REVERSE ENGINEERING THE COAXIAL DIPOLE

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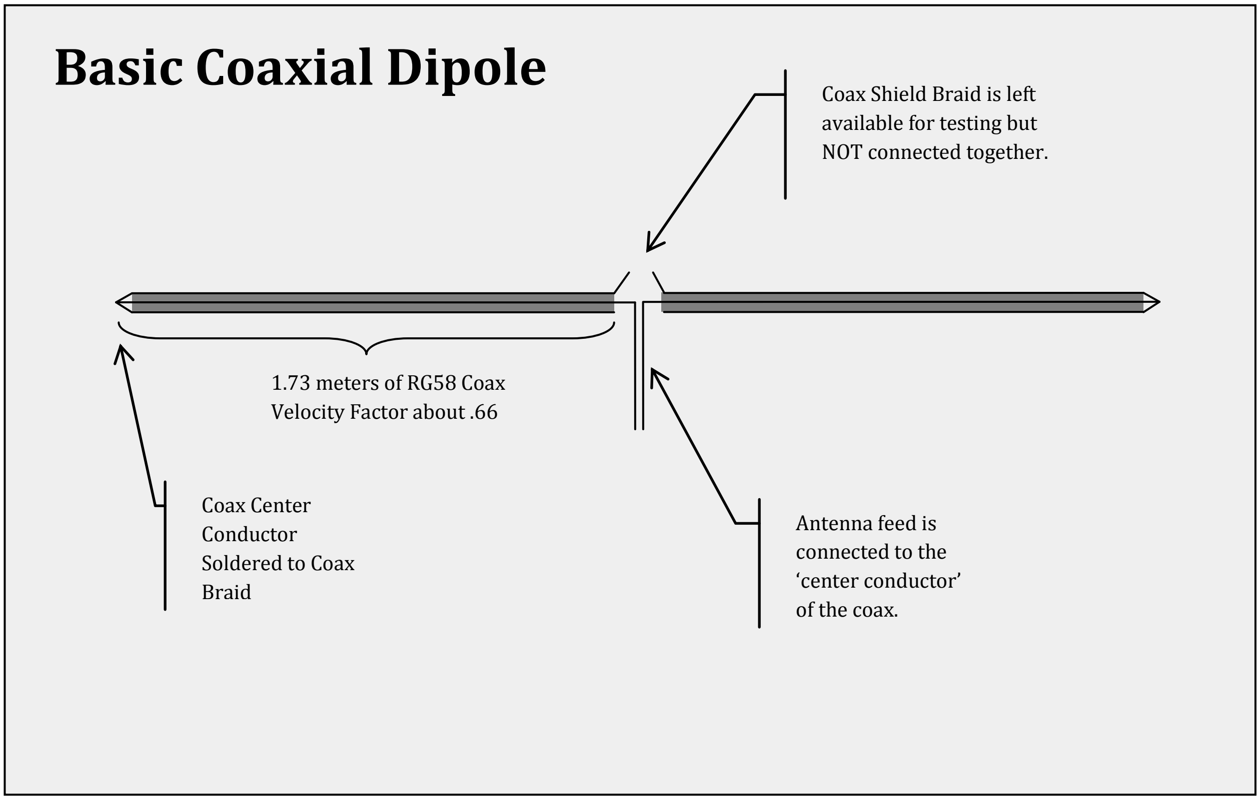
Introduction:

Over the last week or so I've been involved with a discussion concerning the operation of an antenna commonly called a "Coaxial Dipole". Several web sites publish design examples and equations. Some of these equations seemed unreasonable to me and challenged my understanding of how such an antenna must work. Rather than attempt to design a coaxial dipole from first principles I decided it would be easier to build one and 'reverse engineer' it.

