

Tuning a 160M full sized vertical with strong AM broadcast RF present on the antenna. – Jay Terleski, WX0B

I often get asked about how to match a $\frac{1}{4}$ WL vertical to a 50 ohm transmission line and what to do about lightning protection and even how to make RF measurements in the presence of strong AM broadcast RF on the antenna. I have seen solutions from just attach the coax to the antenna and live with it, to adding a capacitor in series to allow tuning the antenna over the band. Even the use of L networks to match the 30ish ohms to 50 ohms. Let's look at a very simple solution that I think is the most useful and most elegant solution to use.

First let's look at my $\frac{1}{4}$ WL 160m vertical. It is sort of an inverted L. Rising up from ground level to 50 feet as a free standing aluminum tube vertical at this point I attach a #12 wire that slopes upwards at a 45 degree angle to my 150 foot tower. The system has 64 buried radials, and fortunately we have excellent ground here. Due to the sloping wire the antenna has a feed impedance less than the theoretical 36 ohms. What we will attempt to do is tune this antenna for a $50 + j0$ ohm 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 phantom capacitance we need, and then a single inductor across the feed point is all we will need to match the antenna to the transmission line. I don't like to use series capacitors since they are prone to failure at high currents and lightning events. The phantom L network technique is a great way to do this kind of matching network.

There are many AM broadcasters in the area, and one is even at 1710 KHz. These stations place 10V peak to peak of RF onto my antenna during the day, and even more at night. Fig 1 shows how to attach a scope probe to the coax stub going to the heliax. Fig 2 shows the scope (not terminated) reading at the end of 150 feet of 50 ohm $\frac{1}{2}$ inch heliax. Trying to make an accurate measurement with any of the impedance meters available to hams is impossible. They overload, and some will even blow their diode bridges and will require a trip to the factory to fix them. The AIM 4170B analyzer that we produce will not blow up, but it will fail to make this measurement due to the strong RF if you just hook it up to the feedline. But, it has a neat feature that can be used to make this measurement accurately, and we will use it to help us tune up this antenna.

10V of peak to peak RF is 0.25 watt of power into 50 ohms. Since the AIM 4170B puts out micro-watts of RF power to make its measurement. So how can this device over-ride the power in the antenna?



