Tips for Tuning a Full-Size 160 Meter Vertical

Jay Terleski, WXØB

I'm often asked how to match a quarter-wave vertical for 160 meters to a 50 Ω transmission line, what to do about lightning protection and even how to take RF measurements with powerful AM broadcast signals in the vicinity. This article will describe how to make a basic — but elegant — matching device for a quarter-wave vertical which does additional duty as a static bleed device and a surge arrestor with a lightning loop. I'll also explain how it's possible to take the antenna measurements needed to make the matching device and to tune the antenna correctly while in the presence of strong RF from nearby AM broadcast stations.

Antenna Matching on 160 Meters

I've seen antenna matching solutions that range from just attaching the coax to the antenna and living with the result to adding a series capacitor to allow tuning the antenna over the band or even using an L network to match the antenna's approximately 30 Ω to the feed line's 50 Ω. Let's look at a very simple solution that I've found useful.

My own quarter-wave 160 meter vertical is sort of an inverted L. It rises up from ground level to 50 feet as a free-standing aluminum tube. At that point I've attached a #12 wire that slopes upward at a 45° angle to my 150 foot tower. The system has 64 buried radials. Fortunately we have excellent ground here. Due to the sloping wire the antenna's feed-point impedance is lower than the theoretical 36 Ω.

What we will attempt to do is tune this antenna for a 50 + *j*0 Ω resonance at 1.830 MHz using an LC network. For a capacitor we will just shorten the antenna length a small amount to create the necessary "phantom capacitance." I don't like to use series capacitors, since they're prone to fail at high currents and in lightning events. Then a single inductor across the feed point is all we need to match the antenna to the transmission line. This technique is a great way to handle this sort of matching situation.

Issues with Nearby AM Broadcast Station RF

There are many AM broadcasters in my area, and one station even operates on 1700 kHz! These stations place 10 V peak-to-peak RF onto my antenna during the day and even more at night. Figure 1 shows how to attach a 'scope probe to the coax stub going to the Heliax™ feed line. Figure 2 shows the scope reading at the unterminated end of 150 feet of half-inch 50 Ω Heliax. Trying to take an accurate measurement using any of the impedance meters available to hams is impossible. They overload, and some will even blow their diode bridges, requiring a trip to the factory. The AIM 4170B analyzer we market at Array Solutions, **www.arraysolutions.com**, will not blow up, but simply hooking it to the feed line won't let you take any measurements in the presence of strong RF either. It does, however, have a neat feature that can be used to take this measurement accurately, and we will use it to help us tune this antenna.

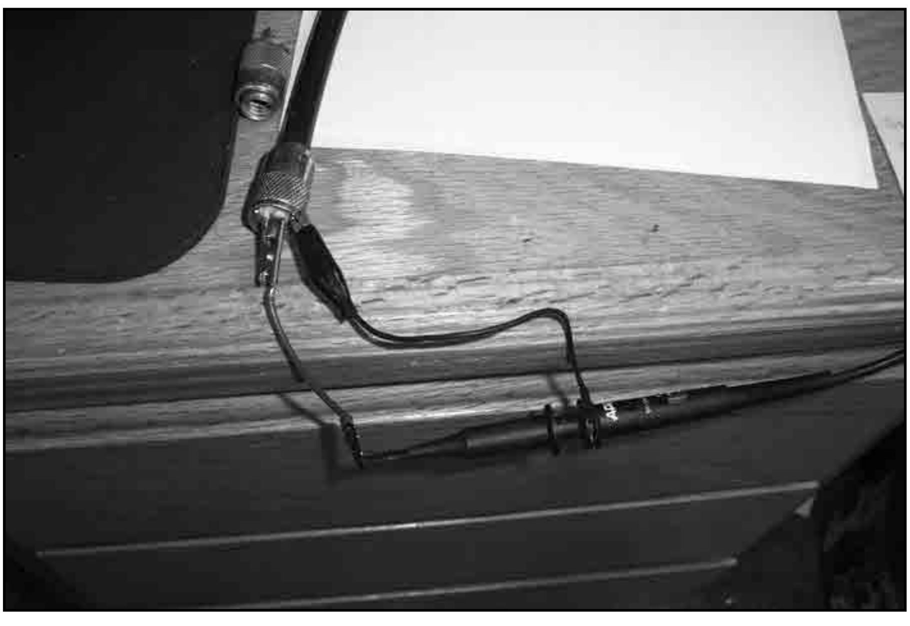

Figure 1 — Connecting the probe to the coax.

