By Kent Britain,* WA5VJB

Cheap Yagis for 2450 MHz

This time, at the suggestion of one of our readers we take the Cheap Yagi construction projects to 2450 MHz (photo A). While this is not the highest frequency for which I have built a Yagi (that is still 10,300 MHz), it is the highest frequency for a "Cheap Yagi" construction project.

The design was more challenging than I had thought it would be. I try to keep all dimensions to .1 inch accuracy. Yes, I've seen published 20-meter beam designs with dimensions to .0001 inch, but that's ridiculous. Also, the 2.4-GHz ISM (Industrial, Scientific, and Medical) band is 83 MHz wide. That is pretty wide for a long Yagi, but after several tries I have two Cheap Yagis that fit the bill.

When things get small, little things become big things. Just how the ends of the elements are cut makes a difference (figure 1). My prototype wouldn't tune up until I cleaned up the jagged ends of the elements. A few quick strokes with a flat file—or in my case, a second on the belt sander—fixed the problem. The antennas covered here have similar dimensions (figure 2 and Table I), and

*1626 Vineyard, Grand Prairie, TX 75052
e-mail: <wa5vjb@cq-vhf.com>

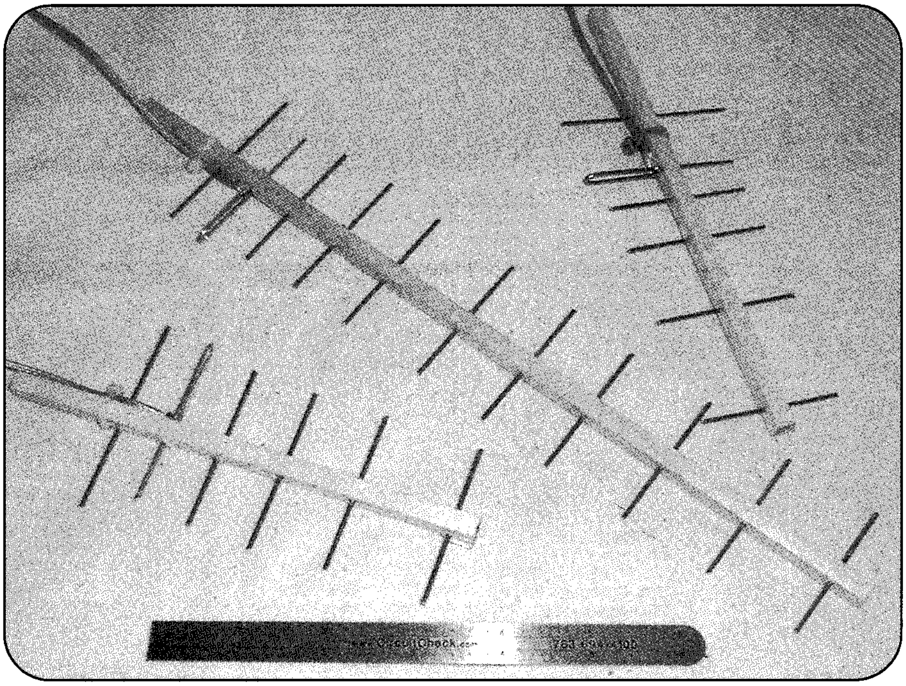

Photo A. 2400-MHz Cheap Yagis.

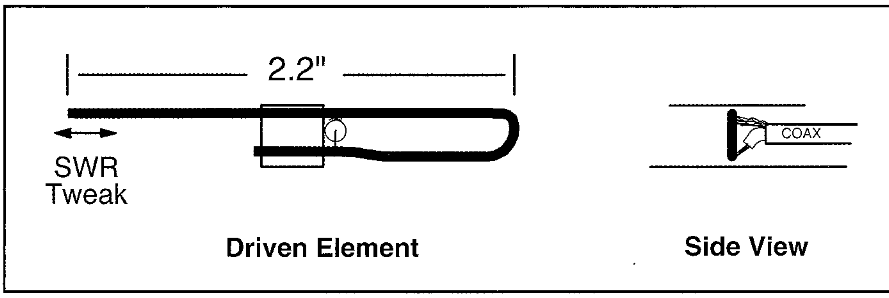

Figure 2. Driven element of both the 6-element and 11-element versions.

