630m Loop On the Ground (LOG) RX antenna experiments

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On the south and west boundaries of my QTH I have polyphase power lines serving local light industry where machines with electrically noisy motor controls are common. I have lots of RFI! My property is only 400' E-W by 600' N-S. At 475 kHz λ=2072' and at 2200m λ≈7000' so all of my QTH is well within the induction field of these lines making receiving antennas a challenge for 630m and even more so on 2200m. I've tried many different antennas, BOG's, large vertical loops, normal and phased terminated vertical loops, etc, but the best one for the past couple of years has been a simple vertical. I have a 3-element vertical array on 160m with 80' top-loaded 4" irrigation pipe elements spaced 100'. Each element has sixty-four 120' radials. For 630m operation I've installed relays in each element to open circuit the element. For the east element, which is the furthest from the power lines, the relay switches the element to the input of a K7TJR Hi-Z amplifier with 75Ω coax back to the receiver. This antenna has worked well but I'm always on the lookout for something better.

A few weeks ago George, W2VJN, sent me a link[1] to a very simple RX antenna, a horizontal Loop of wire lying On the Ground, a "LOG". I've been very skeptical of LOG's because they typically have very low signal outputs (average gains below -40 dB) which might change with time and weather. On the other hand they are simple, cheap, easy to build, invisible, can be mowed and driven over, etc. George also passed me another note[2] with a number of positive comments on LOGs so I thought why not give it a try. While running the tests I discovered an unexpected advantage for the LOG. Listening before and during a rain storm the precipitation noise on the vertical increased dramatically but there was none on the LOG. A wire lying in the grass does not seem to charge up in the rain!

Antenna Comparisons

To compare the performance of two RX antennas I used a pair of TS590s to monitor 474.2 kHz WSPR transmissions. One receiver was connected to the reference antenna and the second receiver to the test antenna. The daily reports were copies to a spreadsheet.

LOG Radiation patterns

Before discussing results it's important to understand the radiation patterns in terms of polarization. Figure 1 is a sketch of the initial LOG, square, 71' side lengths, fed at one corner, the x-axis pointing north.

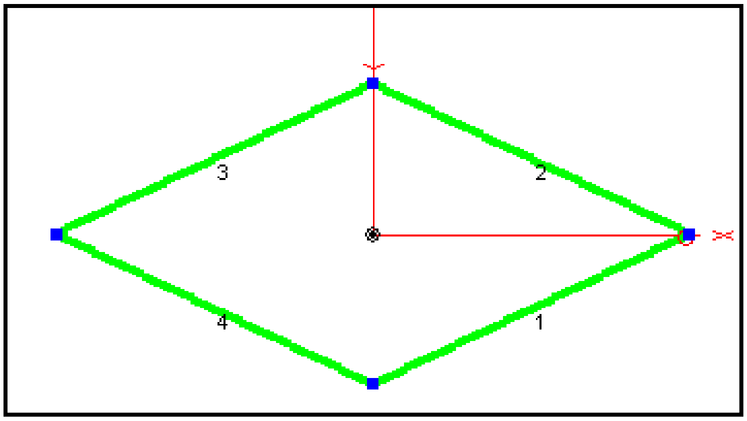

Figure 1 - Initial LOG.

An azimuthal pattern at 25⁰ elevation is shown in figure 2A. There are two patterns superimposed: vertical polarization, blue, and horizontal polarization, red. Note how low the gains are, ≈-50 dBi! The signal output will be very low. The loop was modeled 1" above average ground using EZNEC Pro and AutoEZ.