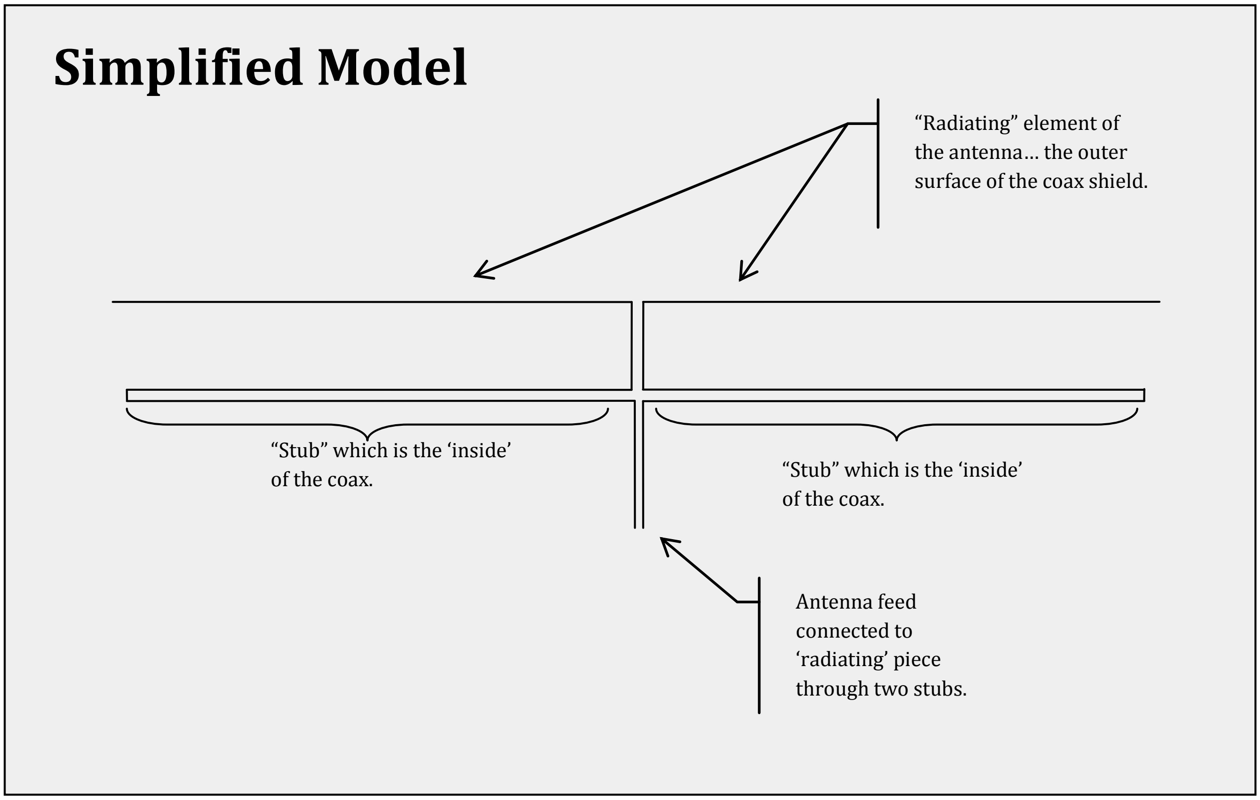
In order to keep things manageable I decided to start with an antenna in the 20 to 30 Mhz range. The exact frequency was unimportant. Ultimately, I ended up with an antenna which resonated at about 24.7 MHz. Again, this was the result…. I simply was not interested in an exact frequency of operation.

Description:

The basic coaxial dipole consists of two pieces of RG58 (or other) Coax. At the outer ends, the center conductor is connected to the coax braid. At the feed point, the feed line is connected to the center conductors of the two legs of the coax. The coax shield braid left unconnected in normal operation.



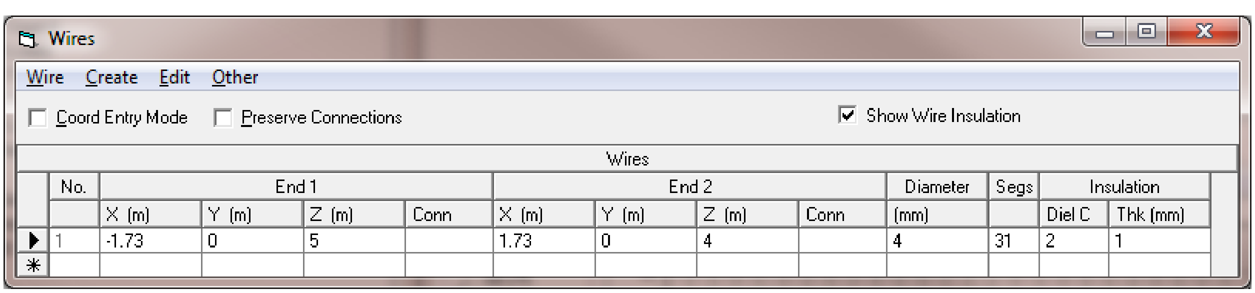
This antenna has much in common with the 'double bazooka' and my immediate 'gut feeling' was that the coax performs two functions. First, the radiating elements of the antenna would be the outer surface of the coax shield. Second, the coax segments would provide some reactance, presumably inductive, which would lower the resonant frequency of the basic dipole. In order to simplify thinking about these two functions I redraw the antenna as:



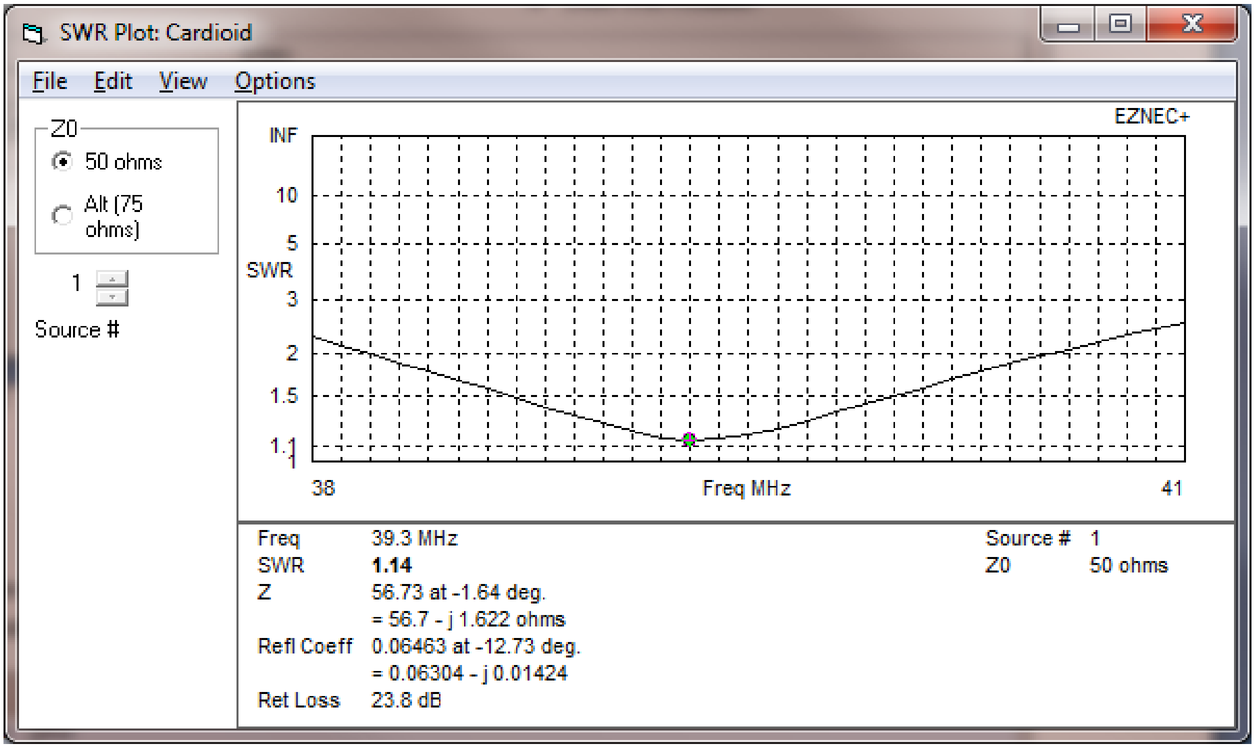
The simplified model consists of three pieces. The first two are simply transmission line stubs. The third is the ‘radiating element’ itself. The idea is to model and measure each of these components individually and then together to see if the model and actual measurements are consistent. If everything lines up we can conclude that the model is correct and a complete understanding of the Coaxial Dipole has been achieved. (Important note: in the simplified model, the ‘stubs’ are not involved with the ‘radiation’ in any way. One could consider them as having ‘zero physical size.’)

STEP 1:

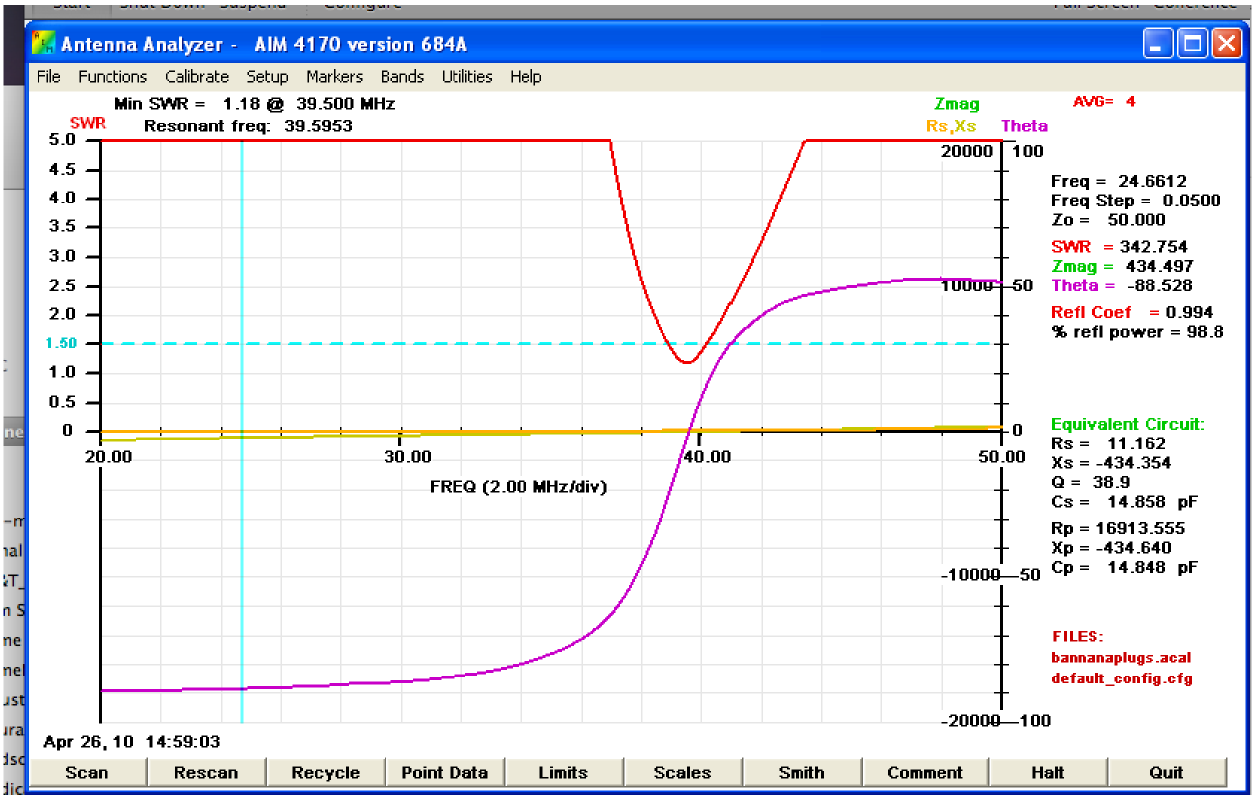
My first set of simulations and measurements ignored the existence of the stubs and simply modeled the ‘radiating element’ of the antenna. I modeled this using a basic wire in EZNEC as follows: I placed a single wire at 5 meters above ground. I specified a wire diameter of 4mm. I added 1 mm of insulation around the wire with a dielectric of 2. EZNEC predicted a resonant frequency of 39.3 MHz. I show the wire declaration and the SWR plot from EZNEC below.



No.	End 1				End 2				Diameter	Segs	Insulation	
	X (m)	Y (m)	Z (m)	Conn	X (m)	Y (m)	Z (m)	Conn	(mm)		Diel C	Thk (mm)
1	-1.73	0	5		1.73	0	4		4	31	2	1



The first *measurement* I made was to find the natural frequency of the 'outer surface' of the coax. To make this measurement I connected my AIM 4170b antenna analyzer to the coax braid. I then lofted the antenna to 5 meters and ran a measurement. Here is the resulting scan:



As can be seen in the trace, the coax 'braid' resonated at about 39.5 MHz. I made the same measurement after connecting the center conductors and the braids at both ends. The scan was unchanged. Thus, EZNEC simulation and actual measurement matched up surprisingly well. Thus, we can be reasonably certain that we understand the 'radiating' piece of the antenna.