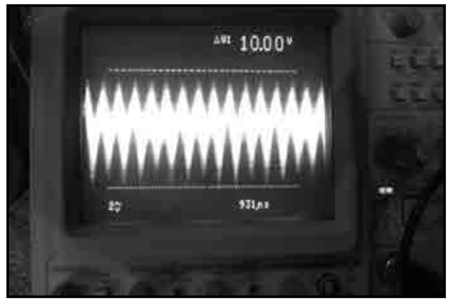

Figure 2 — 10V peak-to-peak RF

The 10 V peak-to-peak RF represents 0.25 W of power into 50 Ω. The AIM 4170B, on the other hand, puts out *microwatts* of RF to enable measurements. So, how can this device override the power that's showing up in the antenna system?

When we attach the AIM 4170B to this antenna and coax and do a scan from 1.5 to 2.5 MHz, we see the plot in Figure 3. The bold line above the X axis is VSWR. The lighter line highlighted with squares is resistance (R), while the lighter line highlighted with dots is reactance (X).

Due to the RF overload, the plot is full of noise and totally useless; we need to alter our measurement technique if we are to get accurate information to allow us to adjust this antenna. What we need is a good broadcast-band high-pass filter. W3NQN makes a superb filter for this purpose, and I connected it to the RF connector of the AIM 4170B analyzer. Before using it, however, it's necessary to null out its transfer function so the measurements we take are not affected by it.

High-order filters like these have phase shifts and other linear parameters due to their design. We must normalize them. To do this the AIM 4170B has a "custom calibration" feature. This is the "neat feature" I mentioned. The software leads you through a "super" calibration using the short, open and load technique through the filter over a limited frequency range of interest. To create a very accurate calibration table requires lots of sample points. I used 500 points of measurement. The software will create a very detailed