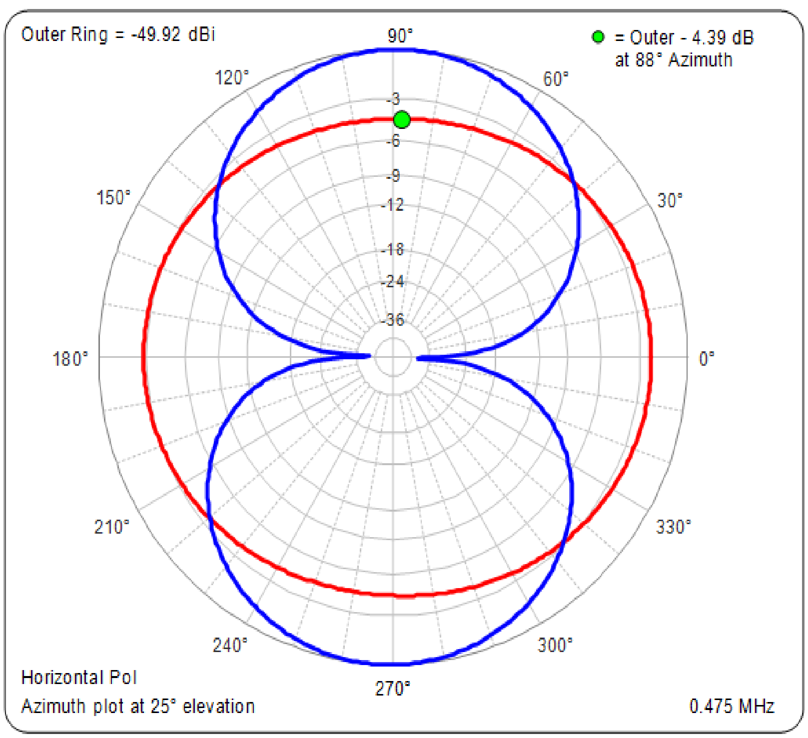

Figure 2A - Azimuth pattern at 25⁰ elevation.

Figures 2B and 2C show elevation patterns at zero and ninety degree azimuths.

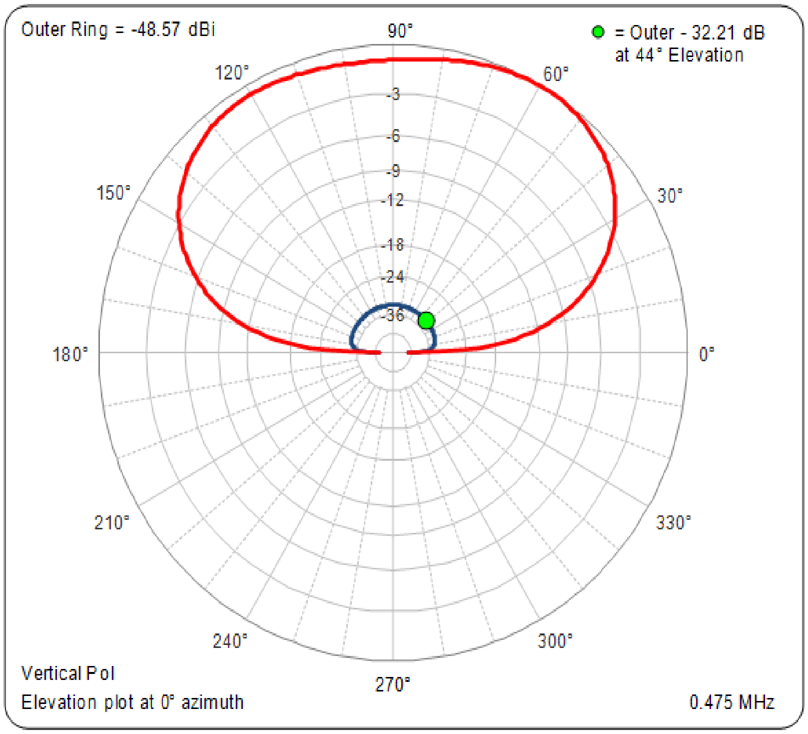

Figure 2B - Elevation pattern 0^o azimuth.

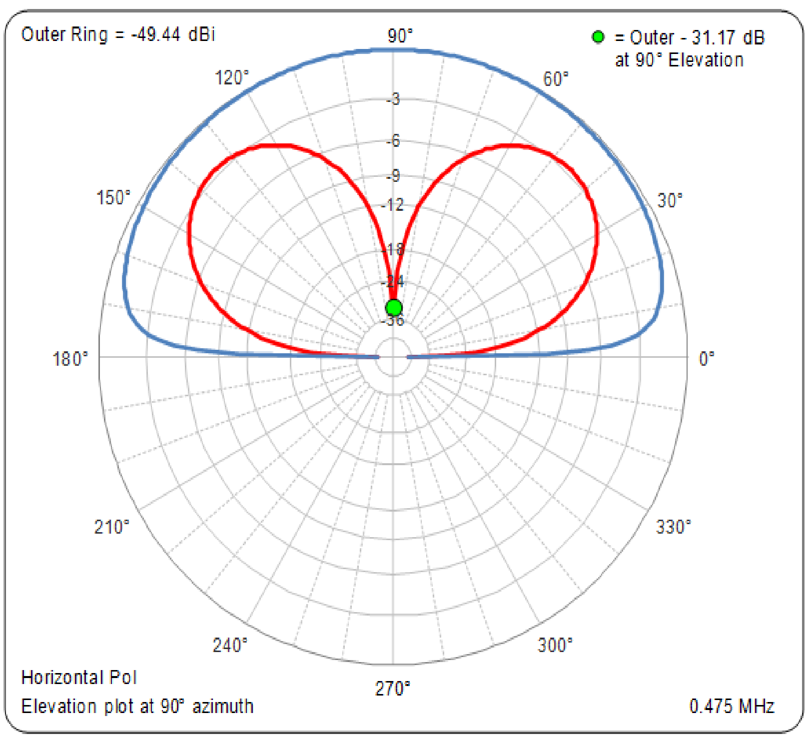

Figure 2C - Elevation pattern 90^o azimuth.