Fig 1 Applying the probe to the coax

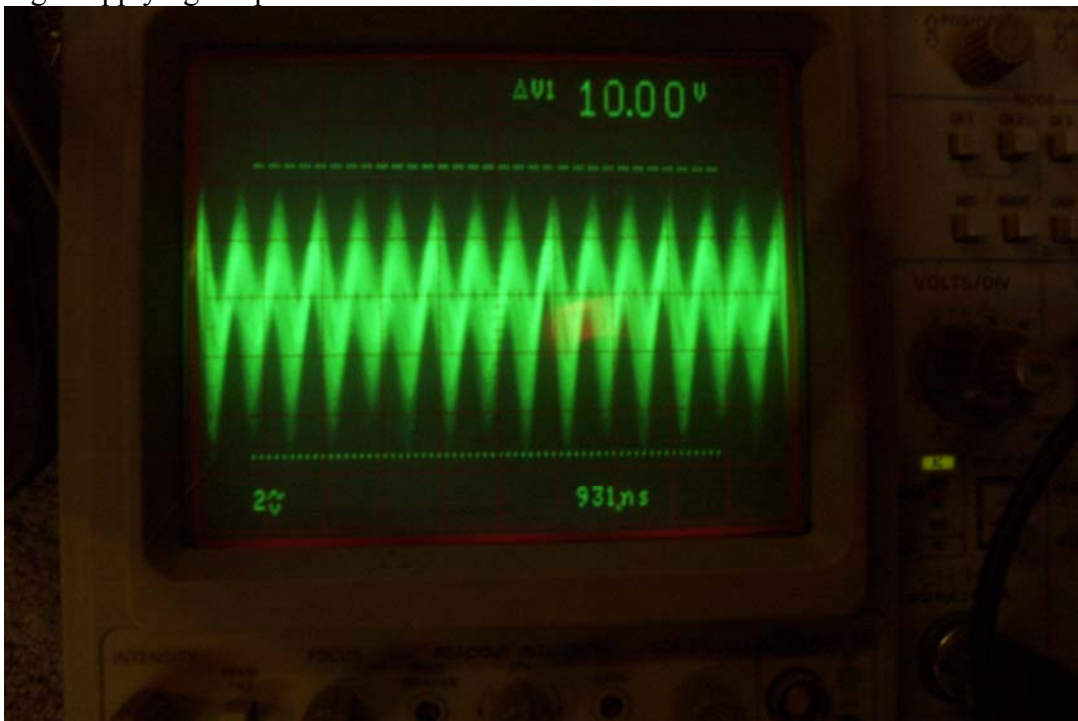


Fig 2 10V Peak to Peak RF

When we attach the AIM 4170B to this antenna and coax, we see the following plot (fig.3) when we do a scan from 1.5 to 2.5 MHz. The plot is color coded and the parameter plotted can be read from the associated colors on the plot.

Red is VSWR, R is orange, X is light yellow. Since this is a black and white publication the plots of the different variables can be customized to use dots, squares, and other charting symbols to make it easier to read them in black and white.



Fig 3 – plot of antenna from 1.5 to 2.5 MHz, AM broadcast is making the measurement useless.

Due to the RF overload, the plot is full of noise, and totally useless. We need to adjust our measurement technique if we are to get accurate information to allow us to adjust this antenna. Hence we need to utilize a good broadcast band high pass filter. W3NQN makes a superb BCB HP filter and I have attached it to the RF connector of the AIM 4170B analyzer. But before we just use it, we need to null out its transfer function so the measurements we make are not affected by it.

These high order filters have phase shifts, and other linear parameters due to the design. We must normalize them out, and to do this the AIM 4170B has a feature called “custom calibration”. The software will lead you through a “super” calibration using the short, open, and load technique through the filter over a limited frequency range of interest. To create very accurate calibration table you use lots of sample points, I used 500 points of measurement. The software will create a very detailed calibration table that will essentially move 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 as a file for future use. Now that we have the analyzer and filter fully calibrated we can retest the antenna and coax system. Fig 4 shows the plot obtained scanning through the filter. Note I added “averaging” of 8x to the measurement to get rid of any residual noise on the measurement. AM broadcast stations have side band power that can be eliminated using the averaging function since they are always changing. You can see the “AVG=8” in the upper right corner of the trace. The AIM 4170B has other tools that can be used including “trend” and “smoothing” but they were not needed since we have a clean plot now.

