By Joel R. Hallas, W1ZR

Achieving Near Perfection with the Imperfect Rhombic

The classic rhombic antenna is still a contender to provide serious performance at low cost—if you have just a little bit of room.

I don't know about you, but I have had a fantasy for some years about having a big chunk of flat land, getting the power company to sink some tall poles and stringing a serious rhombic around them. Perhaps it had to do with my soldiering days at Fort Monmouth, New Jersey when I walked past, and even occasionally operated K2USA, which had exactly that antenna setup (at least in 1962).

Well, it's been quite a few years and somehow I don't think the ideal situation will present itself anytime soon. For the last 20-some years I have been living on a suburban lot of a bit more than an acre with a number of impediments to my dream—a house in the middle, lots of tall trees and not too level ground. The fact that I'm up a bit of a hill is not an accident either, but hasn't helped facilitate the rhombic fantasy.

The Current Farm

My mini HF antenna farm of a G5RV broadside to Europe and a perpendicular biconical lazy-H have done well for themselves, but I wanted to refocus my efforts a bit lower in frequency in response to our current point in the sunspot cycle. I think 30 meters will gain in importance as we move forward and the G5RV just doesn't do it on 30. I spent some time going over options and decided that if I could get good directivity toward Europe on 30 meters and up, I could replace the G5RV with a "mini cage dipole" with a fundamental response on 80/75. This would give me better performance than the G5RV on the fundamental and less feed-line loss, and provide good coverage off boresite on 30 meters and up.

I would then need that coverage to Europe to complete the plan. Of course, a good multiband rotary array would do the trick. If I had an extra few kilobucks for hardware, plus legal fees to get through zoning and deal with the divorce, it would be perfect. What I ended up with was an imperfect rhombic hung from trees of opportunity and providing about 7 dBd or more gain toward Europe on 20 meters and up with significant gain on 30 meters. In addition, I can get 15 dB or more front to back ratio and easy switching toward the US and New Zealand when I want. This performance is better than a three element Yagi for each band, covers the whole range and even can be an NVIS (Near Vertical Incidence Skywave) cloudwarmer on 80 and 40 when the dipole is down. To top it off, it is relatively inexpensive and hasn't incurred any legal fees to date.

How to Make a Rhombic

The ultimate terminated rhombic is made in the shape of a diamond. For a frame of reference, I started with the compromise multiband rhombic shown in *The ARRL Antenna Book*.[1] That design used 3 λ per leg, but my yard would more readily support 2 λ, so I adjusted both the length and the tilt angle to obtain the appropriate pattern across the range; the result is shown in Figure 1.

I used *EZNEC*[2] to estimate the horizontal and vertical patterns at 20 and 10 meters for such an antenna and they are shown below (Table 1 and Figures 2 and 3) along with a summary of operation on all HF bands and a detailed examination of the performance as a function of height on 20 meters in Table 2. Note in Table 2 that for any height, *EZNEC* predicts that the rhombic has a 7 to 8 dB edge over the dipole, both in terms of peak gain and gain at 10° elevation, a measure of long-haul capability.

[1]Notes appear on page 32.

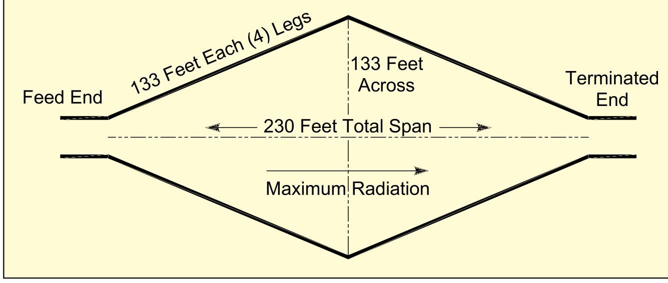

Figure 1—Compromise 2 λ per leg rhombic for 20 through 10 meters.

