Adapting a 160m Inverted-L for 630m

In 2017 the FCC opened up the 630m and 2200m bands for Amateur Radio use with some minor conditions as explained in this ARRL article http://www.arrl.org/news/new-bands-fcc-issues-amateur-radio-service-rules-for-630-meters-and-2-200-meters. During the winter of 2017 I started listening to 630m WSPR activity with my Elecraft K3S and K9AY loop and found it interesting to hear stations a lot farther away than I had originally expected. So in 2018 I decided to investigate how to load my 160m inverted-L up on 630m so that I could do more than just listen. The following is the general process that I used with links to different webpages that were helpful. It's by no means a step by step procedure but serves to collect information from different sources into one location for others to use in case they would like to follow the same path. One of the best resources to get started on 630m is the www.472khz.org website.

1.0 Analyzing your antenna

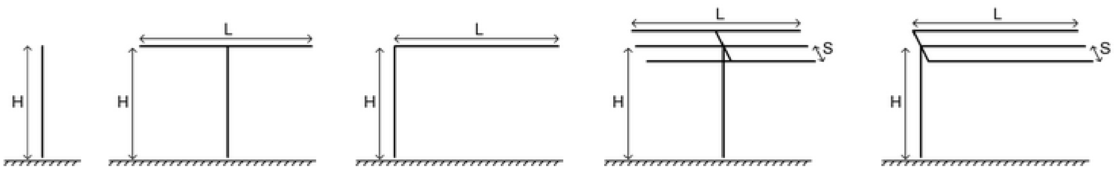
On the www.472khz.org website there is a useful antenna simulation tool for estimating among other things the required value of the loading coil that you'll need http://www.472khz.org/pages/tools/antenna-simulator.php. To use this tool choose the type of antenna, enter its dimensions, and what you think the ground losses might be and then press the GO! Button. Hopefully the result is something similar to what you see in Figure-1 for my antenna. My ground losses are probably somewhere between average and very high so I choose very high. But if I actually knew what the losses were I could have entered it in the tool.

Antenna simulator for small vertical monopoles

This tool calculates the antenna capacitance and radiation resistance of small vertical monopoles at 475 kHz. It is by no means a replacement for antenna design software such as EZNEC, but should give a clue how the antenna will perform. Following limitations apply:

- Total dimension (H+L) less than 15% of the wavelength (= less than 95 m)
- Wire or small tube construction (less than 2.5 cm)
- The calculations assume an unobstructed antenna. Object near or under the antenna will reduce the radiation resistance and increase the antenna capacitance.

1. Select antenna type:



no topload	T-antenna (single topload wire)	Lazy-L-antenna (single topload wire)	T-antenna (multiple topload wires)	Lazy-L-antenna (multiple topload wires)
○	○	◉	○	○

2. Antenna dimensions:

Antenna height (H, in m): 16.764   Topload length (L, in m): 50.292

Number of topload wires: Topload wire spacing (S, in m):

3. Ground loss and environmental losses:

- ○ Very low loss (sea water or open area with many λ/4 radials)
- ○ Low loss (rich agricultural land, unobstructed antenna)
- ○ Average loss (pastoral land, almost unobstructed antenna)
- ◉ High loss (forrested land, suburban location with obstructed antenna)
- ○ Very high loss (urban location, desert, very rocky ground)
- ○ Known ground / environmental loss: ____ Ω (excluding loading coil loss)

4. Calculate: GO !

5. Results:

Antenna type =	Lazy-L-antenna with a single topload wire
Antenna dimensions	Antenna height = 16.764 m Topload lenght = 50.292 m
Antenna capacitance =	427 pF
Required loading coil =	263 µH
Radiation resistance =	0.810 Ω
Loading coil loss =	3.1 Ω (for Q = 250)
Ground / environmental loss =	50 Ω (estimated)
Antenna directivity =	2.2 dBi (estimated)
Estimated antenna current needed for	1 W EIRP = 0.673 A (antenna voltage = 0.53 kV) 1 W ERP = 0.861 A (antenna voltage = 0.87 kV) 5 W EIRP = 1.505 A (antenna voltage = 2.64 kV)
Estimated TX power needed for	1 W EIRP = 24.4 W 1 W ERP = 40.1 W 5 W EIRP = 122.2 W

Figure-1, Results for my 160m antenna

2.0 Designing & Building the Variometer

A Variometer is basically two inductors connected in series where one is placed inside the other. The Inner coil is rotated to either add or subtract inductance so that the mutual inductance can be varied above or below that of the outer coil. The outer coil typically has taps so that large adjustments in inductance can be made by changing the particular tap and smaller adjustments (values between the taps) can be made by rotating the inner coil.