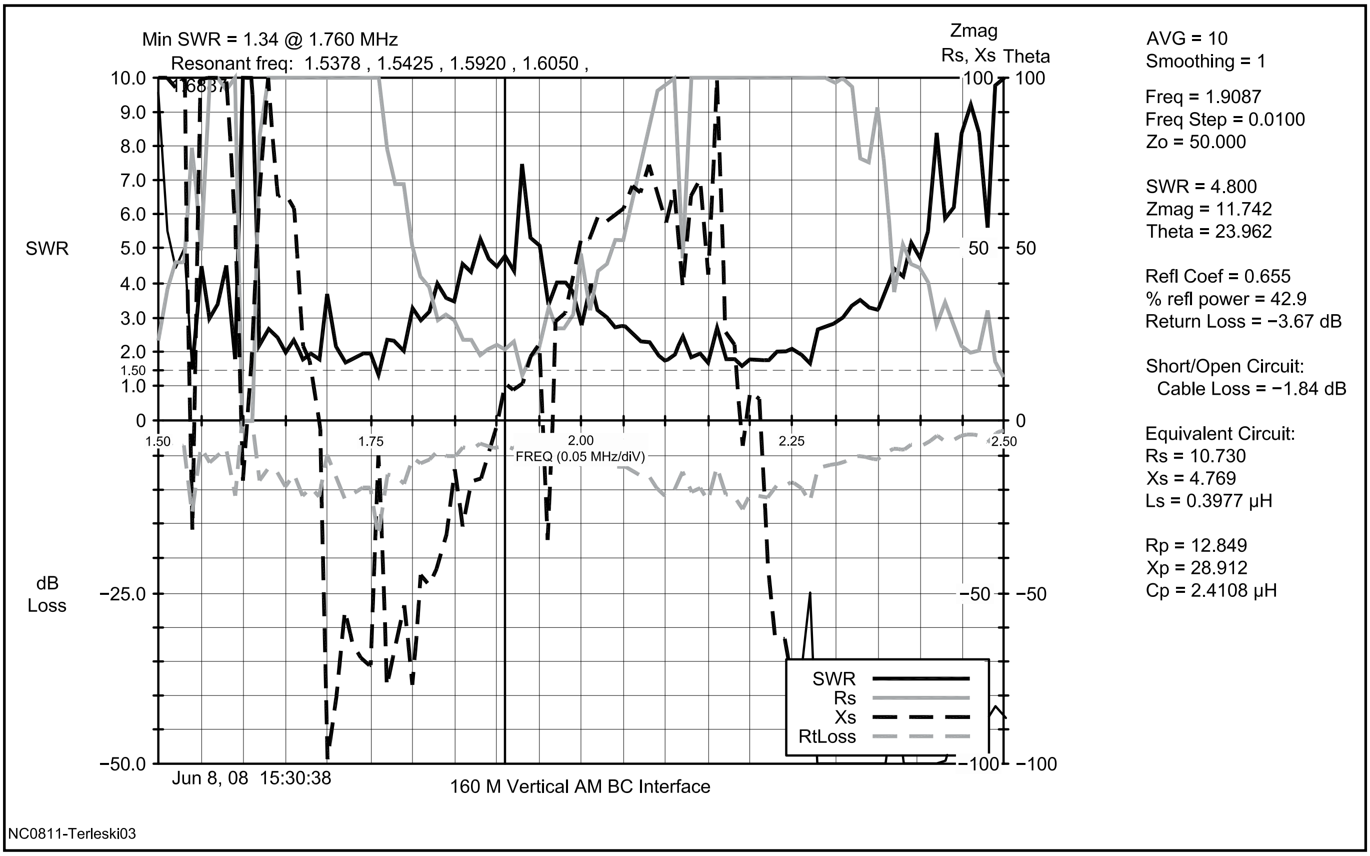

Figure 3 — A plot of the antenna from 1.5 to 2.5 MHz: AM broadcast station RF makes measurements impossible.

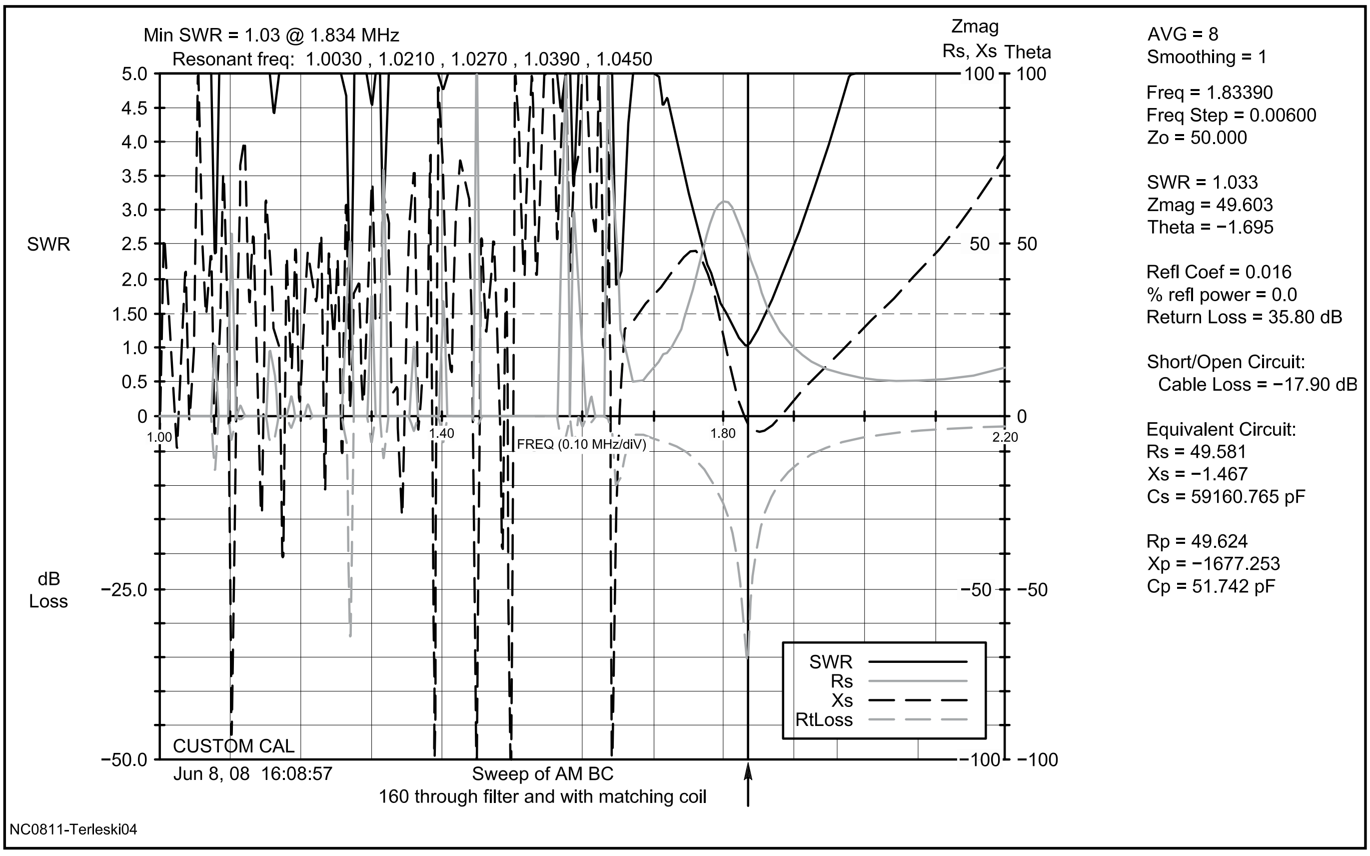

Figure 4 — A very clean plot. X = 0, R = 31.4, VSWR = 1.59. The little glitch is the second harmonic of KRLD.