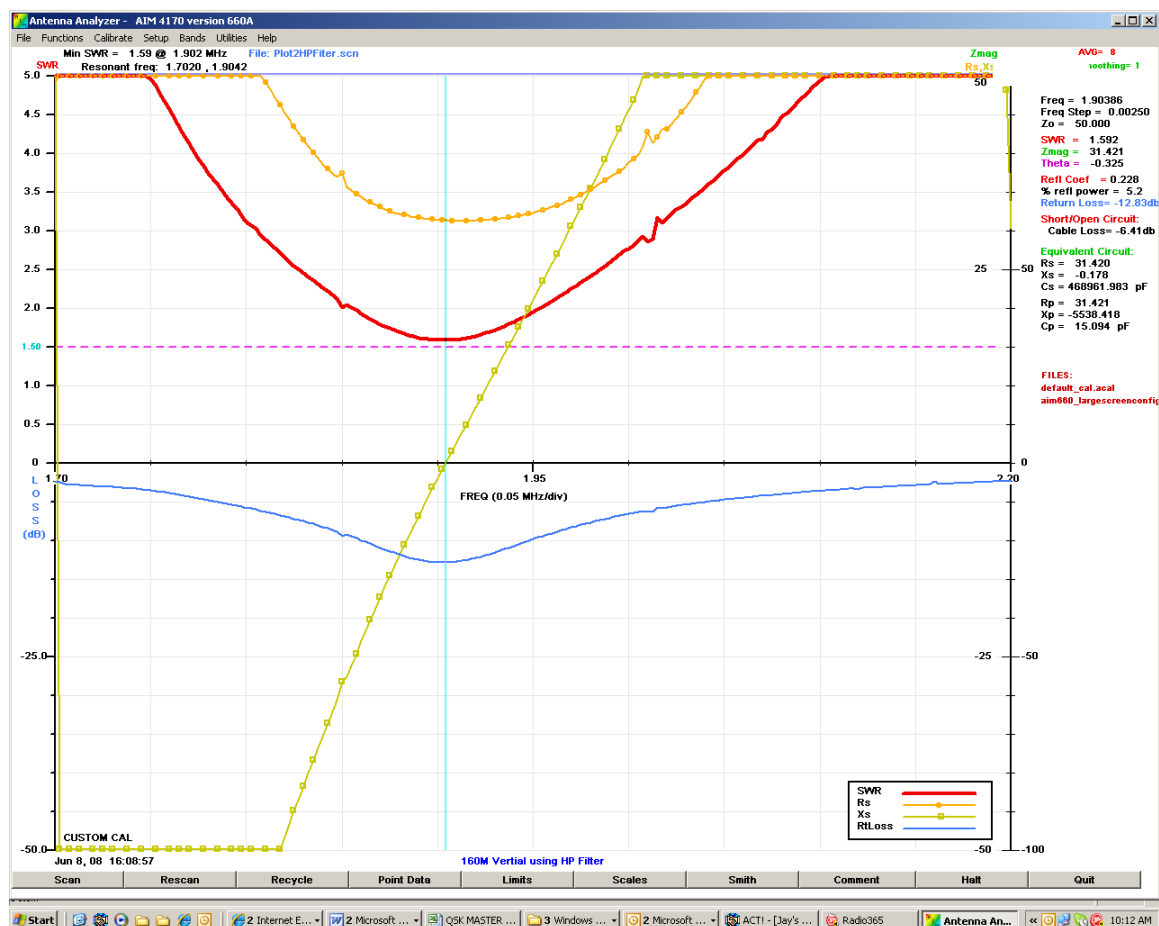


Fig 4 – Very clean plot, Marker (blue vertical line) at X zero crossing, R = 31.4 ohms, VSWR = 1.59 The little glitch is the second harmonic of KRLD.

Just to check, I looked at the antenna through the filter with the scope, fig 5 shows we have about 125 mV peak to peak of RF still getting through the filter. This is still pretty high and probably most analyzers under \$500 will not be able to make an accurate measurement.

The AIM can make the measurement since it has RF immunity up to 125 mV. See our website for more detailed information about the AIM 4170B architecture.