WG2XKA has a great webpage https://wg2xka.wordpress.com/the-variometer/ with a lot of useful info on how to make a bucket Variometer from items found in your local hardware store. On the www.472khz.org page there is also this helpful coil calculator http://www.472khz.org/pages/tools/coil-calculators/cylindrical-coil.php. I ended up using this info as a starting point and then varying it slightly as needed.

Things I learned in making a Variometer that you may find useful

(1) When designing the inner coil use as large an OD for the PVC as possible while still being able to rotate it to ensure the largest amount of inductance, Ideally 25 - 30 uh.
(2) Build the inner coil first and use the final measured inductance value to determine where the taps need to be placed on the outer coil so that there are no gaps in coverage.
(3) Always design the range of the outer coil and its taps to extend well above and below the required loading value. In my case the estimated loading coil value was 257 uh and in the end I only needed 224 uh (13% less than the simulation indicated) but it's always better to have too much then to little range!
(4) When cutting the hole in the bucket for the inner coil shaft make sure the shaft is a snug fit so the shaft isn't apt to change position once properly adjusted.
(5) Duct tape is your friend while winding the coils and a hot glue gun is great when you're done to help anchor everything down.

Figure-2, Bucket Variometer

3.0 Designing & Building an Impedance Transformer

Because the 160m Inverted-L will have an impedance less than 50 ohms a stepdown transformer is required. But without knowing exactly what value is needed to step the impedance down to you will need multiple taps on the primary. I happened on this webpage https://hamsignal.com/blog/the-630m-2200m-antenna-recipe and about and about ¾ of the way down found information on building an impedance transformer using an Amidon FT-240-77 core http://www.amidoncorp.com/ft-240-77/.

Figure-3, Impedance Transformer

The primary is 20 turns of AWG #14 standard copper Romex tapped at every turn starting at the 11th. The secondary is 10 turns using the same type of wire. Based on this construction, Table-1 lists the estimated impedance values that can be properly matched by this transformer. A wire is used to connect the center of the SO239 to the desired tap.

TAP	Turns_Pri	Imp_Pri	Turns_Sec	Imp_Sec
1	11	50	10	41.3
2	12	50	10	34.7
3	13	50	10	29.6
4	14	50	10	25.5
5	15	50	10	22.2
6	16	50	10	19.5
7	17	50	10	17.3
8	18	50	10	15.4
9	19	50	10	13.9
10	20	50	10	12.5
11	21	50	10	11.3
12	22	50	10	10.3
13	23	50	10	9.5

Table-1, Impedance Transformer Values

A Rubbermaid plastic container was used to house the impedance transformer. One thing I realized after building this was that having a tap only every turn rather than every half or even quarter turn meant limitations in the turn's ratio and how well I could match the impedance of the Variometer.

4.0 Setup & Adjusting

In order to properly load my 160m antenna I needed to select the proper Variometer outer coil tap, inner coil position, and Impedance transformer primary tap to achieve the lowest SWR at approximately 475.6 KHz (three variables). If you have one of those antenna analyzers that already covers the 630m band then you're in luck. But if you're like me and have one of those old MFJ-259B ones don't worry you can modify it for 630m and 2200m. Paul N1BUG has a great webpage dedicated to doing this http://blog.n1bug.com/2016/12/22/adding-630-and-2200-meters-to-the-mfj-259b/. The DP3T switch I used was from NKK https://www.nkkswitches.eu/products/Toggles/M/M2044BB1W01/. Figure -4 shows the required strapping to properly configure the DP3T switch.