Table 1
Gain, Peak Takeoff Angle and 3 dB Beamwidth of Rhombic at 50 Feet

Band (Meters)	*Peak Gain (dBi)*	*Elevation*	*Gain at 10° (dBi)*	*3 dB Beamwidth*
30	12.5	30°	5.2	35.4°
20	15.6	20°	12.1	23.8°
17	17.7	15°	16.4	18.4°
15	18.7	13°	18.3	15.6°
12	19.4	10°	19.4	12.8°
10	19.5	9°	19.3	10.6°

As the snow cleared, I went tromping about my yard with my trusty hand-bearing compass[3] pacing off distances between trees in about the right spot. What I found was that I could get a non-ideal rhombic pointing right down the Mediterranean, giving good coverage across most of Europe, the Middle East and into the Indian Ocean. A few days with an EZHang slingshot[4] got my halyards up, but none on the first try! Many thanks to Rich Roznoy, K1OF, for his one shot success on the far corner following days of frustration. This article came very close to being about a V beam!

The resulting configuration is as shown in Figure 4, with corresponding *EZNEC* patterns shown in Figures 5 and

Table 2
Gain and Peak Takeoff Angle of Rhombic and Dipole as a Function of Height (14.15 MHz)

	Rhombic			*Dipole*		
Height (ft)	*Peak Gain (dBi)*	*Elevation*	*Gain at 10° (dBi)*	*Peak Gain (dBi)*	*Elevation*	*Gain at 10° (dBi)*
70	15.3	15°	14.3	7.7	14°	7.0
60	15.6	17°	13.5	6.9	16°	5.4
50	15.6	20°	12.3	7.6	19°	5.0
40	15.4	24°	10.6	8.2	24°	4.2
30	14.6	27°	8.3	6.3	32°	0.4

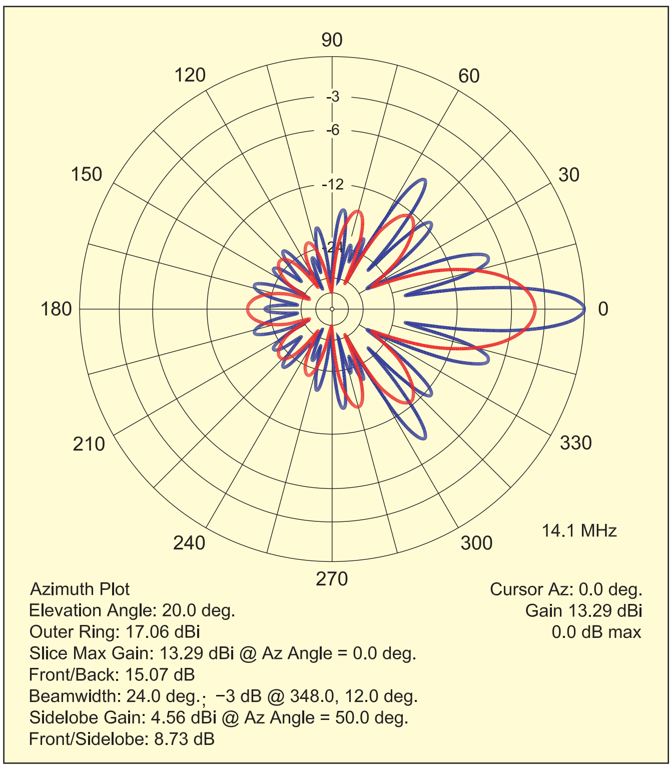

Figure 2—Horizontal pattern of 2 λ compromise rhombic on 20 meters (red) and 10 meters (blue) at 50 foot height.

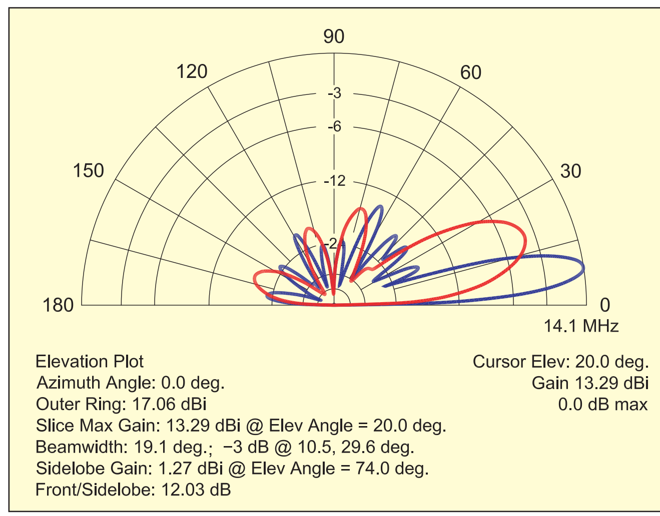

Figure 3—Vertical pattern of 2 λ compromise rhombic on 20 meters (red) and 10 meters (blue).