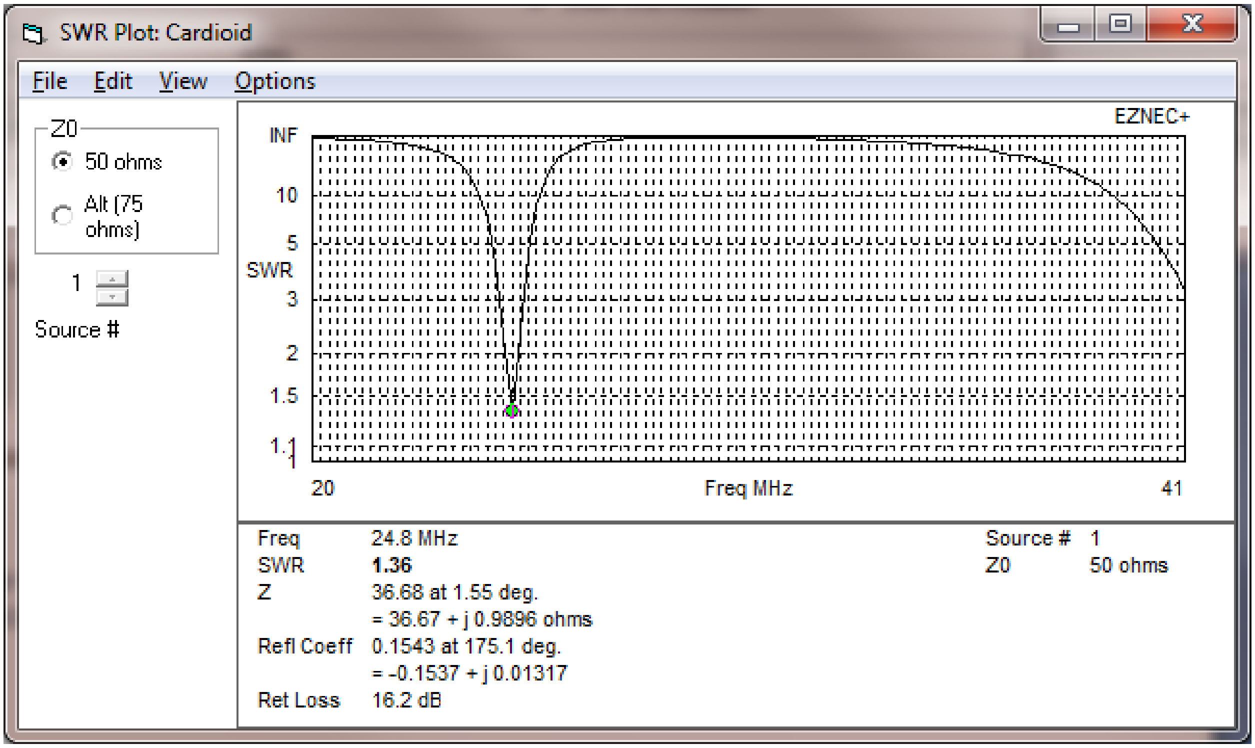
The next step in the project was to introduce the stubs which would model the insides of the coax. This is not so simple because it requires that I know the velocity factor of the coax. I was using pretty cheap coax so I assume 0.66. I also assumed a 2db/100m loss. Here are the transmission lines from EZNEC:

Transmission Lines

Trans Line Edit

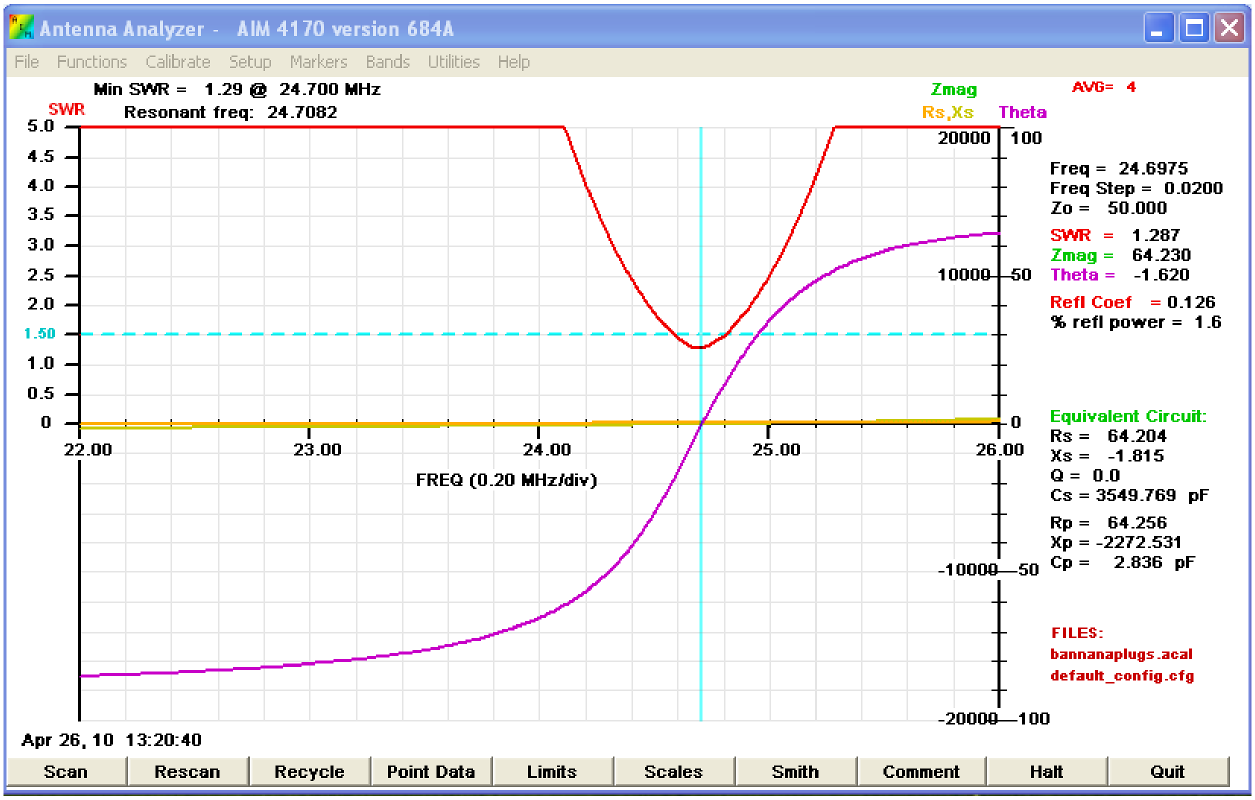
No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm	Loss	Loss Freq
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(m)	(ohms)			(dB/100 m)	(MHz)
1	1	49	49.2806	Short ckt			1.73	50	0.66	N	2	25
2	1	51	50.7194	Short ckt			1.73	50	0.66	N	2	25