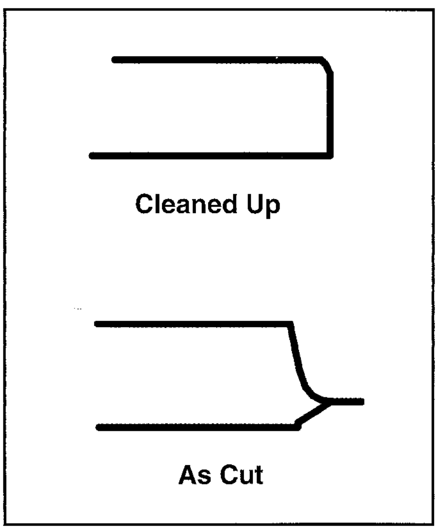

Figure 1. Element ends.

	Ref	DE	D1	D2	D3	D4	D5	D6	D7	D8	D9
6 elements											
Length	2.4	*	2.1	2.1	2.0	1.9	—	—	—	—	—
Spacing	0	.6	1.3	2.1	3.0	4.2	—	—	—	—	—
11 elements											
Length	2.4	*	2.1	2.1	2.0	2.0	2.0	1.9	1.9	1.8	1.8
Spacing	0	.6	1.3	2.1	3.0	4.2	5.2	6.2	7.3	8.5	9.8

Driven element is per figure 2 for both Yagis.

Table I. Dimensions (in inches) of the 6-element and 11-element Cheap Yagis.

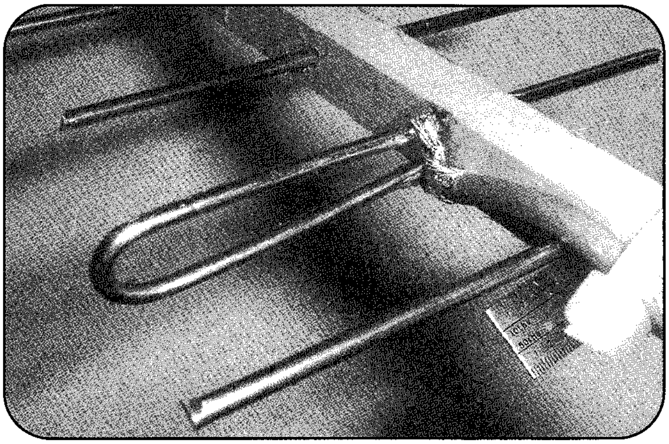

Photo B. The driven element.

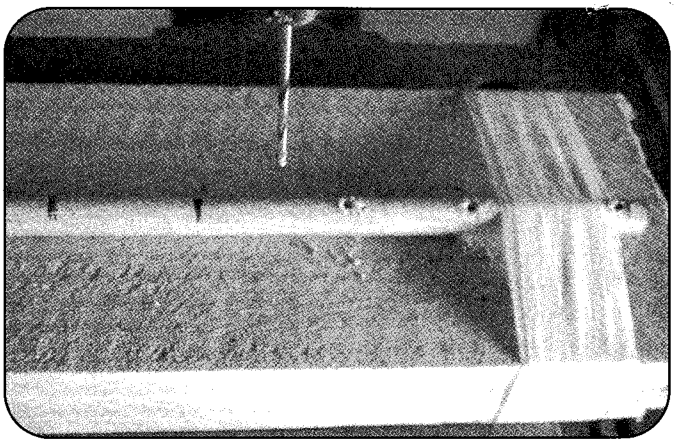

Photo C. Dowel drilling.