The vertical and horizontal polarization patterns are quite different. Note that there is plenty of horizontal response which is contrary to some past assertions[1]. The vertical response is small in the ±x direction but maximum in the ±y direction, broadside to the feedpoint. The horizontal response is much greater in the ±x direction and there is still substantial response in the ±y direction, it's down by only 5 dB or so. The net received polarization is mixed. Most LFMF TX antennas are vertical radiators and it is often assumed that the received signal will also be vertically polarized which is largely true for paths of a few hundred miles or less. But on long paths like that between N6LF and VK4YB (11,612 km) it is possible that some response to horizontal polarization might be useful. My vertical responds very little to horizontally polarized waves but the LOG has substantial horizontal response which is something to keep in mind when reviewing the comparison data given below.

Feedpoint impedance

I measured the impedance of the initial LOG at the corner feedpoint using a vector network analyzer (VNA) with the result shown in figure 3.

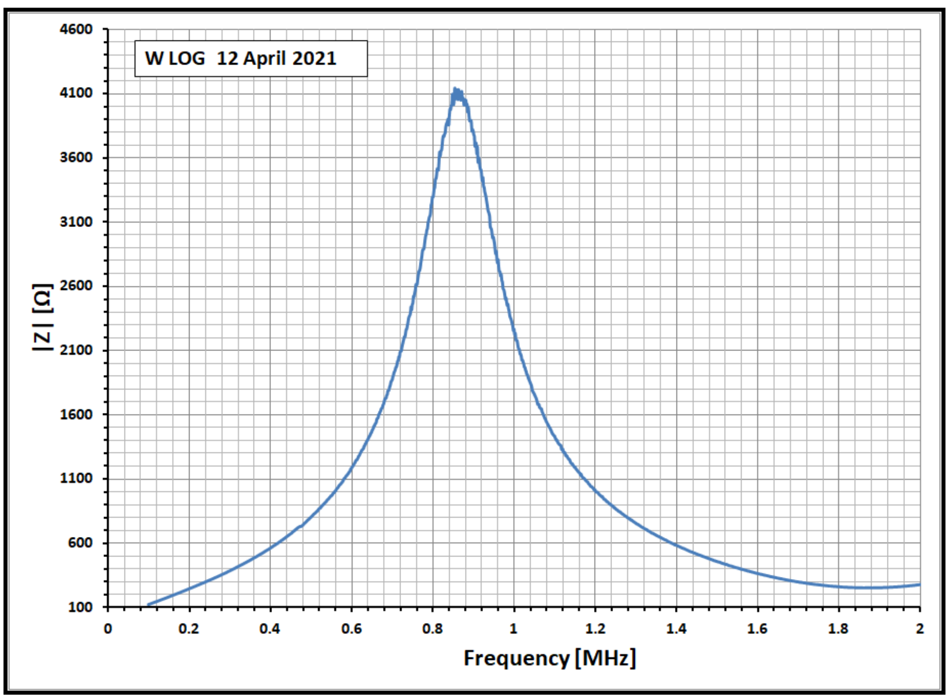

Figure 3 - Feedpoint impedance of the W LOG.

From figure 3 it's clear that the first resonance is a parallel resonance, ≈875 kHz, which can be represented by the equivalent circuit in figure 4. Zi is large and reactive. How are we going to match this to a typical 50-75Ω transmission line? Figure 5 suggests a couple of possibilities.

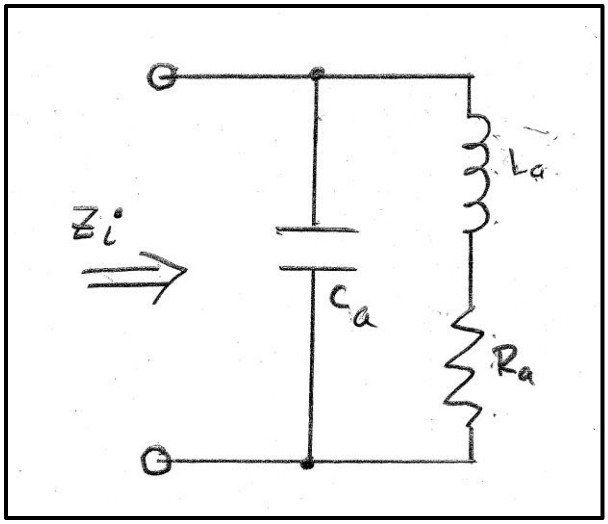

Figure 4 - Equivalent circuit.