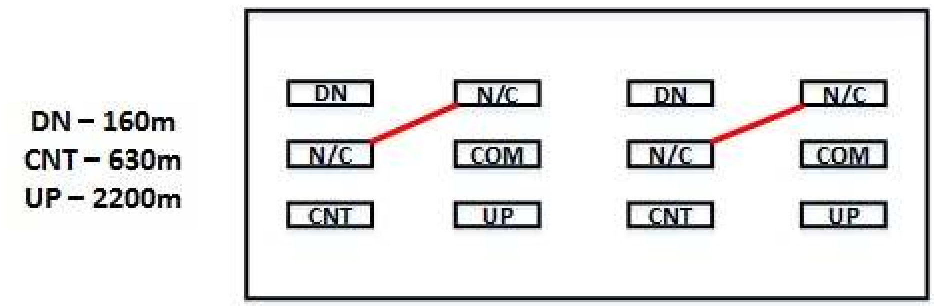


Figure-4 DP3T Switch Strapping

Figure-5, Modified MFJ-259B

To set everything up I removed the existing coax going to the existing feed of my 160m antenna and connected it to the impedance transformer input (SO239 connector). I then connected one side of the impedance transformer secondary to the 160m antenna ground and the other side of the secondary to a tap on the Variometer. The other side of the Variometer was connected to the existing 160m antenna wire. Figure-6 shows how everything is connected for 630m use.

630m Transmit Antenna

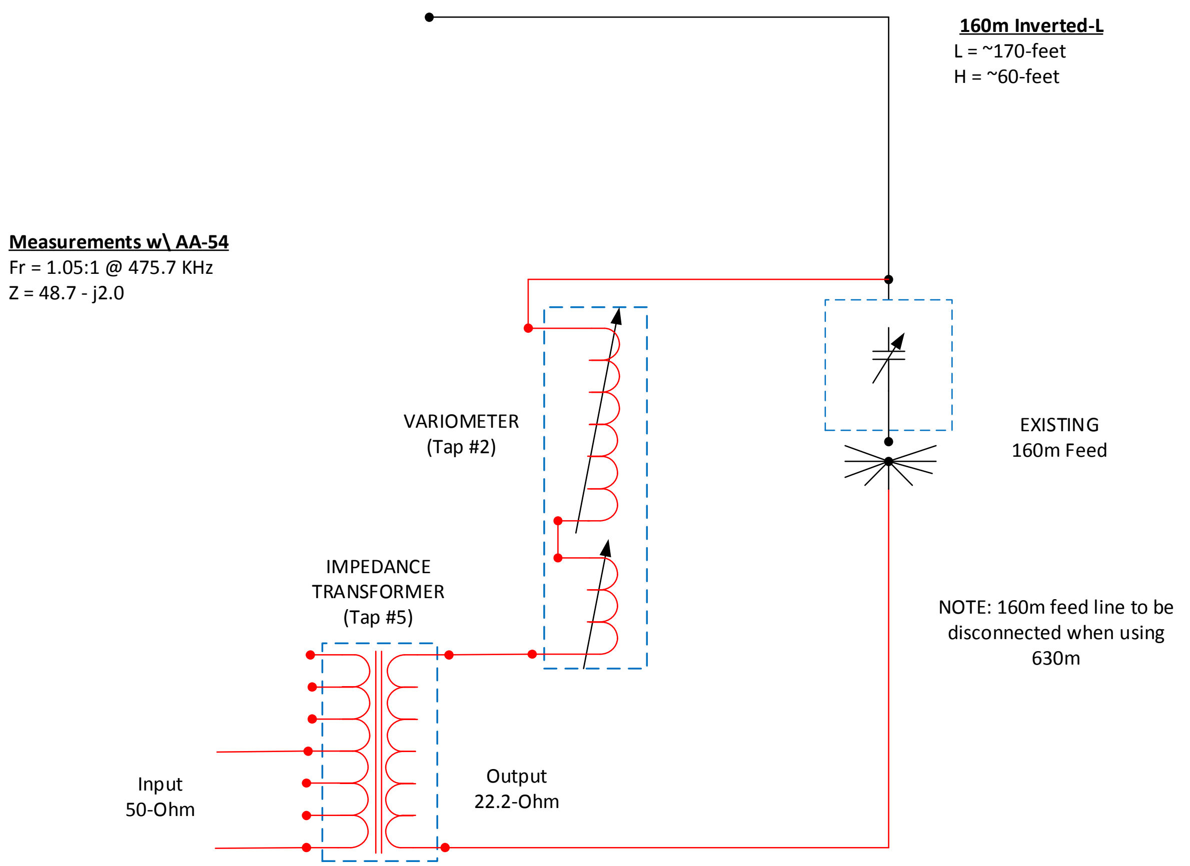


Figure-6, 630m Transmit Antenna System

The procedure I used for making initial adjustments was to start with the lowest tap settings for both the impedance transformer and Variometer and then adjust the Variometer inner coil for minimum SWR at approximately 475.7 KHz. Try different Variometer taps until you find the one that produces the lowest SWR. Then select different impedance taps until again you find the one that produces the lowest SWR with the Variometer. In the end the final setting for my impedance transformer was tap #5 (turn #12) and for my Variometer tap #2 (second lowest inductance value). Figure -7 shows the recorded 630m antenna SWR values using the MFJ-259B. Note the 2:1 bandwidth is almost 9 KHz.

