Some More VE7CA 2-Element Portable Yagis

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VE7CA follows up on his very popular 2-element portable Yagi design with a WARC-band tribander and 40-meter coverage.

The November 2001 issue of *QST* featured a triband portable Yagi I developed to use as a temporary antenna at our summer home. I designed it specifically for easy assembly and disassembly, as well as being small enough to fit in our car's ski boot.

Many living in warmer climates may not even know what a ski boot is. It is a synthetic sleeve that is located between the two rear seats of a passenger vehicle and accessed from the trunk. It is just long enough to fit two pairs of skis into the car without having to use a rooftop carrier. A ski boot can be used to carry ham-radio antennas as well. The limiting factor is that the sleeve is typically only about 7 feet long.

My portable triband Yagi uses wire elements spaced apart with two wooden booms (spreaders) on either end. Most often I hang the antenna from a single support—a tall tree—therefore you could refer to it as a *Sloping Wire Yagi*.

After the article was published, I received many e-mails asking a variety of questions about the antenna, or informing me that they were going to build (or had already built) the portable triband Yagi. There were specific questions about the hairpin match, the V slings, and the design process I used to develop the antenna. However, the most often-requested information was for dimensions for 40 meters and for the WARC bands. The purpose of this article is to address these questions.

The Design Process

In my original design I wanted an antenna for 10, 15 and 20 meters that could be stored in the ski boot of my car, so I was limited to a maximum spacing between the 20-meter driven element and the reflector of just under 7 feet. I used an antenna-modeling program called *AO*, which stands for *Antenna Optimizer*. I originally used a dimension for the driven element based on the standard formula for a 20-meter dipole, 472/frequency (MHz) = 33.5 feet. For the reflector I added 5% to the driven element length.

I then instructed *AO* to optimize the 2-element Yagi by adjusting the length of the reflector only for the best front-to-back ratio at 14.1 MHz, keeping the spacing between the driven element and reflector fixed at 7 feet. I used the same methodology to generate dimensions for 15 and 10 meters. When I built the antenna, I hung the 15-meter driven element 9 cm (3.5 inches) below the 20-meter dipole and the 10-meter dipole below the 15-meter dipole by the same distance. I held the wires apart with ½ PVC pipe purchased from a plumbing store.

By playing with the reflector-to-driven element spacing and the initial driven-element lengths I was able to come up with a feed-point impedance on each band that allowed the use of a single setting for the shorting bar on the hairpin match. I thus shortened all three driven elements by about 1.5% and then joined them together at the center insulator. The result was a very acceptable match over the lower portions of each band. The layout of the 10, 15 and 20-meter triband wire Yagi is shown in **Fig 1**, with the dimensions provided in **Table 1**.

The dimensions shown in Table 1 are what resulted after tuning for the lowest SWR in the middle of the lower portion of each band. I hung one end of the antenna from a tree and sloped it downwards at 45º, tying the lower end to a peg in the ground. The height at the feed point was 30 feet.

The feed-point impedance of an antenna is affected by many environmental factors. The presence of a reflector relatively close to the driven element has a major effect, since the impedance at the driven element in a Yagi is affected by the tuning of the driven element itself, by the spacing and length of the reflector element and to a lesser extent the height of the antenna above ground and the character of the soil itself. The real challenge in a multiband Yagi with a single feed line is to obtain a low SWR on all the bands.

The hairpin match is one of the easiest matching systems to make. It is easy to adjust and since wire is the only ingredient, it can be coiled up with the rest of the antenna when the antenna is disassembled. The feed-point impedance of the Yagi with a reflector element spaced 0.1 λ behind the driven element typically produces a resistance around 20 Ω. By shortening the driven element from its resonant length, capacitive reactance is added to the feed-point resistance. This can be cancelled by shunting the feed point with an inductor in the shape of a wire loop resembling a *hairpin*. This causes a step up of the 20-Ω feed-point resistance to 50 Ω.