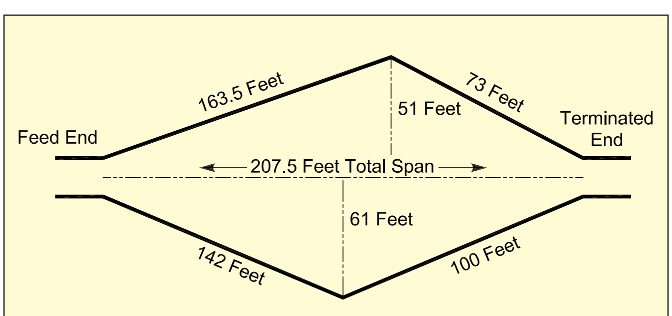

Figure 4—W1ZR achievable single-wire terminated rhombic for 30 through 10 meters.

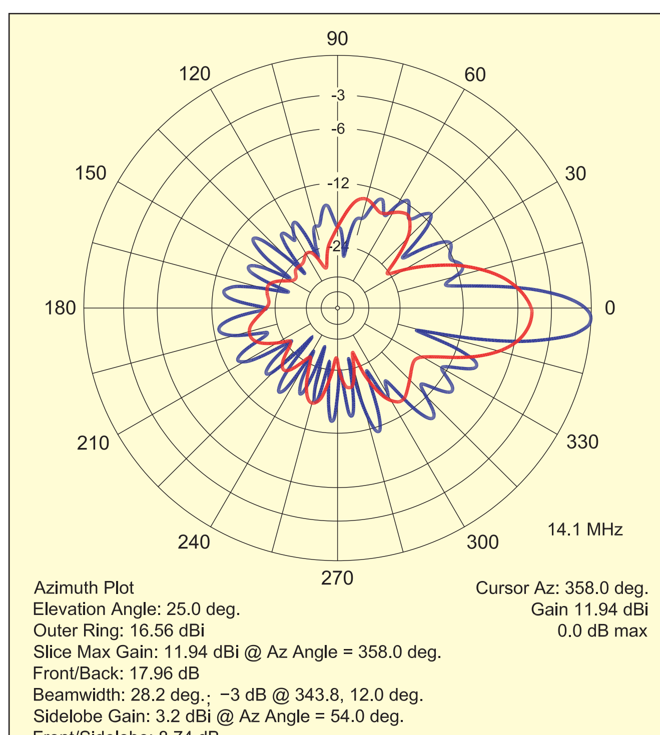

Figure 5—Horizontal pattern of W1ZR rhombic on 20 meters (red) and 10 meters (blue), fed from left end.

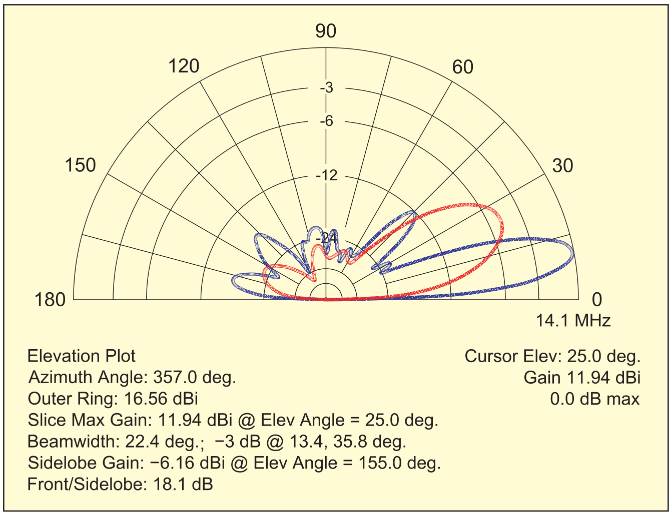

Figure 6—Vertical pattern of W1ZR rhombic on 20 meters (red) and 10 meters (blue).