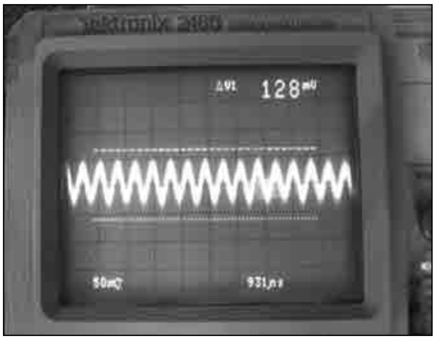

Figure 5 — The sidebands show about 125 mV of RF still getting through the filter.

calibration table that essentially moves the measurement point from the analyzer's RF connector to the input connector of the broadcast band high-pass filter.

Once the custom calibration is run, it can be saved in a file for future use. Now that we have the analyzer and filter fully calibrated, we can retest the antenna and coax system. Figure 4 shows the plot obtained while scanning through the filter. Note that I added 8× averaging (see the "AVG=8" in the upper right-hand corner of the trace) to the measurement to get rid of any residual noise. This way we can eliminate the effect on the measurement of the AM broadcast station's ever-changing sideband power.

As a further check, I looked at the antenna through the filter with the 'scope. Figure 5 shows approximately 125 mV peak-to-peak RF is getting through the filter. That's still pretty high, but the AIM 4170B can handle it.

Adjusting the Antenna to Create the Phantom Capacitor

To create a "phantom capacitor" as part of a matching network, we need to adjust the antenna's resonant frequency to make it short or capacitive. Instead of resonating the antenna at 1830 kHz, we'll move its resonant point up in frequency. Since I don't care about operating above 1875 kHz, I use 1900 kHz as my target frequency so the antenna exhibits a capacitive reactance at 1830 kHz. Using an L-network program like the *Network* program we offer, it's easy to create a match for this antenna.

First we need to find the impedance at our desired frequency. Figure 6 shows a plot with a vertical line marker at 1830 kHz. The corresponding resistance is 41.6 Ω and the corresponding impedance is –41.5 Ω (capacitive reactance) at the end of the transmission line.

To obtain the exact reactance at the antenna we could take the AIM to the antenna and measure the input terminals, or we can just use the "Refer to Antenna" function in the software, describe the 150 feet of 50 Ω Heliax, the cable loss (a lookup table) and its velocity factor (also a lookup table). Plugging these numbers into the software prompts and rescanning will now give the measurement *as if we were at the feed point* all from the comfort of my air conditioned shack! The R and X values turn out to be almost exactly the same as at the transmitter end of my cable. At 160 meters this is probable, but you cannot assume they will be the same at higher frequencies; they could be drastically different.

The L-network software calculates that we need a shunt coil of about 5.8 µH to match this impedance to 50 Ω. Using a three-inch piece of PVC pipe as a coil form, I wound 12 turns on it per the network

Figure 7 — The inductor attached to the insulated vertical element is grounded at its far end (not seen).