There are several software programs that can be used to determine the dimensions of a hairpin match, such as *BETA.EXE* by N6BV. [The hairpin match is also called a

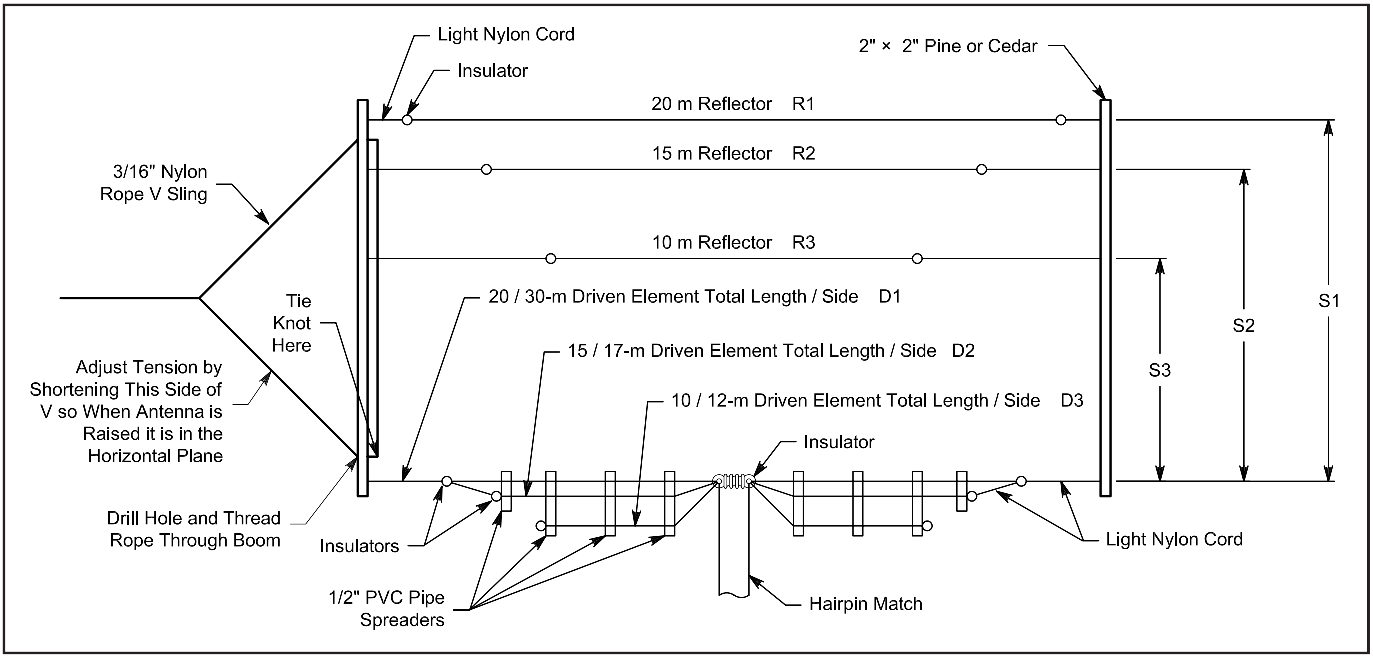

Fig 1—Dimensions for VE7CA's 2-element triband Yagi.

Table 1
Dimensions for 20/15/10-Meter Tribander

Frequency MHz MHz	*Spacing DE to Refl cm (feet)*	*Driven Element Half Length cm (feet)*	*Reflector Length cm (feet)*	*Hairpin Length cm (inches)*
14.1	213 (6.99)	488 (16.01)	1065 (34.94)	43 (14.9)
21.1	175 (5.74)	335 (10.99)	708 (23.23)	
28.25	125 (4.1)	254 (8.33)	531 (17.42)	

Spacing between hairpin wires is 10 cm (4 inches).

"beta" match by HyGain. *BETA.EXE* is included with the software/data for *The ARRL Antenna Compendium, Vol 7* at **http: //www.arrl.org/notes8608**. For more details of the theory behind a hairpin/beta match, see Chapter 26 of the 19th Edition of *The ARRL Antenna Book*.—*Ed*.] To be able to use a single dimension for the hairpin match, I juggled the lengths of the driven elements and the distances between the driven elements and the reflectors in my computer model so that the resultant feed-point impedance on each band could be transformed to 50 Ω.