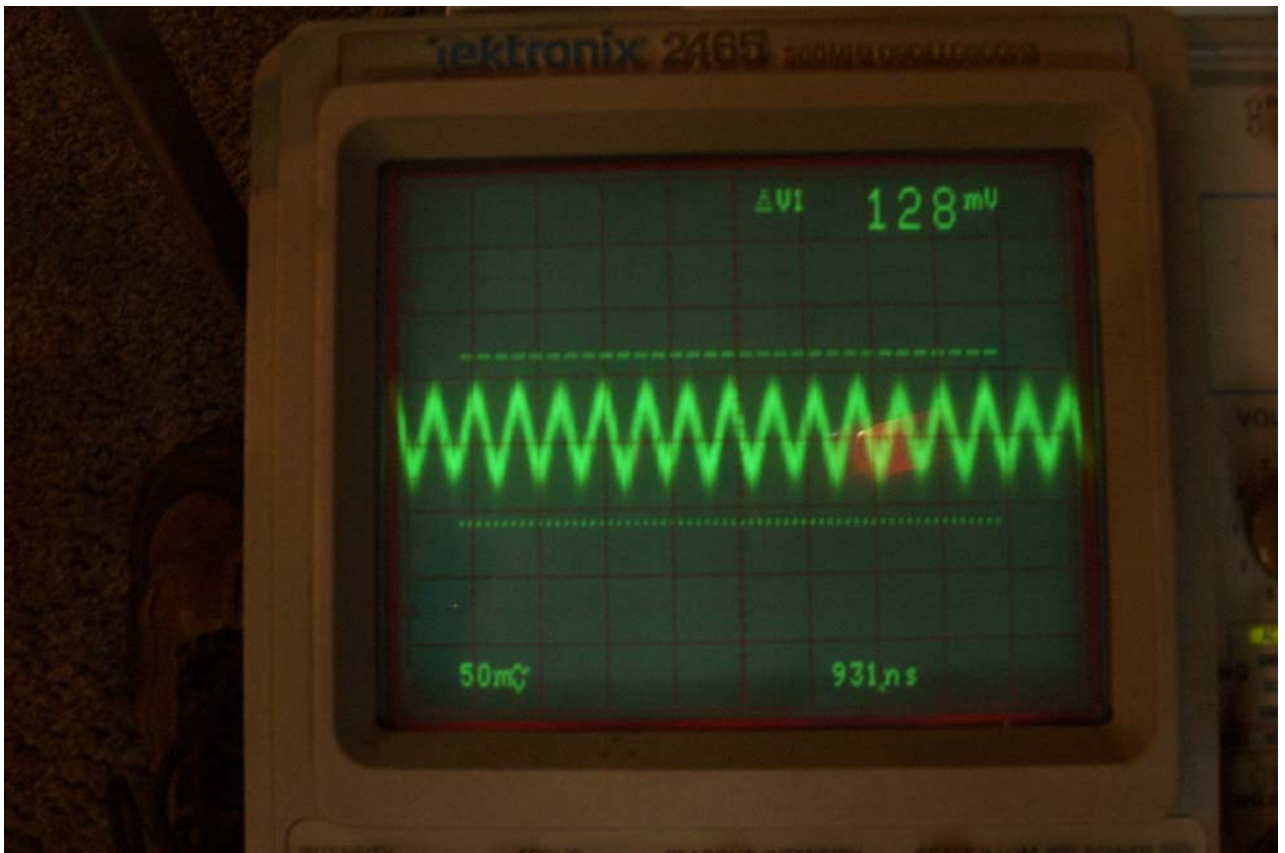


Fig 5 – sidebands show about 125 mV of RF still getting through the filter.

Adjusting the Antenna to create the phantom capacitor

What we need to do is adjust the resonant frequency of the antenna to make it short or capacitive, so instead of resonating at 1830 KHz we should move it up to around 1900 KHz or above. Since I don't care about working over 1875 KHz, I used 1900 KHz as my target frequency to create a capacitive X at 1830 KHz. Using an L network program like the Network program we sell, it is easy to create a match for this antenna. First we need to find the impedance at our desired frequency. Fig 6 shows a plot with the marker at 1830 KHz and the corresponding R and X are shown at the right of the plot. $R = 41.6$ ohms and $X = -41.5$ ohms. This is 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 ohm heliax, the loss of the heliax (which is a lookup table),

and the velocity factor of the coax (also a lookup table). Putting these numbers into the software prompts, and doing a new scan will now give us the measurement as if we were at the feedpoint. All from the comfort of my air conditioned shack! The numbers R and X numbers turn out to be almost exactly the same as at the transmitter end of my cable. At 160m this is probable, but don't 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 uH to match this impedance to 50 ohms. I built an inductor on a 3 inch PVC pipe form and placed 12 turns on it per the network software's coil design program. You might want to make the inductor larger then tap it down for best match. Fig 7 shows the inductor at the base of the antenna.