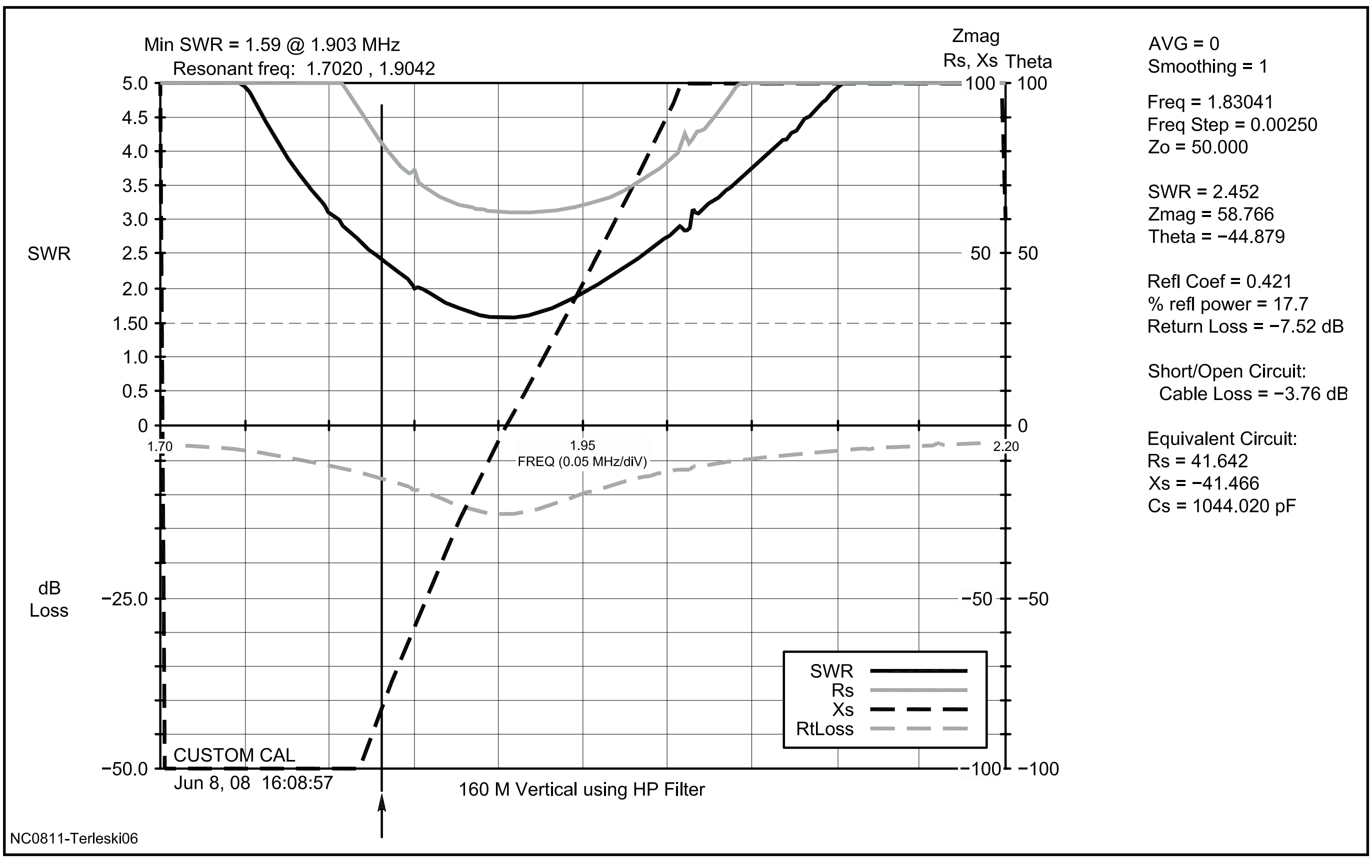

Figure 6 — With the marker at 1830 kHz, R = 41.6 and X = –41.5 (capacitive reactance). The measurement is referred to the antenna by the AIM 4170B software.