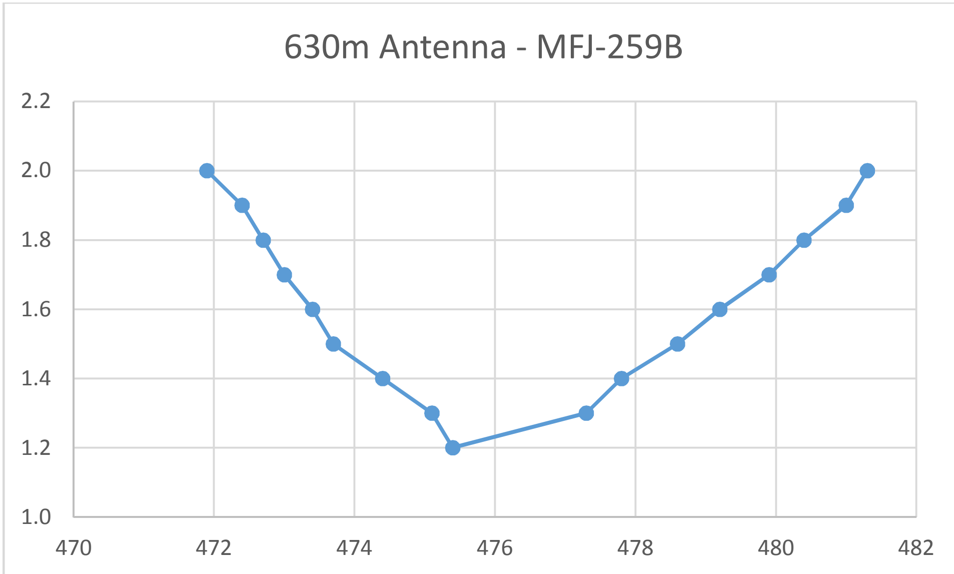


Figure-7, 630m Antenna SWR using MFJ-259B

I also used a RigExpert AA-54 antenna analyzer which can operate down to 100 KHz so I was able to check the values obtained using the MFJ-259B against it. The AA-54 is a newer instrument and probably a little more accurate. Figure-8 shows the SWR performance and Figure-9 is the Impedance / Reactance curve. The two analyzers appear to track each other reasonably well.