Adding the WARC Bands

When I attempted to add 17 and 12 meters elements to the existing 20/15/10-meter Yagi I became exasperated. Adding two more driven elements and reflectors brings many more variables into the equation! Working with my antenna-modeling program, it became clear that there was serious interaction between the elements. I could not obtain a workable feed-point impedance on all five bands that could be transformed to 50 Ω using a single hairpin match. There was also serious pattern distortion on 12 meters.

Even building a WARC-only triband Yagi turned out to be a real challenge. I had difficulty finding a combination that would allow me to use a single matching system to transform the feed-point impedance of the combined driven elements to 50 Ω. I couldn't create a 30/17/12 triband Yagi using the same design principles as my 20/15/10-meter version. The main problem occurred on 12 meters. Not only was the feed-point impedance unmanageable, but the radiation pattern had four lobes, not the single lobe you'd like from a Yagi.

My next modeling approach was to hang a single 17/12-meter trap dipole below the 30-meter driven element and tie the feed points together for a common feed. Again, I ran into the same problems. It became obvious that there was serious interaction between the 12-meter driven element and the other elements.

Not being one to give up easily, I considered several other methods for multibanding an antenna system. I decided to try the *Modified Coaxial-Sleeve* method, more aptly termed by K9AY the *Coupled-Resonator (C-R)*.[1] This method uses a single driven element, with other elements placed in very close proximity (but not physically connected) to the driven element. By starting with the dimensions suggested by K9AY for a triband 30/17/12-meter dipole I was able to develop a Yagi with acceptable feed-point impedances on all three bands using a single hairpin match. Notice that this WARC design uses a 2 × 2-inch wooden boom length that is 230 cm (7.5 feet) long. Now the antenna won't fit into my ski boot, so I must resort to putting it on the roof rack.

The space between the tightly coupled driven elements is only 3.7 cm (1.5 inches), so you need to use more PVC pipe spreaders than in the 20/15/15 design to make sure the driven-element wires stay as close as possible to the desired spacing without physically touching each other. The driven elements lie in the horizontal plane and the hairpin match and feed line hang down vertically from the center of the 30-meter driven element.

The spacing between the 30-meter driven elements and the other two conductors and the size of the wire all played a part in developing this antenna for a single feed line with the common hairpin match. Do not change the wire size from the recommended #14 for the driven elements unless you are willing to spend a considerable amount of time with a *NEC*-based modeling program retweaking the antenna! This is not the case with the 20/15/15 tri-band Yagi, where any convenient sized wire is acceptable.

Using #14 gauge wire allows all the Yagi antennas in this article to be used at the maximum power levels allowed in North America. The only limiting factor is the power handling capability of the feed line. However, even RG-58 should work for the relatively short length from the feed point down to ground level, where you can change to RG-8 or some other higher-power, lower-loss coaxial cable if you wish. **Fig 2** is a detailed drawing of the 30/17/12-meter driven element. The other dimensions for the 30/17/12-meter triband Yagi are shown in Fig 1 and **Table 2**.

Assembly

When you are ready to assemble your Yagi, start by attaching the longest reflector element and the driven element assembly to the wood end booms. Do this with the wires and the booms on the ground. Next attach the V slings to both of the booms and with ropes attached to the V slings pull the array up off the ground between two supports (perhaps two trees). A height of 1.5 meters (5 feet) above the ground makes it easy to work on the antenna while you add the other reflector elements and adjust the V slings. Pull them tight so that the array is fairly flat. It won't stay horizontal, because the driven elements are heavier than a single reflector element. So you will need to support the 2×2-inch spreaders so they are horizontal. Lean the booms on something at a convenient height, such as the rungs of two step ladders. Now add the two other reflector elements, but don't pull them as tight as the longest reflector. Next attach the feed line.

V Slings

Since I wanted to be able to raise the 30/17/12-meter triband antenna by myself, I again used only one rope on either end of the array. One end goes over a tree limb and the other end is tied to a stake in the ground or some other nearby support, perhaps a tree trunk. Using only one attachment rope on either end makes it very easy to change beam direction by walking the antenna around the antenna support tree or tower. To accomplish this I used two V slings, one on each end attached to the 2×2-inch spreaders.