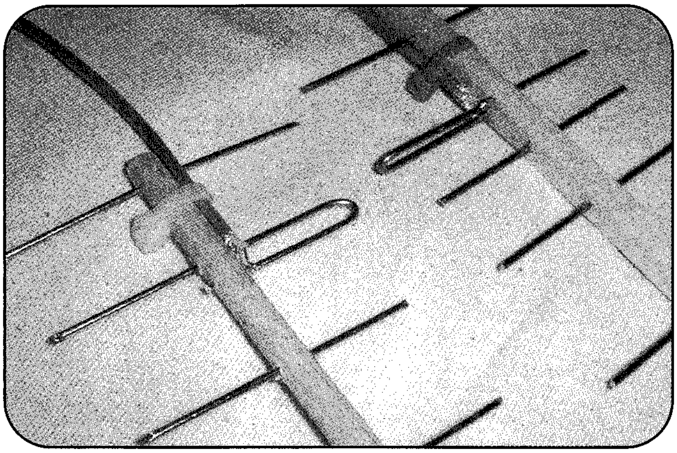

Photo D. Rotated driven element.

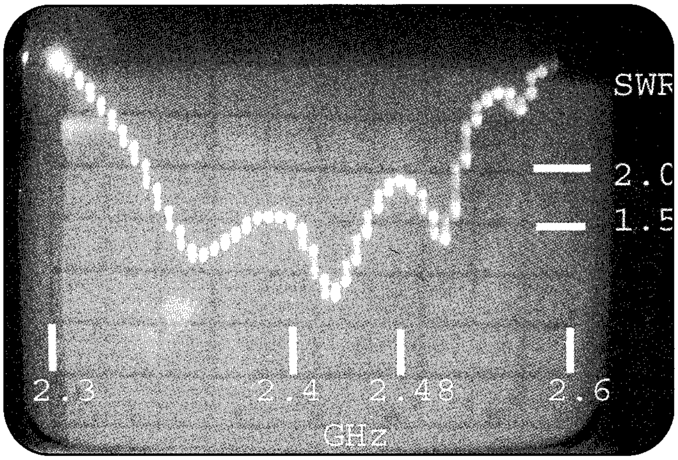

Photo E. Network-analyzer plot of the 11-element antenna.

that was not by accident. For the sake of simplicity, I forced the designs to converge. There is no real loss in performance, but it did take a bite out of my sanity to get to that point.

Construction

All elements are 1/16-inch material. I used silicon bronze welding rod, but 14-gauge copper wire or any .062-inch diameter rod can be used (photo B). A drop of Super Glue® was used to hold the elements in place. For my prototypes I used 1/4-inch-square wood from the local home-improvement store, as it's much easier to drill.

If you do insist on using 1/4-inch dowel, taping it to a block of wood makes it much easier to drill the elements in a straight line (photo C). You also will need to use a lot of glue to hold the driven element in place, or flip it 90 degrees when using dowel (photo D). There are several technical reasons for not wanting to flip the driven element. It creates quite a bit of uncertainty as to exactly where the phase center of the element is. However, it can be done. Note the flipped driven element on the PC-board version later on.

The shield of your 50-ohm coax goes to the center of the driven element. The center of the coax goes to the inter tip of the J element. Yes, they are offset slightly and not exactly in the center of the J, but that has been allowed for in the final dimensions. The bend in the end of the J is going to end up .2 to .25 inch wide just so it will go back into the boom. The radius of the bend, and the distance between the tip and body of the J are not a critical dimension. Just make it fit and you'll be okay. If you have the equipment to measure return loss or SWR at 2.4 GHz, the free tip of the J can be trimmed for best SWR (photo E).

Performance

While the Yagi does cover the entire 83 MHz of the ISM band, it does work a bit better in the ham portion of the band

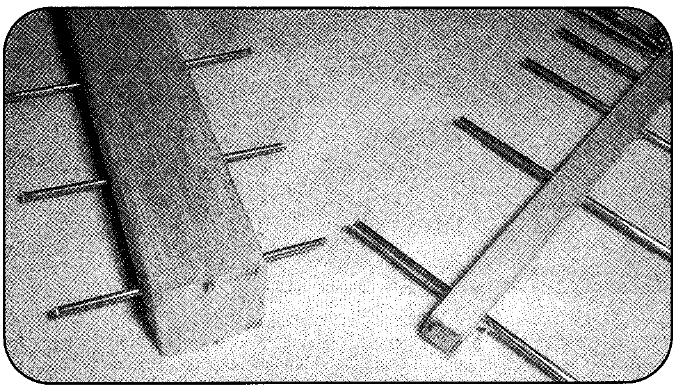

Photo F. "But I built it exactly to your dimensions!"

