenna*, not at the transmitter end of your transmission line. This ensures that you are tuning *just the antenna*. For a quick adjustment of the matching network, you can try positioning the antenna straight up toward the sky, with the reflector sitting on the ground. Using this approach, however, I found that when I raised the antenna to a height of 10 feet on a metal mast, the gamma capacitor needed readjustment. If

you're a perfectionist, it might ultimately be less work to tune the antenna while it's mounted in the clear a few wavelengths above ground or sitting at its intended operating position. If you're going to use a metal support mast, attach it to the antenna prior to tuning. Use a nonmetallic mast (wood, fiberglass, etc) if you're going to mount the Yagi vertically (so that the elements are in line with the mast); otherwise, antenna performance will suffer a bit. It's okay to use a metal mast when using horizontal polarization.

Reduce your transmitter's output power to about 1 or 2 W for safety use or, an antenna analyzer. Don't use more than a few watts—you don't need it. Set the transmitter frequency to that for which you cut the antenna. (Remember to ID your station during this adjustment period.) First, adjust the gamma strap (sliding it back and forth) on the driven element for the lowest SWR. Then slide the gamma tube (capacitor) back and forth within the strap for lowest SWR reading. You should be able to get a match by alternately making adjustments to the strap and gamma tube. I was able to tune my antenna to a 1:1 match. (An SWR of 1.5:1 or less is acceptable.) Recheck the SWR reading after finally tightening the strap to be certain that everything is still okay. Check by eye to ensure the gamma-capacitor tube is parallel with the driven element from one end to the other. It doesn't matter if the gamma-capacitor tube is slightly in front of or behind the driven element, but it should be parallel to it.

Performance

I don't have the proper equipment for making antenna-gain measurements. However, I made a crude comparison of the Yagi to a dipole using the following approach: First, I erected a 2-meter dipole on a 10-foot-long metal mast and adjusted the antenna for a 1:1 SWR. While feeding the dipole with a few milliwatts, I placed my H-T about 75 feet away from the dipole. The S meter reading on the H-T went full scale, so I removed the antenna from the H-T. The reading was *still* full scale. I then wrapped the H-T case with a shield of aluminum foil and the S meter reading dropped to S3. After that, I never touched or moved the H-T throughout the rest of the test. I rotated the dipole 90 degrees and, as



Figure 6—The gamma match and driven element.

expected, I got a zero reading on the H-T's S meter. I then turned the dipole back to its original position and rechecked the S meter. Again, it read S3. I used this reading as the dipole reference. Then, removing the dipole, I replaced it with the Yagi. I pointed the Yagi directly at the H-T and fed it with the same power level used to feed the dipole. The S meter read full scale on my H-T! Because S meters are notoriously inaccurate and not calibrated, I have no way of knowing how much gain that indicates, but it's a lot! (A five-element Yagi on a boom this long is capable of producing a gain of about 10 dB.²) When I turned the Yagi so that its reflector faced the H-T, the meter reading dropped to S4. That's a nice front-to-back ratio!³ I also checked radiation off the sides of the antenna. I was pleased to see an S0 meter reading from each side. [*The ARRL Lab modeled Ron's Yagi using YO software and verified his claims.*—Ed]

Summary and Acknowledgment

After I finished my project, I decided that

it might be a good idea to make sure that the gamma match worked okay when the elements were cut for 146 MHz because many readers might want to use the antenna for working distant FM repeaters. I sawed off 1/2 inch from each element and went through the tuning procedure again. I was still able to get a 1:1 match. Those wishing to use the antenna for FM repeater work should orient the antenna elements vertically.

I wondered what effect moisture would have on the gamma capacitor. So, I poured water into one end of the gamma tube until it came out the other end. I rechecked the SWR and I found only a barely noticeable effect. I recommend you plug the ends of the tube with a dab of RTV or other noncorrosive sealant to keep out dirt and insects.

The driven element holding the gamma match will not fold for portable use if the bracket holding the SO-239 connector is bolted to the boom. One simple solution is to remove the bolts holding the bracket. Removal and replacement is made easier if you use wing nuts on the bolts. An optional,

second support for the gamma-capacitor tube, made from nonmetallic material, provides better support for the tube during transportation.

My thanks to Larry, K3PEG, for instructing me about this type of gamma match fabrication.

If you're looking for a good 2-meter antenna, try this one! It's inexpensive, easy to tune and is the simplest construction approach I've seen for quickly "homebrewing" a 2-meter Yagi.

Notes

¹The element lengths and spacing dimensions for this antenna are taken from page 631 of *The 1974 ARRL Handbook*.

²See also Edward P. Tilton, W1HDQ, *The Radio Amateur's VHF Manual* (Newington: ARRL, 1972), third edition, p 155, Figure 8-4.

³Using YA and assuming 1/4-inch-diameter elements with no tapering, modeling the 1974 *Handbook* antenna shows a gain of about 10 dBi and a 9-dB F/B ratio.—Zack Lau, W1RF

Ron Hege, K3PF, has been a radio amateur since he got his Novice ticket in 1968. The following year, he took and passed the General and Advanced class exams, then holding the call sign WA3JFX. In June 1998, Ron got his Extra class ticket, held the call sign K3OR for about one month, then opted for his present call sign, K3PF. Ron worked as an aircraft electrician in the USAir Force and at Martin Marietta Corp. He has a BS in management/leadership from Johns Hopkins University. Ron is retired from his position as supervisor of electronic technicians at the Westinghouse Engineering Research and Development Labs. You can contact Ron at 3425 Taylor Ave, Baltimore, MD 21234; heger@erols.com.

All photos by the author.