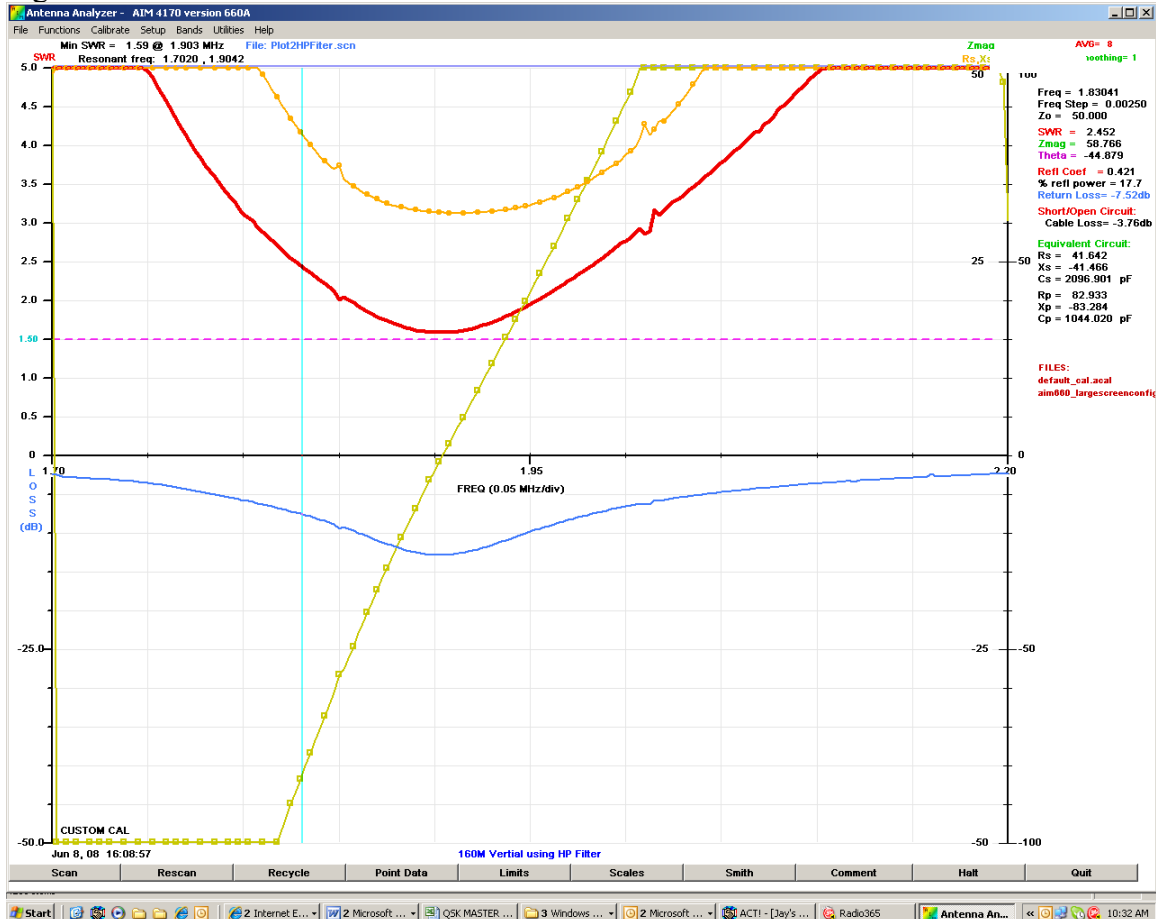


Fig 6 – Marker at 1830 KHz, R= 41.6 ohms and X = -41.5 capacitive ohms. Measurement is referred to the antenna by the AIM 4170B software.



Fig 7 – Inductor attached to the insulated vertical element and grounded at far end (not shown in picture).

Re-running the plot (Fig 8) we can see we now have matched the antenna. The inductor acts just like a hairpin match on a Yagi. And the loss in the inductor is only about 5 watts at 2,000 Watts input. The inductor also works as a static bleed choke and will definitely help save equipment if the antenna has a lightning hit or nearby hit. This is a pretty elegant solution for a matching device, a static bleed choke, and a surge arrestor all in one single component! To make the design even more lightning proof you can add a loop, or one turn of copper pipe to the center conductor of the helix 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 facing each other. The gap is adjusted so that a 700V RF signal will not jump the gap. If there is interest in this I can offer a second article on making a spark gap and lightning loop for this antenna.

How accurate is the measurement?

Fig 9 shows a wide band sweep from 1 to 2.2 MHz. Note that the filter's attenuation is so large that it is perturbing the measurements below the 160m band, which is fine we don't care about the AM Band anymore, but the filter's attenuation of the AM Band RF allows the AIM 4170B to make the measurement in the 160m band. But how accurate is it considering there is such turmoil of RF nearby?

I used a NIST calibrated PowerMaster watt / VSWR meter and my IC781 to verify the readings of the AIM 4170B. The AIM plot fig 8, shows the VSWR is 1.027 at 1832 KHz. Tuning the IC781 to 1832 KHz (fig 9) and sending out some RF we see the calibrated VSWR meter (fig 10) has 1.03 VSWR. That's pretty darn close and well within the margin of error of these measurements. And we have some other components in line that could affect the reading such as the amplifier, coax cables, wattmeter coupler, etc.

Now let's check the bandwidth of the antenna with the VSWR meter and compare it with the plot of fig 12. I moved the VFO to both of these frequencies and tested the VSWR with the rig and wattmeter . The VSWR meter shows almost the exact same VSWR readings and the bandwidth is exactly the same. Matter of fact even at higher VSWR numbers these measurement are identical.