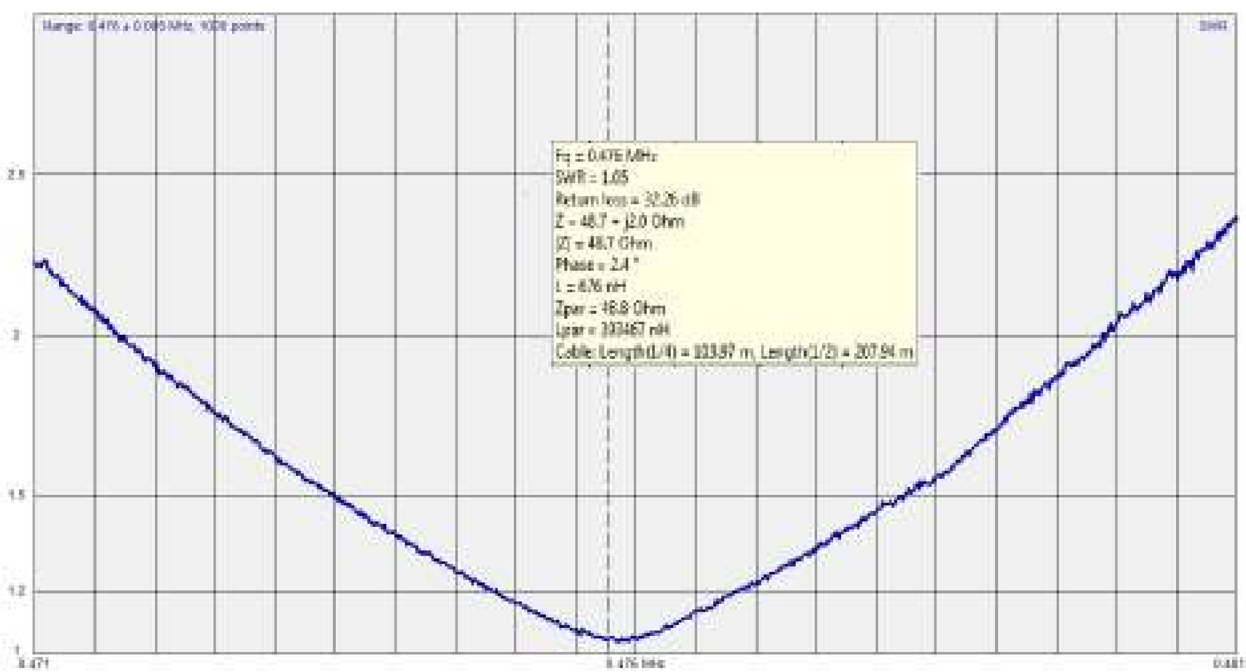


Figure-8, 630m Antenna SWR using RigExpert AA-54

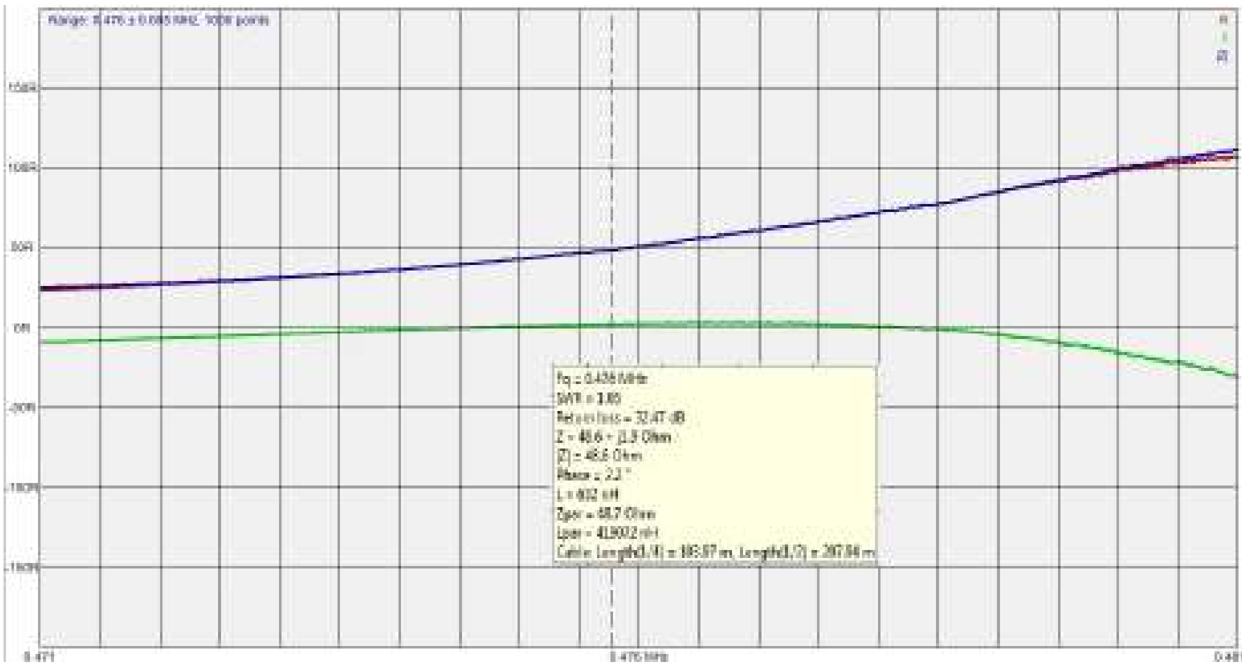


Figure-9, 630m Antenna RXZ using RigExpert AA-54

I purchased a 100w solid state amplifier from K5DNL which included a low pass filter and integrated scopematch. While I was appreciative for the low pass filter, I wasn't initially sure what to do with the scopematch, since I really had no previous knowledge of it. A scopematch is a device that allows one to sample the voltage and current of a signal on a piece of coax and display it on a two channel oscilloscope. KB5NJD has a good explanation of it here http://njdtechnologies.net/want-a-little-more-info-than-an-swr-meter-alone-can-provide-meet-the-scopematch/. The scopematch allows you to monitor the match of your antenna system in real time from inside your shack. And for those with remote control of their antenna matching network it allows them to adjust their antenna using the scopematch as real time feedback. So this is basically what the **V** and **I** waveforms viewed on the oscilloscope mean.