Once the stubs have been introduced I expected the resonance of the antenna to be significantly lower. Here is the simulation of the 'radiating element' wire with the stubs attached:



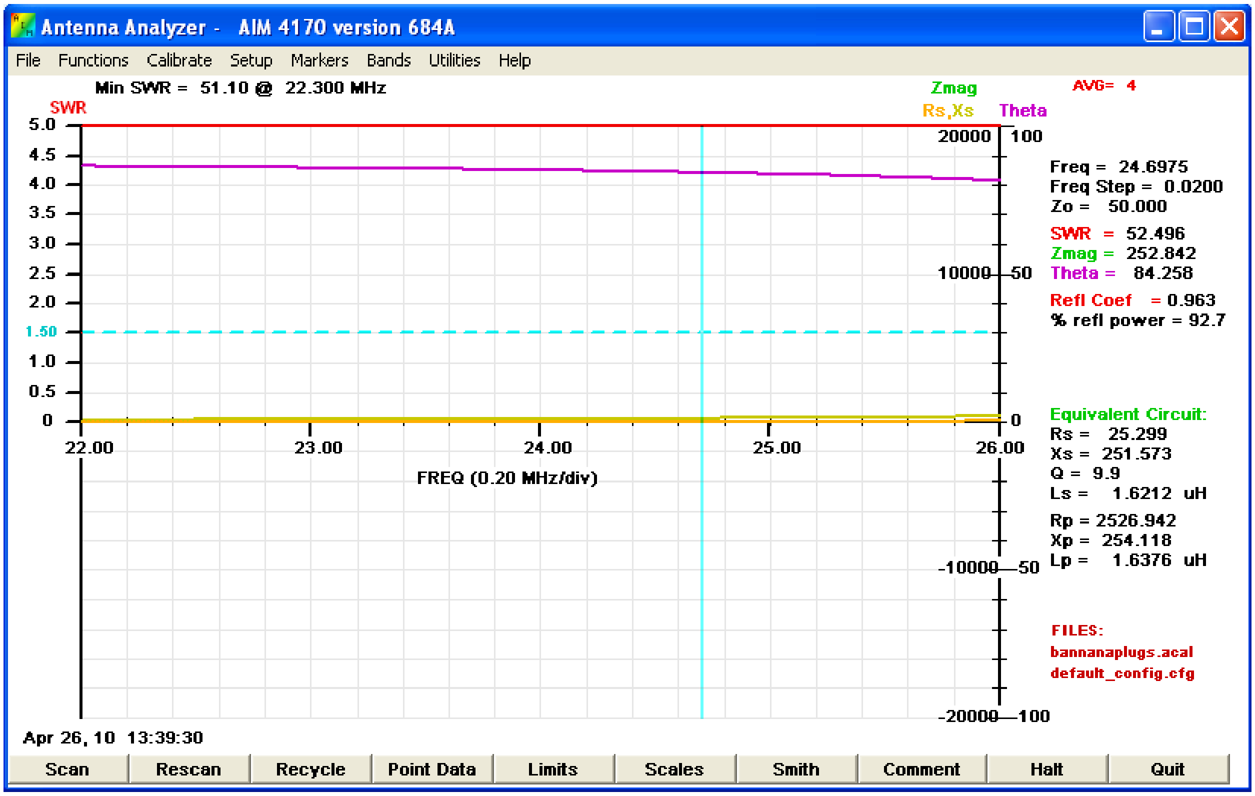
As can be seen in the above trace, EZNEC predicted that the resonant frequency of the antenna had been modified by the introduction of the transmission lines. Specifically, EZNEC indicates a resonant frequency of 24.8 MHz.