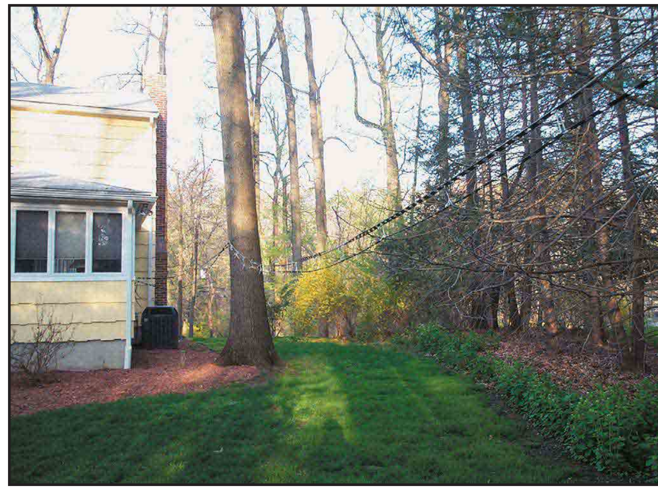

Figure 8—View of the feed line from the New Zealand feed point in the back yard. The "messenger rope" also holds up the feed from the Lazy H.

Figure 7—If you look *very* closely with a magnifying glass, you can just about see the catenary leading to the Europe feed in the front yard.

6 for comparison with the textbook model. Although some of the trees looked like 50 feet high or higher, we ended up at about 40 feet, raising the main lobes a bit. Also note that we were not able to line trees up with as much symmetry as I would have hoped. This turned out to be a mixed blessing, since the main lobes are a bit broader, although the peak gain is reduced slightly. The pattern shown is while fed from the left end (toward Europe). Fed from the other end, the pattern is similar except by 28 MHz, the major lobe breaks into multiple lobes.

We looked at a number of different configurations to get an idea of the sensitivity to dimensional changes for other locations. If the antenna is made wider, changing the tilt angle from our 60° target toward say 55°, the result is about a dB increase in forward gain and about a degree lower main beam on 20 meters, but the 10 meter pattern starts to break up into multiple lobes. If you make it narrower, say to 65°, it favors 10 meters with about a dB more gain, but the 20 meter gain drops almost two dB and the pattern shifts up about a degree. As you change the length to width ratio, you shift the operating frequency up and down a bit, but it still works well over most of the range.

Note that there is nothing magical about the leg length either. A terminated rhombic is a wideband antenna and does not need to be an integral number of wavelengths on each leg to function well. Below about 1 wavelength per leg, it may not be the best use of the available wire and supports, but whatever can be fit can be easily modeled to see if the performance is what you want. A 1 wavelength per leg rhombic may be a viable solution for a smaller or squarer lot shape.

My installation is hardly noticeable, unless you are looking for evidence of antennas. The prime feed is in our front yard and, as shown in Figure 7, the feed line is barely visible. Part of the rear run is shown in Figure 8, and is visible in the backyard, but no one has complained. Note that if you *just* were interested in high performance in one direction, a 9:1 balun and dummy load could be made waterproof and placed near the base of the terminating end. This would avoid one transmission line run, saving money and making the antenna even less visible.

Feeding a Rhombic

A nice feature of a terminated rhombic is that it has relatively constant impedance over frequency, if well constructed and terminated. The traditional rhombic is viewed as a 600 Ω system, probably closer to the truth if made with multiple wires in each leg separated more widely in mid span. There was no way I was going to pull that through my small forest!

This rhombic is closer to an 800 Ω system, with an SWR that varies within about 2:1 of 450 Ω ladder line. The *EZNEC* SWR plot is shown in Figure 9. Note that the antenna works continuously across the range, making it suitable not only for all the ham bands, but also as a great SWL receiving antenna.

The relatively constant impedance makes feeding and terminating this antenna relatively easy. Nine-to-one balun transformers[4] can be used for the feed line or the terminating line, or both. If used on both ends, a pair of coax switches or relays[5] can be used to switch directions easily and the resulting 2:1 VSWR is usable with many transmitters directly, and is certainly within range of any internal tuners. A single 9:1 balun can be used with a 50 Ω dummy load as a termination and a tuner can be used directly on the feed line to the driven end.