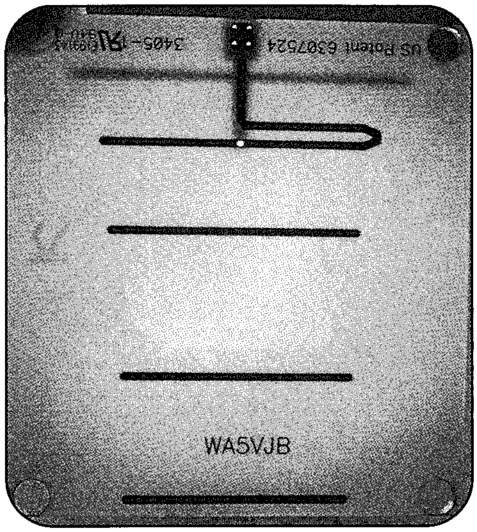

Photo G. A 5-element Cheap Yagi etched on PC board.

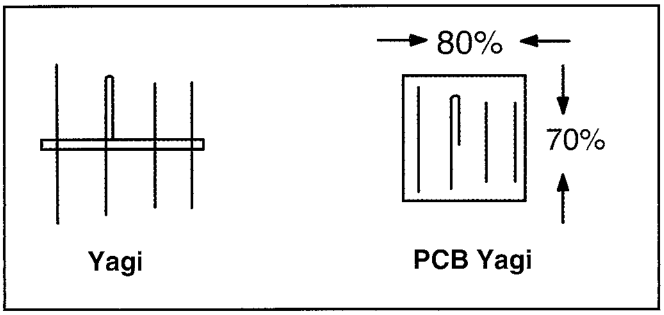

Figure 3. Free-space Yagi and PC-board Yagi.

and has good performance in the AMSAT portion. How about this antenna for a small S-band AMSAT station? Gain varied over the band, but ran between 12 and 13 dBi for the 11-element antenna and 9.5 to 10.5 dBi for the 6-element version.

Wood

Since wood doesn't conduct electricity, many seem to assume it has no effect on the antenna. Well, that's not entirely true (photo F). Wood contains cellulose and moisture, and these give the wood an E_r, or dielectric constant.

When light travels through water or glass, it travels more slowly. The same is true when a radio wave travels through plastic, air, wood, etc. The E_r of wood varies quite a bit between dry balsa wood and damp teak, but through typical construction woods, the radio wave travels at about half the speed it does in air. Wood around a wire is a bit more complex, and the effect varies greatly with wavelength. However, for 1 inch of wood you need to make the element about one-tenth inch shorter to allow for the effects of the wood. That's no big deal on 2 meters, but above 400 MHz or so a very thick boom can kill a Cheap Yagi. Now just put the Yagi in/on a dielectric material, and you quickly learn about E_r effects.

A Cheap Yagi Etched on PC Board

Photo G shows a Cheap Yagi etched on PC board. Taking the photo was not a lot of fun, since there are elements on the top and bottom of the board, but the back lighting shows the elements well.

Thus far I have developed nine different PC-board Cheap Yagis from 434 MHz to 5800 MHz with over 10,000 of the 915-MHz versions in the field. In general, start with a design for a free-space Yagi (figure 3). Shorten the elements about 30% and reduce the element-to-element spacing about 20% when you generate the PC-board artwork. These are general factors, and that .062-inch thick PC board looks a lot thicker to a 11-GHz radio wave than it does to a 400-MHz radio wave (photo H). Also, the E_r of the fiberglass tends to drop as you go up in frequency. While the fiberglass board may have a E_r rating of 4.0, that is usually measured at 1 MHz and drops to 3.7 or 3.8 in the GHz range. All these factors really cause problems when designing PC-board log-periodic antennas from 400