So the next step was to ***measure*** the antenna with the stubs included. Remember, in this measurement I drive the center conductors and leave the shields unconnected at the feed point:

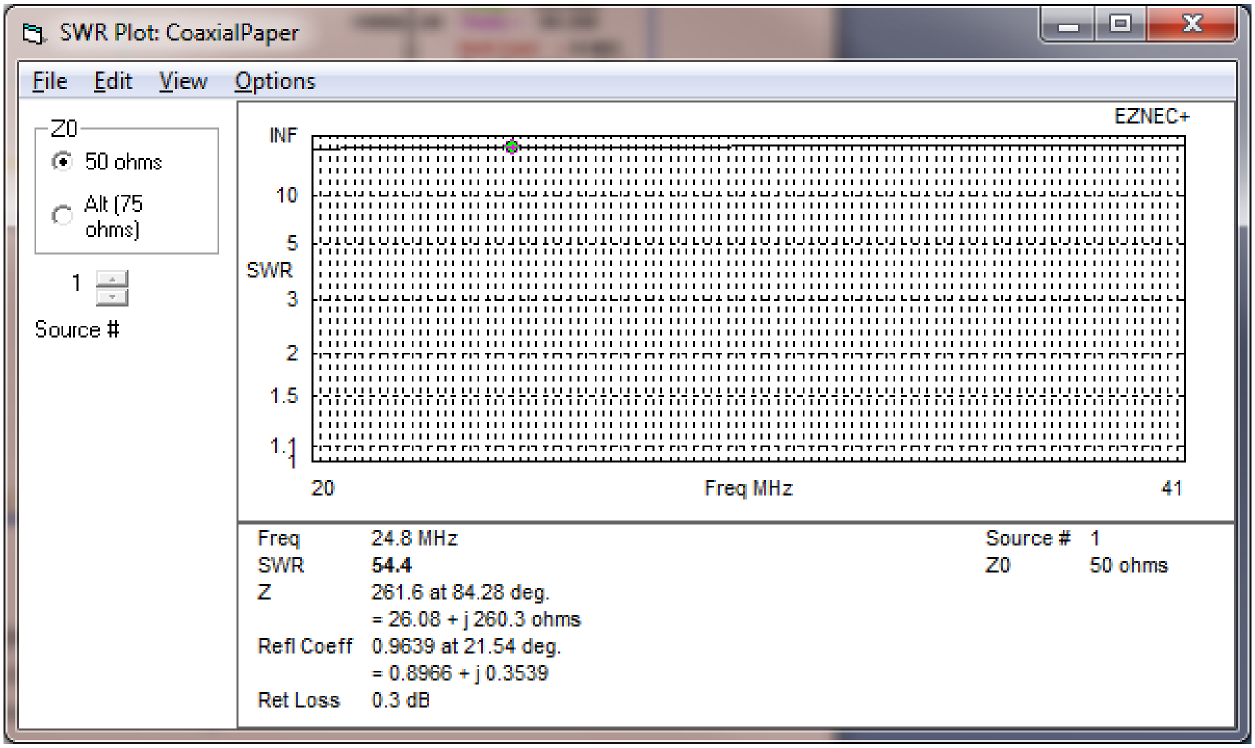


As can be seen from the above scan, EZNEC correctly predicted the resonant frequency. However, EZNEC did not correctly predict the impedance. EZNEC predicted 36 and I measured 64. This was unexpected and a little disconcerting so I went looking for an explanation.

I immediately suspected that my model for the transmission line was wrong. So, I went and measured the coax transmission line directly. I connected my analyzer to the center conductor and shield of one of the coax segments. Here is the result of the measurement:

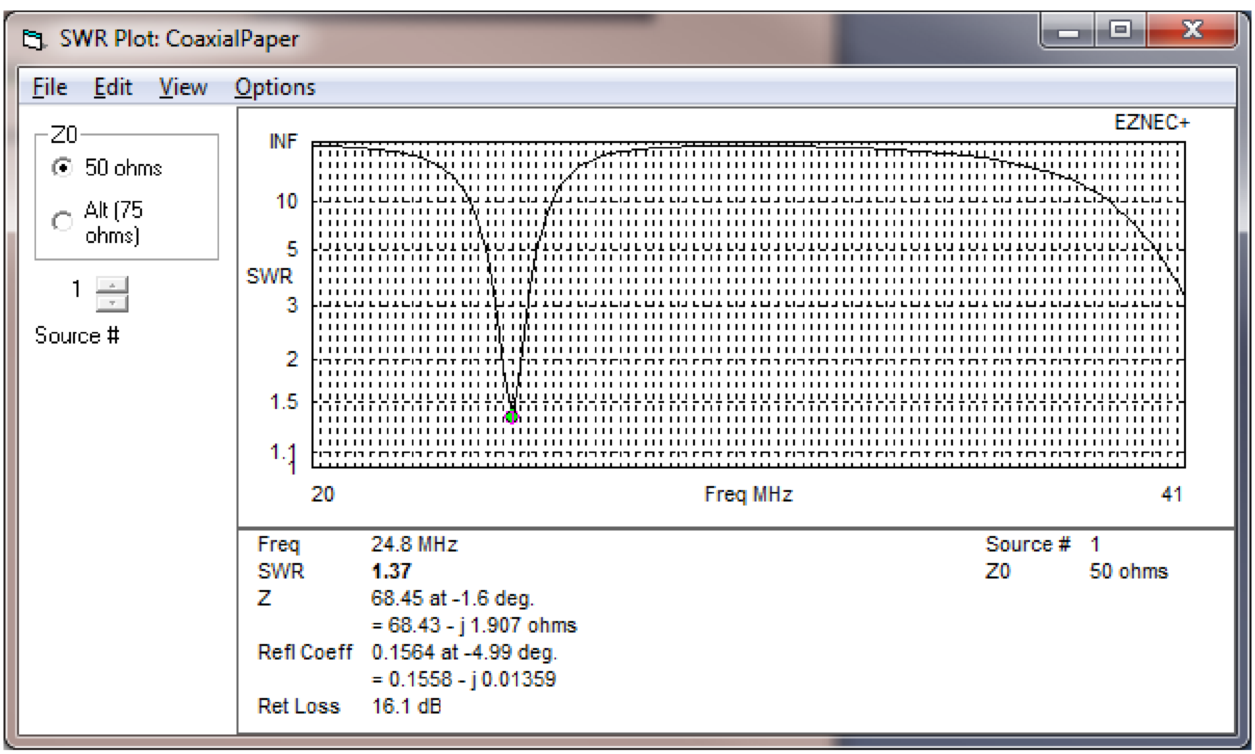


In the above scan I placed the cursor (vertical blue line) at the operating frequency. Notice the resistance is 25 ohms and the Q is only about 10. I knew the coax was cheap but this was way worse than I expected. I repeated my measurements in a variety of geometries and with multiple stubs. All were measurements were essentially the same. Using EZNEC I adjusted the coax loss to match the measured loss. Here is scan from EZNEC of just one of the coax segments:



The above simulation shows the correct impedance at 24. Mhz. To get these results I had to set the coax los to 8db/100m.

So I put the 8db/100m back into the EZNEC model of the whole antenna and re-ran the simulation. Here's what I got:



This matches VERY NICELY with the actual measurements. From these measurements and simulation I conclude that the coaxial cable operates along the lines predicted by the simplified model.

(Later research shows where I messed up. Even 'normal' RG58 can have a loss of 2.5db per 100 FEET (not meters). Adjusting for meters, the loss should have been 8.2db per 100 meters. PRETTY CLOSE!)

As independent verification of the modeling I went and made another measurement. Specifically, consider, again, the radiating element: a wire 4mm in diameter and 2x1.73m long. Driven at 24.8 MHz, the impedance was 11 –j484. We know the impedance of the stubs was measured at 25 + j251. If we add the impedances together we get:

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11      -j484   radiating element with no stubs.
25      +j251   first stub
25      +j251   second stub
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61      +j18    total impedance
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This is very encouraging. I measured impedances of the stubs and the impedance of the radiating element. The model predicted that the sum of the impedances would be the impedance of the whole system. The independent measurements summed up to 61 +j18 while the actual measurement was 64 -2j; a very close comparison. Independent simulation confirmed essentially the same results.

Conclusion:

The coaxial dipole can be successfully modeled using EZNEC. Given the proper loss and velocity factor of the coax it is possible to precisely predict the operation of any chosen design, at least in the HF band. There is no substantial mystery concerning the operation of the antenna.

A second conclusion: The coaxial dipole is a VERY inefficient antenna. In the described configuration, 80% of the power went into heating the stubs. RG58 is definitely contra-indicated but even very good coax will still dissipate significant power.

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