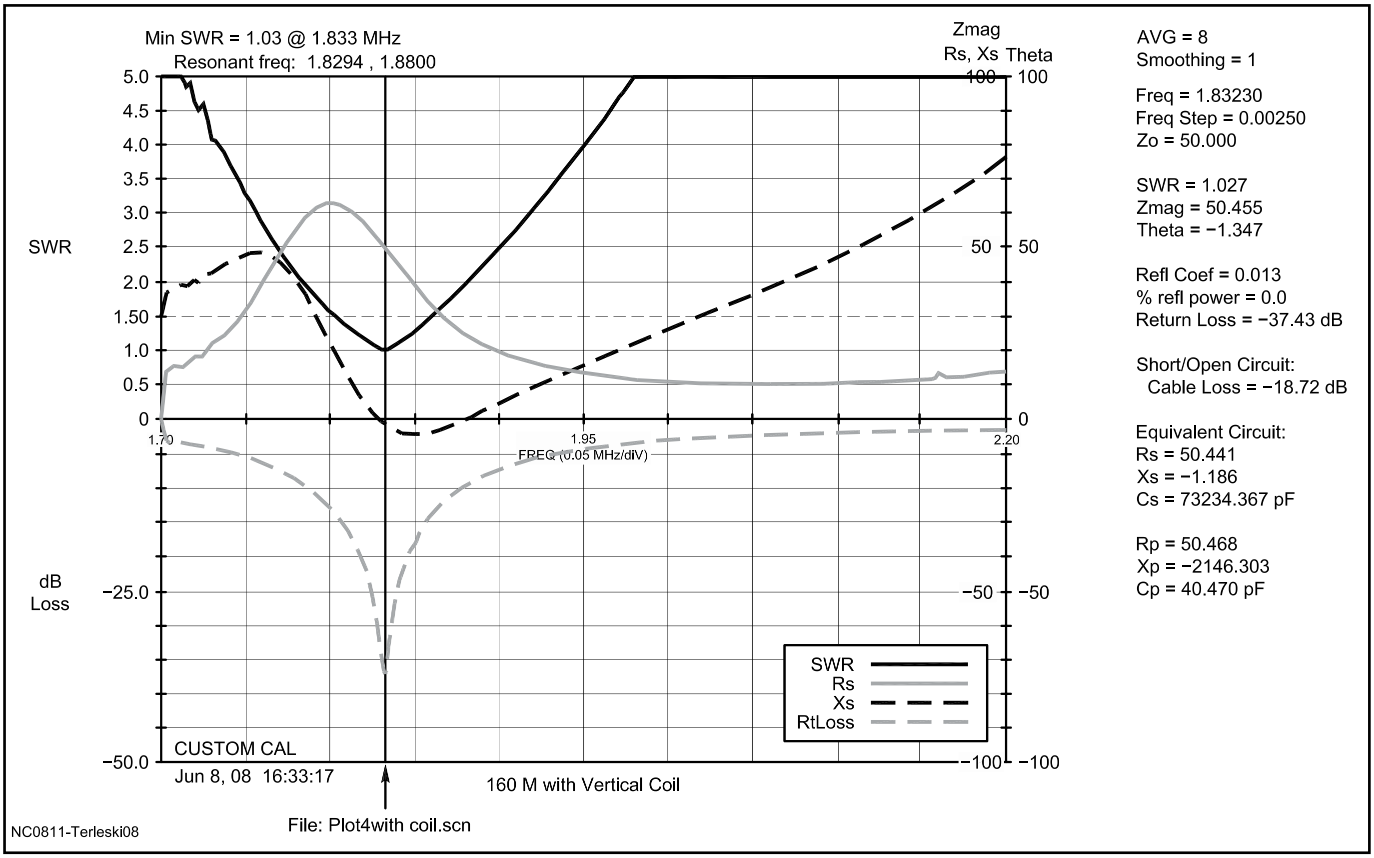

Figure 8 — At 1832 kHz, R = 50.7, X = –1 and VSWR = 1.03.