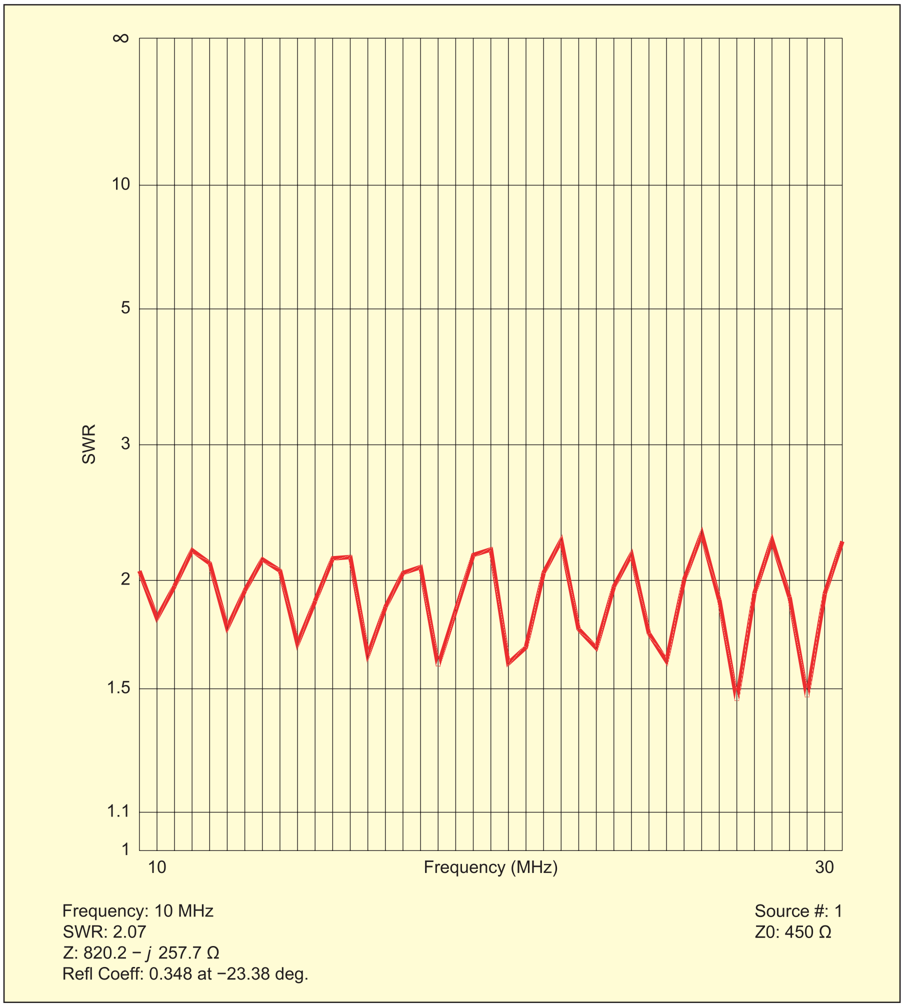

Figure 9—*EZNEC* plot of 450 Ω SWR of as-built rhombic, far-end terminated in 800 Ω.

Note that the SWR is within the range that is generally satisfactory for use with a balun on the antenna side of the tuner. This arrangement requires switching directions with the 450 Ω line, which can be done with relays, switches or even double banana plugs. Figure 10 shows the switching arrangements. Note that double the set of contacts are needed if switching the ladder line rather than coax.

This is all fine for feeding the driven end with any of the arrangements described above. Unfortunately, the terminated end will not always be well matched. The consequence of this will be a reduction in front-to-back ratio due to reflection from the termination mismatch and additional radiation in the rear direction. The result is a front-to-back ratio I found to be typically around 10 dB. While this isn't terrible, a simple way to get close to optimum results is shown in Figure 11. Any old tuner (losses don't matter in this application) should do, as long as it can match over the range required. Adjustment can be made as in either of two ways as follows:

1. Get in range by terminating the desired *transmit* side, apply power to your "terminating tuner" and adjust the tuner for a match to 50 Ω.

2. Switch ends, put the load back on the terminating tuner and tune to null a station in the back direction (so long Tex!).

Alternately, if you have a power meter, you can put it into the line going to the terminating load and adjust the tuner for maximum power delivered to the load.

Note that in either case, you will need to recheck the transmitter (or transmitter side tuner) settings since the drive impedance will change with an adjustment to the termination.