The secret to keeping the antenna level in the horizontal plane is that the V slings are not equilateral in shape. The combined weight of driven elements, balun and feed line is heavier than the reflectors. If the length of the sides of the V are equal, the array will rotate downwards. The driven elements will end up facing the ground, with the reflectors facing up. Adjust the V slings so that the antenna will stay level in the horizontal plane by shortening the length of the side of the V attached to the driven elements. It is quite easy to adjust in the field, and once you have it adjusted it stays balanced.

Once you raise the antenna to its operating position and in the horizontal plane, you can change direction 180° by pulling on the feed line. As you pull, the whole array will slowly turn over. Stop it from turning by holding onto the feed line once the array has swung over to face the opposite direction.

The Balun

In the original *QST* article, I was a little unclear describing the coil of coax at the feed point, so I've redrawn it in **Fig 3**. You should let the coax drop straight down from the center insulator and attach it to the center of the hair-pin shorting bar. Continue by making a coil using the coax of 6 to 8 turns, with a diameter of about 4 inches. This balun will choke off RF flowing along the outside of the coax shield that would otherwise distort the radiation pattern of the antenna. The center of the shorting bar is at a neutral potential, so there is no harm in attaching the coax feed line at that point.

SWR Adjustment

Since you may situate your antenna in an entirely different position than I did, you may need to fine tune your antenna. Begin with the dimensions in Table 2 as a starting pint. Make a temporary shorting bar using two alligator clips joined by a piece of wire and attach them at the recommended position. Next raise the antenna to the desired final position. Using an antenna analyzer (or transmitter and SWR meter) plot the SWR over all three bands. Start with the lowest band, 30 meters and adjust the shorting bar up or down to find the lowest SWR point in the portion of the band you plan to operate in. (This procedure holds if

Table 2
Dimensions for 30/17/12-Meter Tribander

Frequency	*Spacing*	*Driven Element*	*Reflector*	*Hairpin*
MHz	*DE to Refl*	*Length*	*Length*	*Length*
MHz	*cm (feet)*	*cm (feet)*	*cm (feet)*	*cm (inches)*
10.12	230 (7.5)	713 (23.4) Half	1476 (48.4)	24.5 (9.5)
18.11	165 (5.4)	808 (26.5)	822 (27.0)	
24.91	120 (3.9)	570 (18.7)	606 (19.9)	

Spacing between hairpin wires is 10 cm (4 inches). Note that dimensions for 17 and 12-meter driven elements are full lengths, since they are not broken with insulator in the middle, unlike all driven elements for 20/15/10-meter triband design in Table 1.

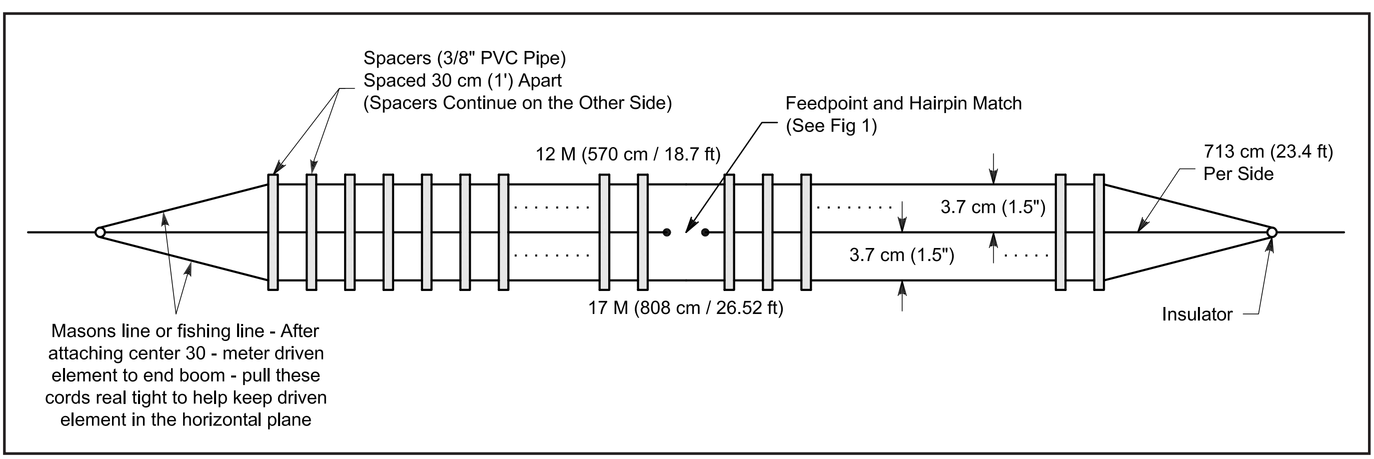

Fig 2—Layout of 30-meter driven element with coupled resonators for 17 and 12 meters.