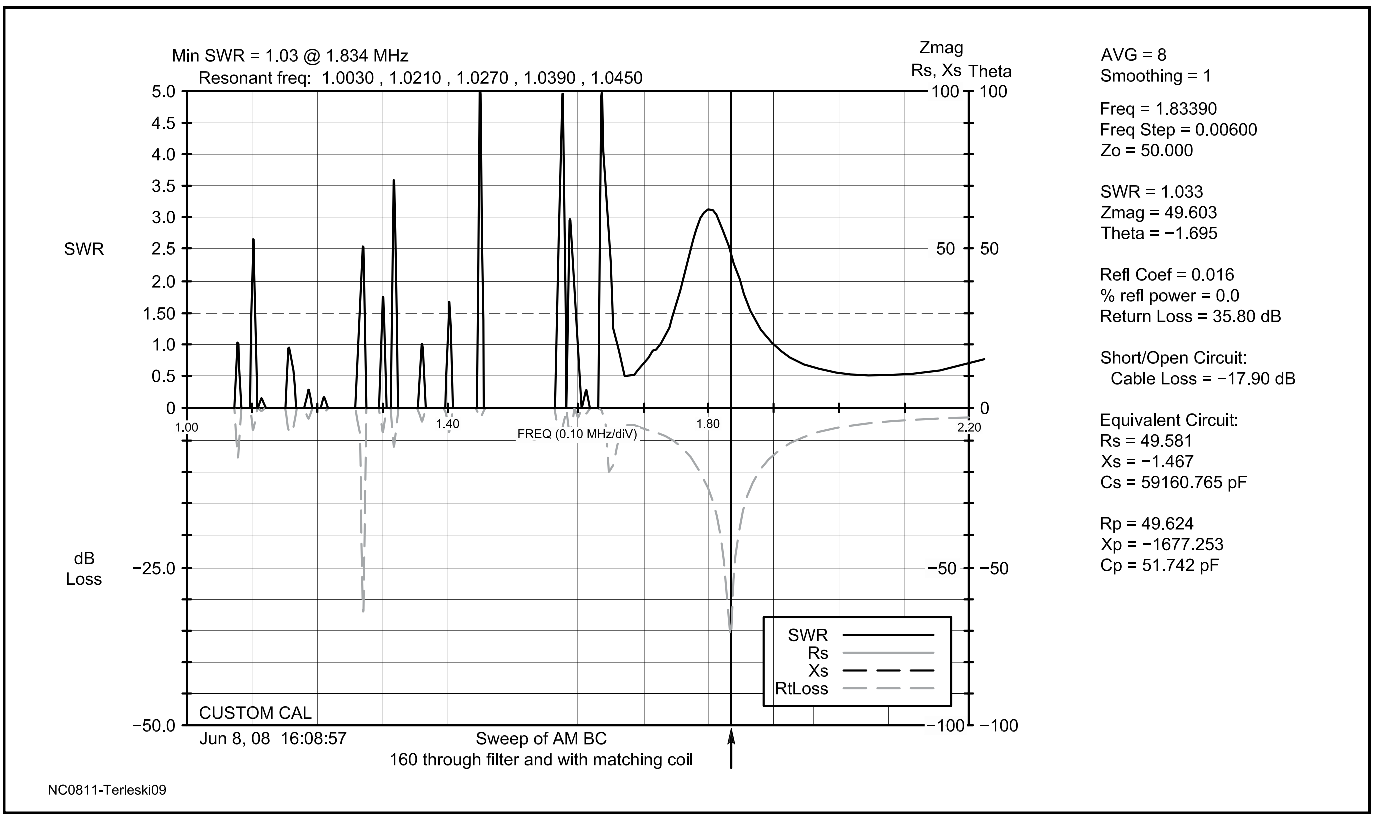

Figure 9 — A wideband sweep of the antenna from 1 to 2.2 MHz. Note all the noise below 1.7 MHz caused by the substantial attenuation in the filter at these frequencies. Everything above 1.7 MHz is valid.

Figure 10 — The VSWR = 1.03 at 1832 kHz.

software's coil-design program. Initially you might want to make the inductor larger and tap down for the best match. Figure 7 shows the inductor at the base of the antenna, while Figure 12 is a schematic diagram of the coax feed system.

Re-running the plot (Figure 8) shows that we now have matched the antenna. The inductor acts just like a hairpin match on a Yagi, and the loss in the coil is only about 5 W at 2000 W input. But the coil serves another function: It also works as a static bleed choke that will definitely help to save your equipment in the event of a direct or nearby lightning hit. This is a pretty elegant solution for a matching device, a static-bleed choke and a surge arrestor in a single component!

You can make the design even more lightning proof by adding a loop — or one turn of copper pipe — to the center conductor of the Heliax to create a lightning loop and perhaps even a spark gap from the vertical element to ground. A suitable spark gap can be fashioned from bolts and rounded acorn nuts opposing each other. The gap is adjusted so that a 700 V RF signal will not arc. This may be a good topic for a future article.

Measurement Accuracy?

Figure 9 shows a wideband sweep from 1 to 2.2 MHz. Note that the filter's attenuation is so large that it perturbs the measurements below 160 meters. This is fine, since we don't care about the AM band anymore; the filter's attenuation of the broadcast band RF allows the AIM 4170B to take the measurement on 160. The question remains: How accurate is the measurement considering the nearby RF turmoil?

I used a NIST-calibrated PowerMaster watt/VSWR meter and my ICOM IC-781 transceiver to verify the readings of the AIM 4170B. The AIM plot, Figure 8, shows the VSWR is 1.027 at 1832 kHz. Tuning the IC-781 to 1832 kHz and putting out some RF, we see in Figure 10 that the calibrated VSWR meter shows 1.03. That's pretty darn close to unity and well within the margin of error of these measurements. Keep in mind that some of the other components in line — amplifier, coax cables, wattmeter coupler, etc — could affect the reading.

Now let's check the bandwidth of the antenna with the VSWR meter and compare it with the plot seen in Figure 11. I moved the VFO to both 1804 kHz and 1859 kHz and checked the VSWR with the rig and a wattmeter. The VSWR meter shows almost the exact same VSWR readings, and the bandwidth is exactly the same. As a matter of fact, these measurements are identical at higher VSWR.

I'd like to express my appreciation and gratitude to Grant Bingeman, KM5KG, and Bob Clunn, W5BIG, for their assistance in developing this article.