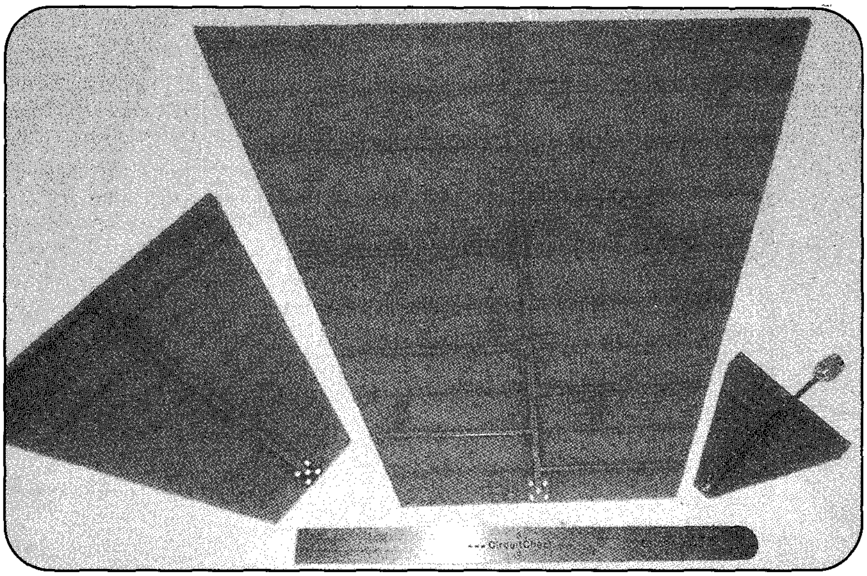

Photo H. PC-board log-periodic antennas from 400 MHz to 11 GHz.

MHz to 11 GHz. In my case, there is a big box of prototypes in the shack with trimmed elements that just weren't quite right. However, once you get the dimensions right, thousands and thousands of high-quality antennas can be etched with high repeatability.

I've been asked many times what computer program I use to design PC-board antennas. To the best of my knowledge, there is no program for designing them. For IE3D, HFSS, SONNET, etc., users, you can use all that computing horsepower to analyze an existing design, but those programs do not design the antenna for you. These programs also require you to know things that you rarely know, such as the E_r of the PC-board material over an octave of frequency.

Last, I don't have the space here to explain, but you *cannot* accurately frequency sweep log periodics with these programs. I'm waiting for the e-mails to come pouring in, but you cannot accurately frequency sweep a PC-board log periodic antenna with these programs. This is a road I and others have been down!

Are you planning to be at the Dayton Hamvention®? If the timing belt on my car doesn't break, I should be in slot 915 selling 915-MHz PC-board antennas. I'll be happy to show you some of the 200-plus 13 MHz to 11 GHz antennas that I have designed.

E_r for Quad Builders Bare Wire vs. Insulated Wire

Making that quad antenna designed for bare #12 copper wire out of insulated #12 copper wire moved it down in frequency about 5%, didn't it? Your 147-MHz quad resonates in the 130s, and the element spacing now is all wrong. You can compensate for this. Make the elements about 95% as long, but the smaller elements won't couple quite as well, so the element-to-element spacing has to be changed as well. In theory, all of this can be incorporated into the new design—that is, when you know the E_r of the plastic (see main text below)! Just try going down to the local hardware emporium and asking the clerk for the E_r of the #12 insulation when measured at 147 MHz. Be prepared for that "deer in the headlights" stare. The electrical wire insulation materials are optimized for voltage puncture, UV exposure, moisture resistance, flexibility, etc. The dielectric constant of the insulation is not controlled from batch to batch or manufacturer to manufacturer. Thus, a quad design using insulated wire might not be able to be replicated by others.

Next Time

Next time I'll cover why you don't want to use a 1/4-wave antenna with those new RF transceiver chips from Chipcon, RFM, Micrel, etc. This applies to many ham rigs as well. I'm also trying again to come up with a 6-meter Cheap Yagi. It's a mechanical, not an electrical, problem.

As always, some of my best ideas for this column come and from your e-mails and questions.

73, Kent, WA5VJB