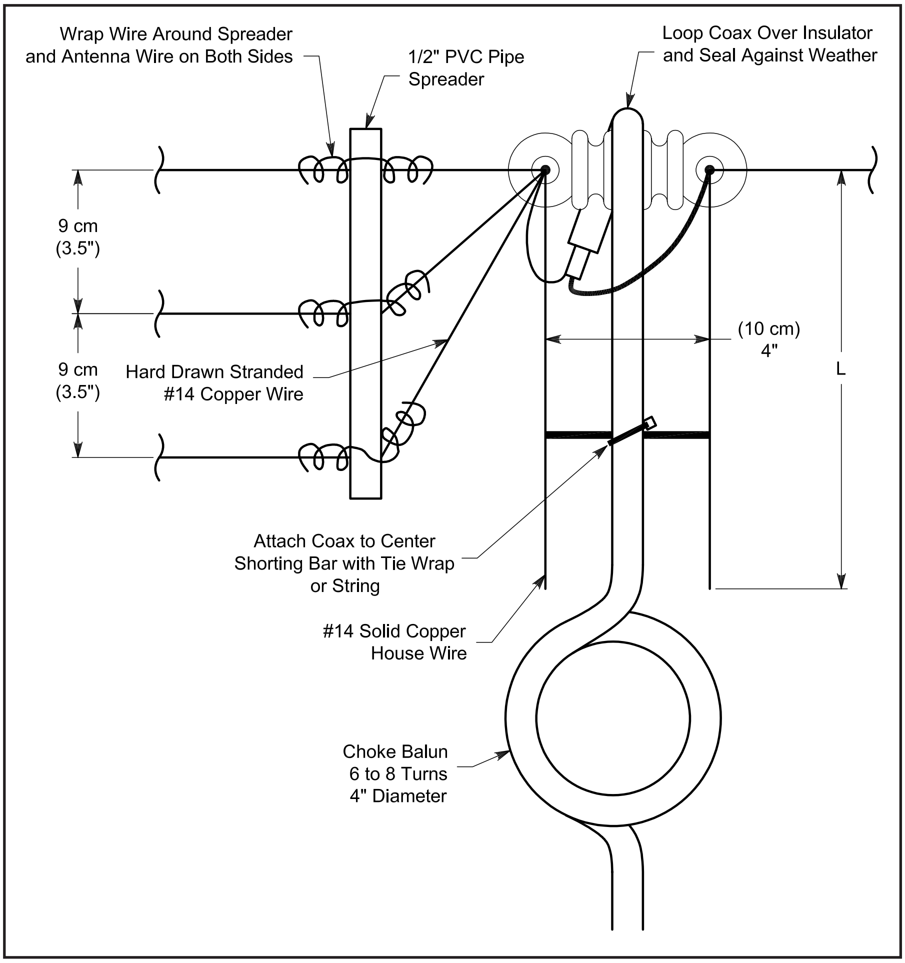

Fig 3—Details of feed point for 20/15/10-meter triband Yagi. The same mechanical support is provided for the balun and feed coax for the 30/17/12-meter tribander.

Table 3
40-Meter Wire Yagi Configurations

Configuration cm (feet)	*Driven Element cm (feet)*	*Reflector cm (feet)*	*Hairpin Length*
1. Horizontal	1978 (64.90)	2098 (68.83)	Approx 50 cm
2. –30° Sloper	1978 (64.90)	2113 (69.32)	(22 inches)
3. –65° Sloper	1978 (64.90)	2101 (68.93)	
4. Inverted V	2040 (66.93)	2126 (69.75)	

Spacing between driven element and reflector is 427 cm (14 feet). Spacing between parallel hairpin wires is 10 cm (4 inches). The lengths shown above are the total wire length for each element.

you wish to adjust the 20/15/10-meter tribander. Start with the lowest frequency.)