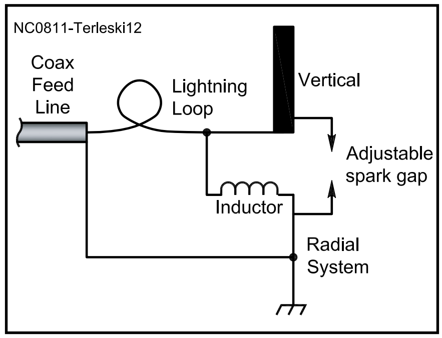

Figure 12 — Schematic diagram of the coax feed system.

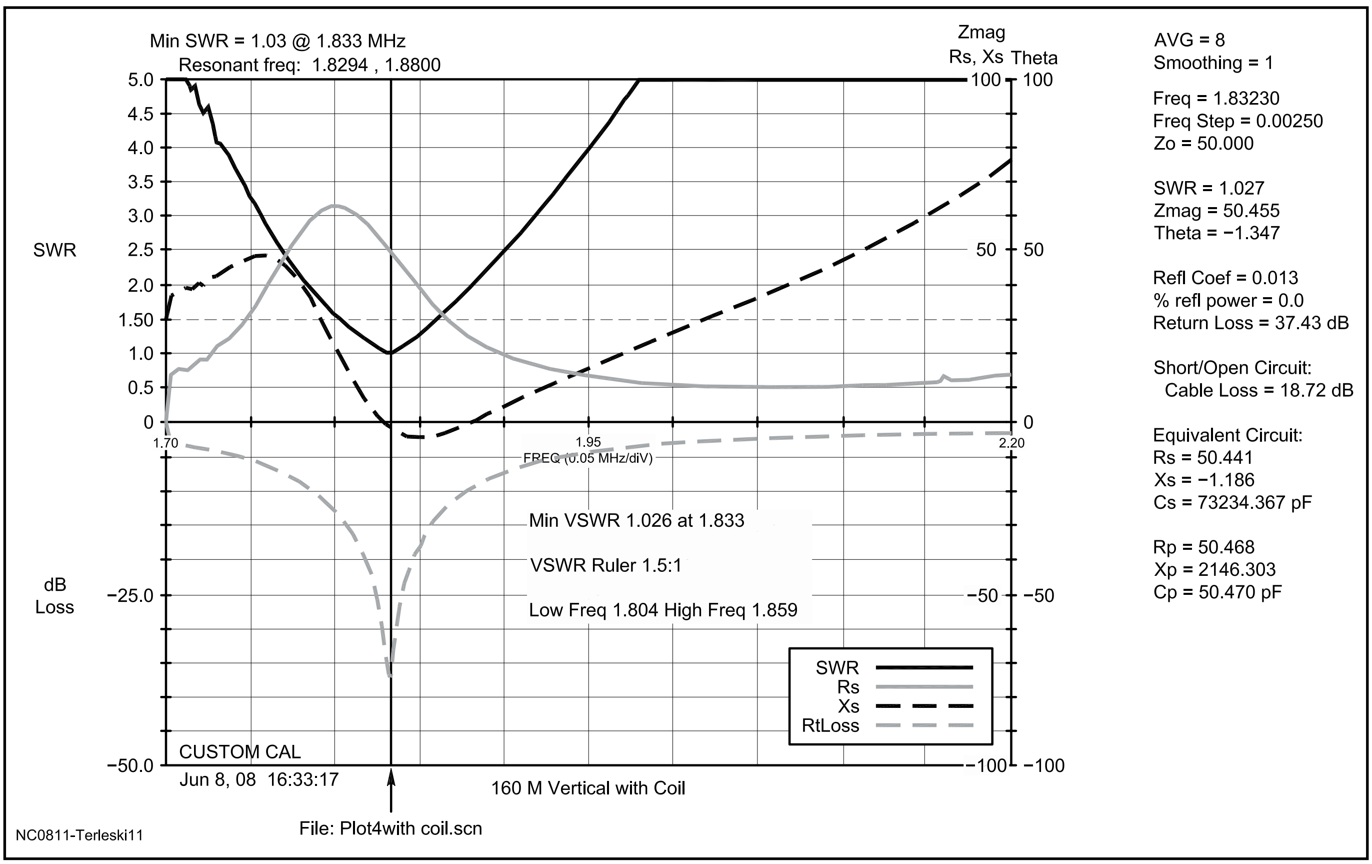

Figure 11 — Using the antenna bandwidth tool and setting the VSWR ruler at 1.5. The bandwidth is 55 kHz, with the lower end at 1804 kHz and the upper end at 1859 kHz.

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