This is kind of handy and can be applied whenever needed. If your termina-

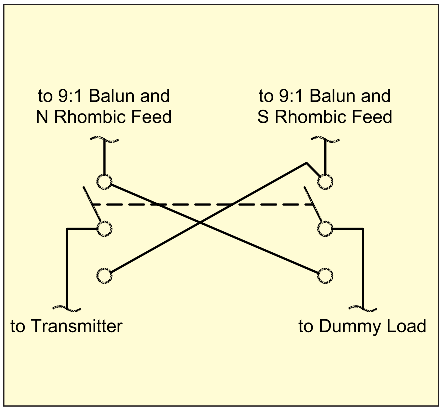

Figure 10—Diagram of coaxial switching arrangement. All shields are in common at the switch. For ladder line switching, twice the connections and switch points are required.

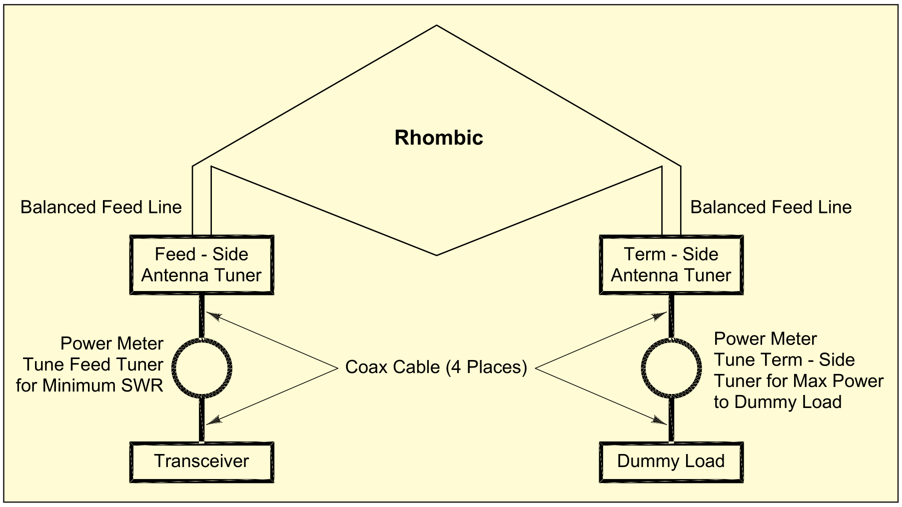

Figure 11—Terminating the non-ideal rhombic with an antenna tuner and dummy load.

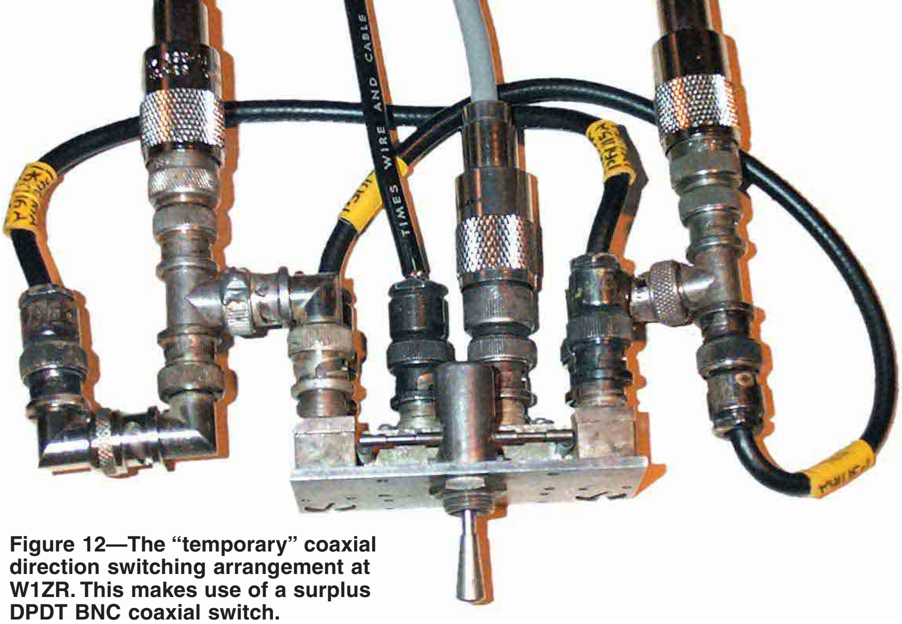

Figure 12—The "temporary" coaxial direction switching arrangement at W1ZR. This makes use of a surplus DPDT BNC coaxial switch.