You shouldn't have to move the shorting bar very far from the suggested length. Now that you have determined the right shorting-bar position, adjust the other two driven elements lengths for the lowest SWR in the portion of those band in which you plan to operate. You may have to compromise with the position of the shorting bar to find a satisfactory range where the SWR is acceptable on all three bands. After satisfying myself with the position of the shorting bar, I replaced the alligator clips simply by folding one side of the parallel hair-pin wire lengths over to the other side and soldering it in the position where the alligator clips had been attached. I do not recommend changing the reflector element lengths unless you are familiar with antenna modeling programs and are willing to model different spacing or element lengths.

40-Meter Wire Yagis

I've had several requests for a 40-meter wire Yagi. One ham mentioned that he wanted to be able to pull up a 40-meter Yagi between two towers and be able to flip it over to change direction. Another wanted a 40-meter Yagi he could pull up on a single tower for the winter DX contests and then put it away during the summer. I ran four different 40-meter scenarios in my computer models:

1. A horizontal 2-element wire Yagi at 65 feet.
2. A sloping 2-element wire Yagi, with one end at 65 feet and sloping downward 30° from vertical.
3. A sloping 2-element wire Yagi, with one end at 65 feet and sloping downward 65° from vertical.
4. An inverted-V 2-element wire Yagi with the apex at 65 feet and an included angle between the wires of 120°.

Fig 4 shows the layout for an inverted-V system and **Table 3** lists the element and hairpin lengths. Elevation patterns for the 40-meter antennas are compared in **Fig 5**, with a reference antenna of a single flattop dipole at 65 feet. As they say, a picture is worth a thousand words. If your interest is DX, it is very clear that horizontal and high is a very good rule of thumb for most antennas.

Yes, a ¼-wave vertical over salt water or 120 ¼-wave radials will produce very low radiation angles, but they are not exactly portable and we don't all live near the ocean. Mind you, if you can locate antenna Number 3, the most vertically oriented wire Yagi, next to the ocean the story would be very different.

The point here is that if you have two towers and you're not fortunate enough to be located on a saltwater marsh, you should pull the array up as high and as horizontal as you can. If you have only one tower and don't need to change direction often, then try the inverted-V configuration. You can still change the direction by walking each end around the tower.

However, even the sloping 40-meter Yagi with one end at 65 feet up a tower (or tree) and the other end attached with a long rope as far as possible from the tower will still put out a very respectable signal. It is directional, and you can walk it around the tower to change direction or you can flip the antenna over and change direction 180° very quickly.

Summary

You don't need a 10-meter (60-foot) high tower, a commercial triband Yagi and a rotator to put out a good signal on the HF bands. Wire Yagis work very well and they can be inexpensive and easy-to-build, using components found at your local hardware store. I was pleased to receive the following testimonial:

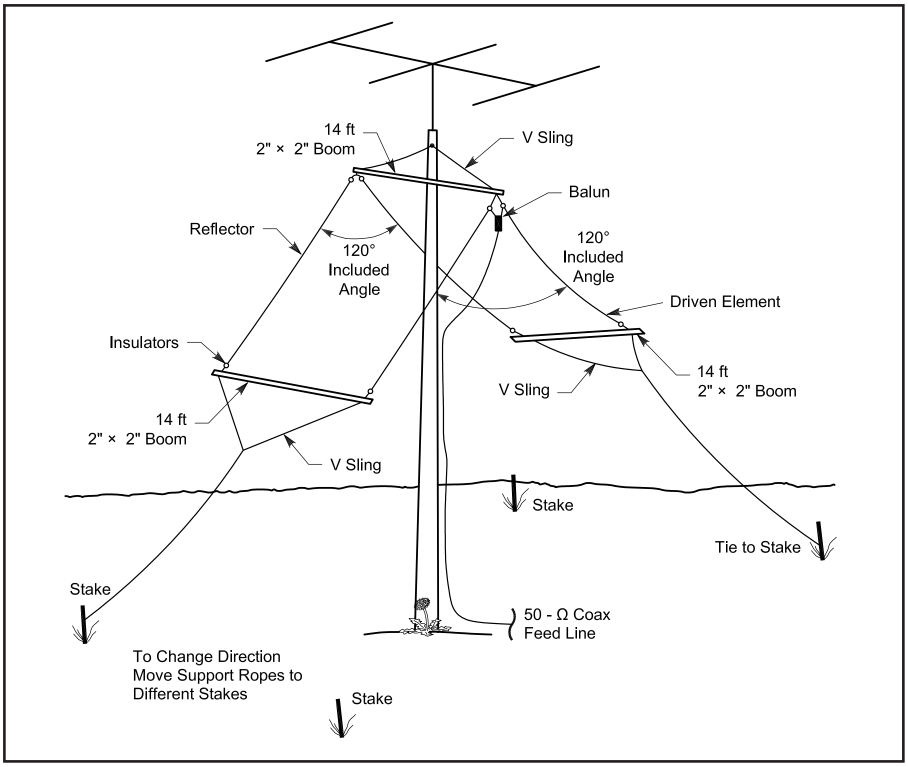

Fig 4—Layout for inverted-V 40-meter portable wire Yagi suspended from tower.

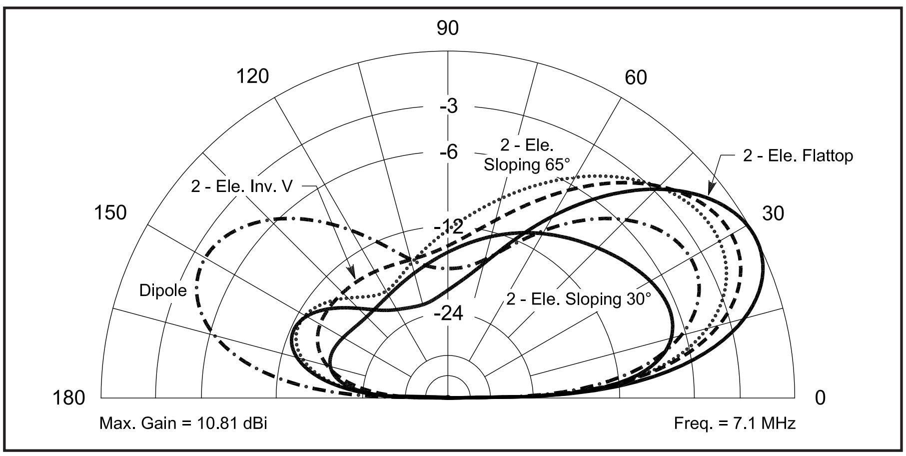

Fig 5—Comparisons of elevation patterns for five 40-meter antennas: a 2-element flattop Yagi at 65 feet; a 2-element inverted-V Yagi at 65 feet; a 2-element Yagi sloped 65° from the vertical plane; a 2-element Yagi sloped 30° from the vertical plane; and a horizontal dipole at 65 feet.

Fig 6—VE7CA portable 2-element wire Yagi installed at Plimoth Plantation in Plymouth, Massachusetts. (*Photo courtesy K1HTN.*)

N1WWI, Chris, W5IRW, Jim and K1HTN, Bruce, constructed the Portable 2-Element Triband Yagi featured in the November 2001 issue of *QST*. We installed it this past weekend at Plimoth Plantation at Plymouth, MA, for our yearly Special Event Station WA1NPO that we set up on the Saturday/Sunday right after Thanksgiving and the last weekend that the Plantation is open before winter.

Our operation started Saturday morning at 0900 and despite the very poor 20 meter band and nothing on 15 and 10 due to the solar eruption we had many QSOs, all with glowing signal reports. On Sunday the band was in much better shape and we had a 5-hour pile up on our frequency. Its performance far exceeded our expectations.

It worked out pretty well with the Hairpin match. When we put the MFJ analyzer on it in the air and it was not that high up, it showed 1.2/1 at 14.2, 1.3/1 at 21.250 and 1.1/1 at 28.4.We almost didn't believe the analyzer. Hi Hi. 73s…Bruce Beaman, K1HTN.

The photo in **Fig 6** by Bruce, K1HTN, shows the 20/1515 Triband Yagi installed over the Hornblower House at Plimoth Plantation.

NOTES

Gary Breed, K9AY, "The Coupled-Resonator Principle: A Flexible Method for Multiband Antennas," *The ARRL Antenna Compendium, Vol 5*, p 109.