- If the **V** and **I** Waveforms are of equal amplitudes and are in phase your antenna system resistive component is at 50 Ω and the reactive component is 0 Ω (in-phase).
- If the **V** waveform is of a greater amplitude then the **I** waveform (regardless of phase relationship) the resistive component is greater than 50 Ω.
- If the **V** waveform amplitude is less than the amplitude of the **I** waveform (regardless of phase relationship) the resistive component is less than 50 Ω.
- If the **V** waveform leads the **I** waveform (regardless of the amplitude of either waveform) then the reactive component is inductive (Z = R + j) indicating that inductance needs to be reduced.
- If the **I** waveform leads the **V** waveform (regardless of the amplitude of either waveform) then the reactive component is capacitive (Z = R - j) indicating that inductance needs to be increased.

Figure-10 shows the scopematch waveforms for my 630m antenna system transmitting 30w at 475.7 KHz. As you can see the **I** waveform is leading the **V** waveform slightly indicating the reactive component is slightly capacitive. And the amplitude of the **I** waveform is slightly less than the **V** waveform indicating the resistive portion of the impedance is less than 50 Ω. This seems to correlate with the data from Figure-8 where Z = 48.6-j2.0.

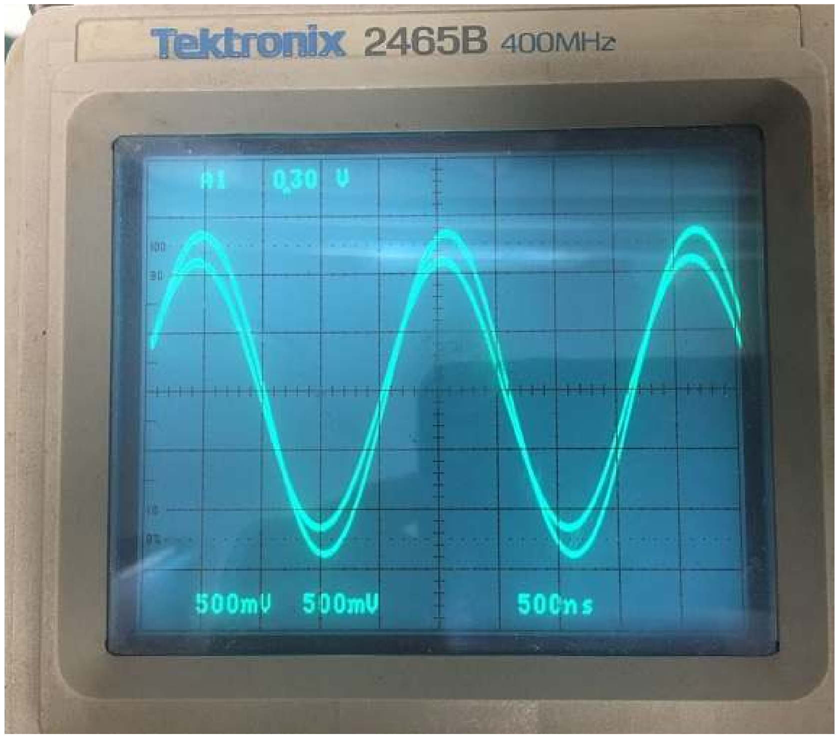


Figure-10, Scopematch waveform of my 630m antenna @ 475.7 KHz

5.0 Final Thoughts

While I have been happy with the antennas performance, there are always things that can be improved on. The 630m antenna configuration is not permanent so it requires reconfiguring it manually back and forth between 630m & 160m. This can sometimes be a hassle having to go out in the dark to switch things back and forth so I'll have to give some thought to adding some sort of remote switching.

Also I've found that the antenna systems resonant frequency can change from day to day even without any precipitation by 1-2 KHz so the match must be checked with the antenna analyzer before using it each day and the Variometer adjusted as necessary. When it rains the resonant frequency can change by 5 KHz or more and going out in inclement weather to adjust it is no fun. Others have implemented servo motors to remotely tune their Variometers and I'll also need to look into this more in the future.

And finally while the impedance transformer I constructed has worked out fairly well the limitation in the turn's ratio and therefore how close it can match the antennas impedance could be improved (currently about 2 Ω). I'd like to look into other designs to improve this going forward including Implementing mulriple taps on both the primary and secondary coils to increase the number of turn's ratio combinations that are available potentially improving impedance matching down to +/- 0.5 Ω.