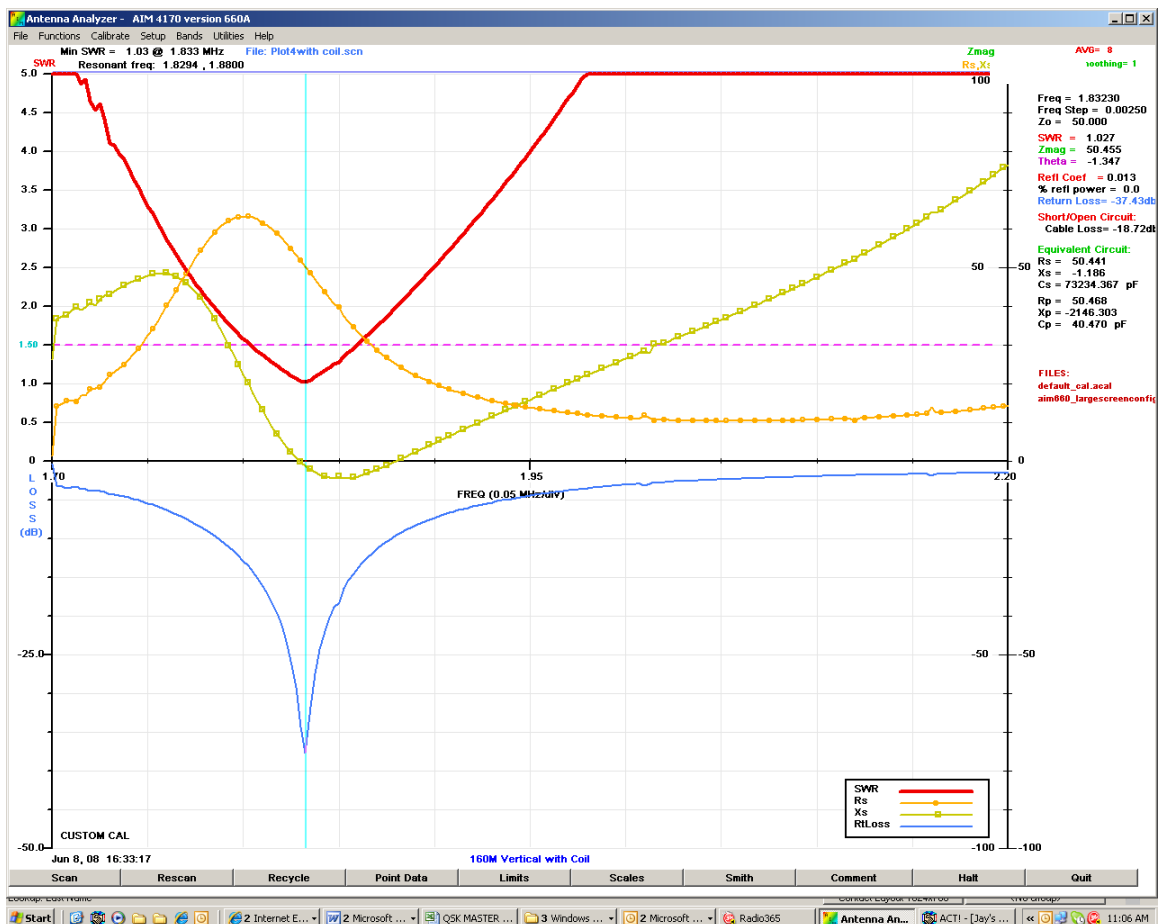


Fig 8 – 1832 KHz, R = 50.7, X = -1, and VSWR = 1.027

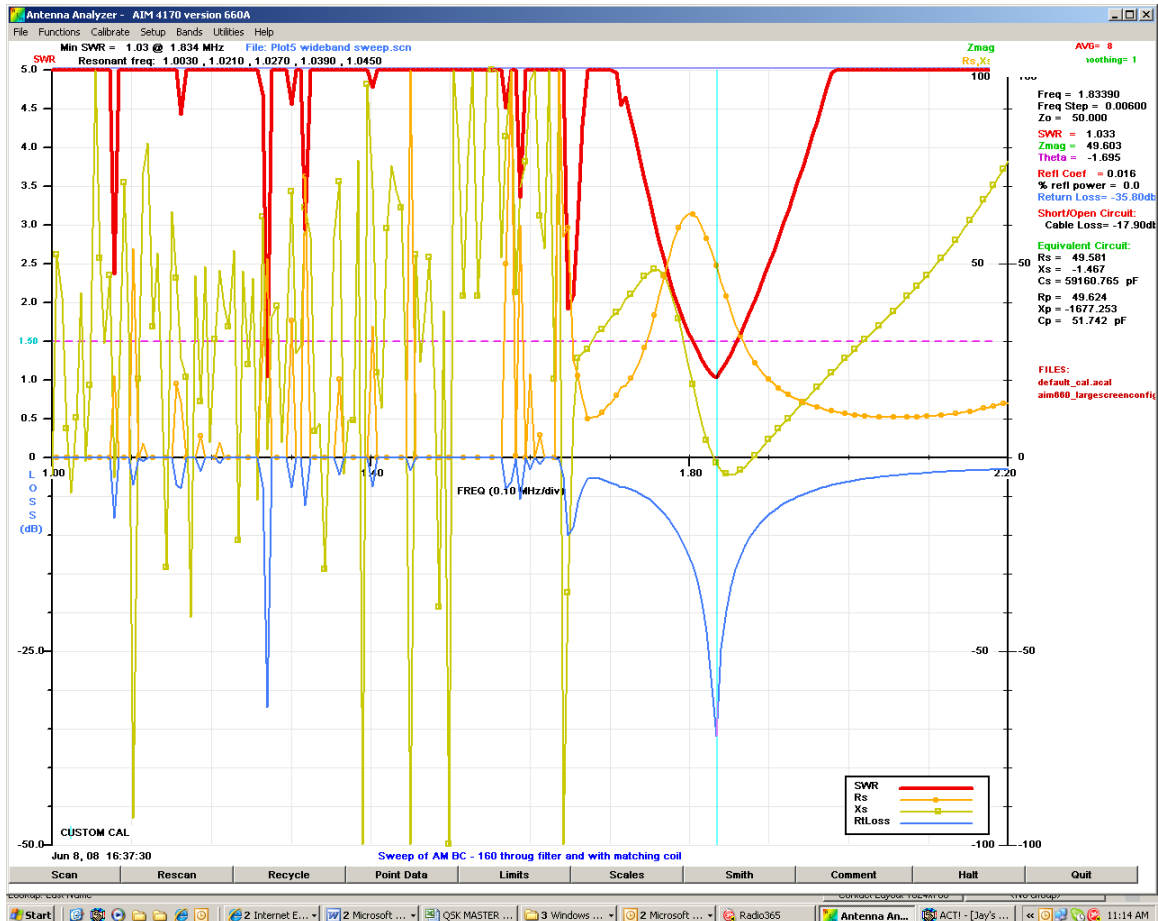


Fig 9 – wide band sweep of the antenna from 1 to 2.2 MHz, Note all the noise below 1.7 MHz. This is caused by the huge amount of attenuation in the filter at these frequencies, and is just noise, it is not important. Everything above 1.7MHz is valid and the 160m band is not affected