tion tuner has calibration markings on its controls, you may want to record the approximate settings for each band so you can skip step 1 above. Note that the tuner can be adjusted to meet other objectives. If you tune to maximize signals from the back, you may not need to switch directions. Although the performance will be down, it may be just fine for stateside contacts. You also may be able to reflect a short up to the termination and make the antenna work like a "loop skywire." You can also do that by making the terminating line a half wavelength (or multiple) on 80 meters and shorting it at the bottom. It will reflect a short on 80 and all harmonics back to the terminating end. It won't work quite as well as a square loop, but there's no extra charge.

For my operation, I grew tired of fooling with the tuners and put a 9:1 balun on both ends where the ladder line entered the house and switched the coax (see Figure 12 for my "temporary" switching setup made out of a "junk box" DPDT BNC coaxial toggle switch) to change directions. This allows the use of standard coaxial lightning arrestors, which should be applied at both ends and grounded at the house entry point.

So, How Does it Play?

I have been very happy with the results. I observe both the predicted forward gain (in A/B tests with my G5RV and using my ARRL Lab calibrated S-meter) and front-to-back ratio. On the air results in the European direction have validated the data with many reports such as "booming in," even when the bands are not great. Unfortunately, I have not encountered conditions to Asia/Pacific that allowed a good test to that region, although WWV provided a good measurement source on 10 and 15 MHz in that direction, at a higher angle than optimum for this antenna. The difference on 30 meters is particularly dramatic, since the G5RV has a high mismatch on that band and significant loss in the coax. I didn't know what I was missing!

And What Does it Cost?

The needed parts are available from many sources. I obtained almost all the pieces of the antenna itself at Radio Works (**www.radioworks.com**). Although there are other sources and flavors, I have learned a few things in my 50 years of antenna work:

1. Don't use cheap halyards. I have found Dacron braid or double braid the least subject to abrasion from tree movement.

2. Use stranded, not solid wire, ladder line for unsupported runs.

3. Order the antenna wire in two pieces so you don't have to stretch out the whole length to find the center.

For my installation, I ordered the following:

Halyard rope, 5/16 inch black Dacron braid, 500 feet	$45
Antenna wire, 520 feet #14 hard-drawn copper	$47
Ladder line, #14 stranded copper clad, 300 feet	$69
Ladder lock insulators, 2	$27
Standard insulators, 2	$3
Total	**$191**

In addition, I purchased two of the optional CWS-Bytemark W2FMI 9:1 baluns at $90 each. I think this is an excellent price to performance ratio and I'm very happy that I pulled this together after all these years.

Notes

[1] *The ARRL Antenna Book*, 20th edition, Chapter 13, pp 9-15. Available from your local dealer or the ARRL Bookstore, order no. 9043. Tel toll-free in the US 888-277-5289, or 860-594-0355; **www.arrl.org/shop**; **pubsales@arrl.org**.

[2] *EZNEC* is available from Roy Lewallen, W7EL, at **www.eznec.com**.

[3] Make sure you compensate for the difference between True and Magnetic North if using a compass (magnetic) to line up antennas against the typical polar projections in true coordinates. This varies by area. (In my part of Connecticut, one needs to add almost 14° to true bearings to get the magnetic equivalent. This makes a big difference if you are working with narrow beam antennas.)

[4] EZHang slingshots are available from **www.ezhang.com**.

[5] J. Sevick, *Understanding, Building and Using Baluns and Ununs*, CQ Communications, Inc. Available from the ARRL Bookstore, order no. 8982. Tel toll-free in the US 888-277-5289, or 860-594-0355; **www.arrl.org/shop**; **pubsales@arrl.org**. I purchased my W2FMI 9:1 baluns preassembled from CWS Bytemark (**www.cwsbytemark.com/prices/baluns.php**). An alternate source is DX Engineering (**www.dxengineering.com**).

[6] Note that typical antenna relays (such as the popular "Dow Key" type) short the "receiver" terminal on transmit and thus will not work in this application unless that feature is disabled.

Photos by the author.

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