Fig 10 – IC781 set to 1832 KHz



Fig 11-VSWR 1.03 at 1832 KHz

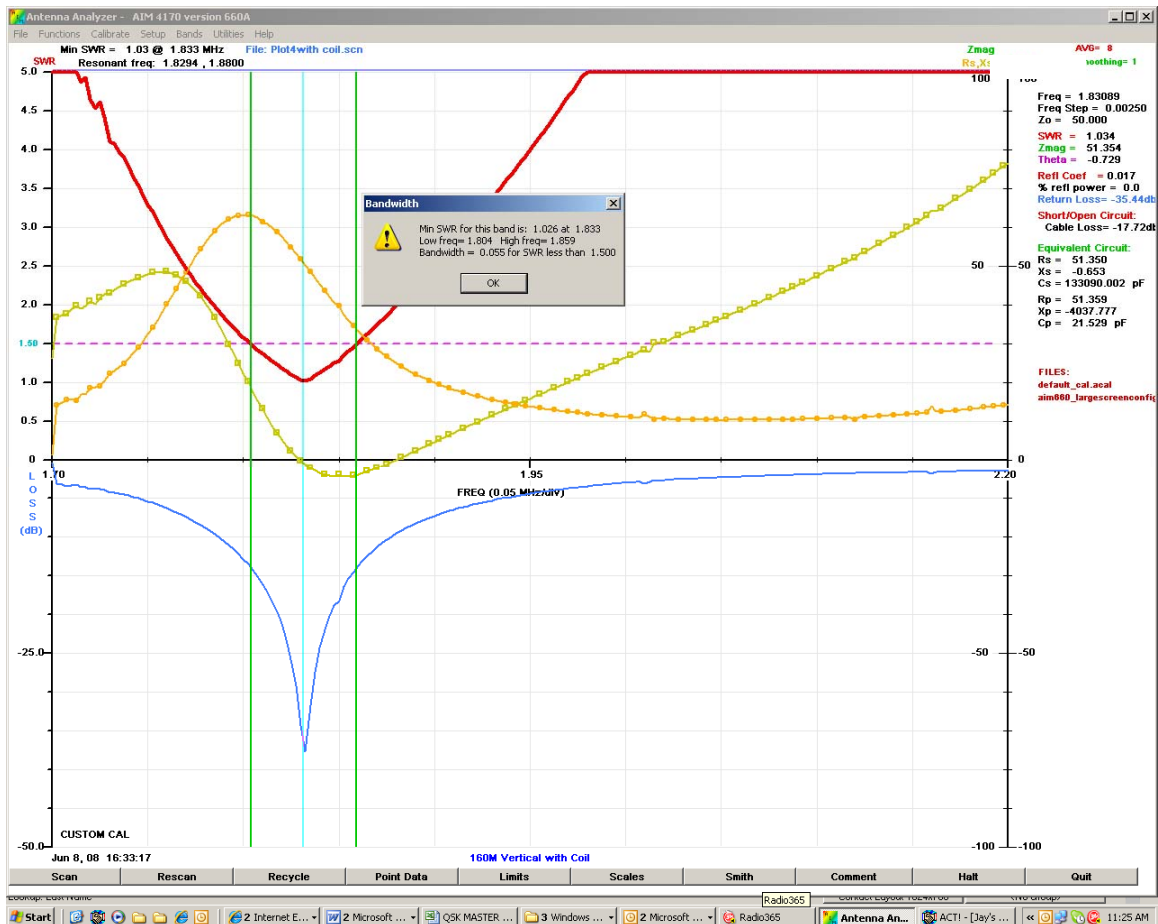
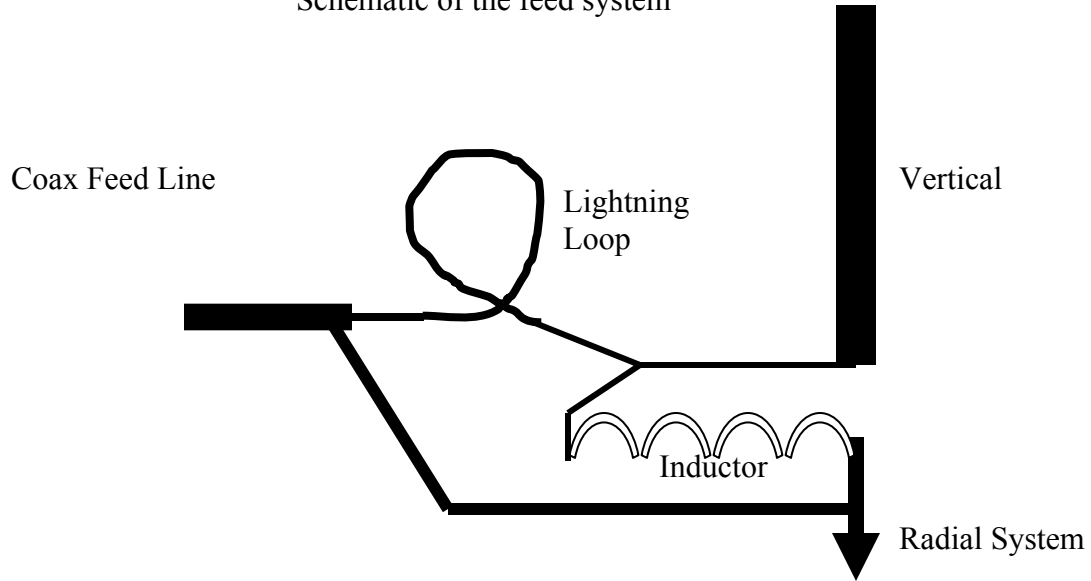


Fig 12 – Using the Antenna Bandwidth tool, and setting the VSWR ruler at 1.5 Bandwidth is 55KHz, low end at 1804 KHz and high end at 1859 KHz.

Summary

I have shown how to make a very simple but elegant matching device for a $\frac{1}{4}$ WL vertical, which also operates as a static bleed device and a surge arrestor with a lightning loop. To measure the antenna and get the data needed to make the matching device and to tune the antenna correctly the AIM 4170B analyzer was used in the presence of strong RF from nearby AM broadcast stations. Using the custom calibration tool, and a Broadcast band high pass filter we were able to make accurate measurements of VSWR, R, and X. This enabled us to design the matching network, and verify its characteristics.

Schematic of the feed system



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