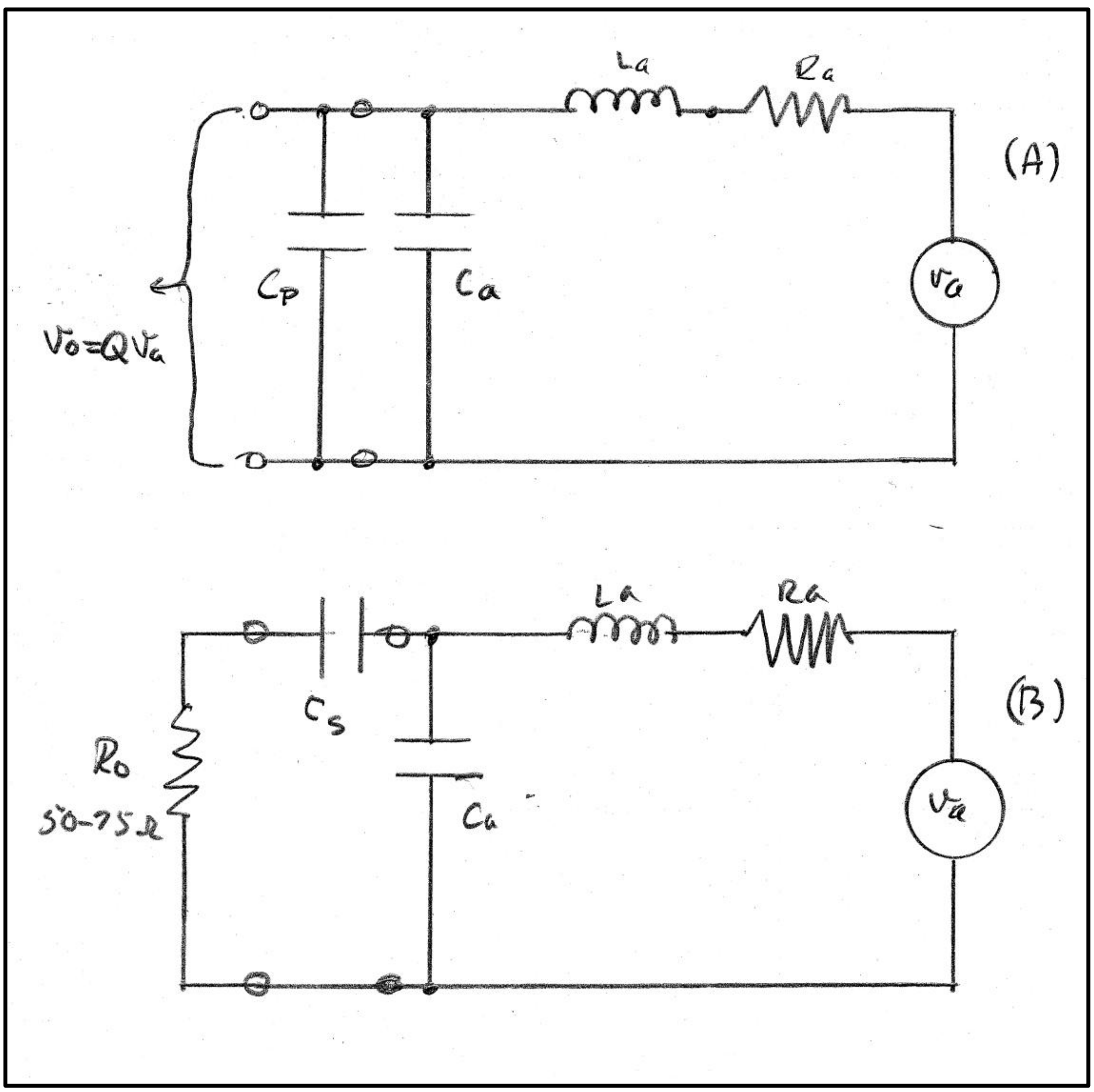

Figure 5 - Feedpoint matching schemes.

In (A) a shunt capacitor is placed across the feedpoint to resonate the antenna at the operating frequency. This approach has the advantage of multiplying the received antenna voltage (va) by the Q of the loop. In vertical loops elevated above ground Q's of several hundred are possible which yields a large increase in va. However, LOGs are very close to ground (roughly 1") and heavily loaded by the soil so LOG Q's are more like 5-10 at most. A gain of 5 is equivalent to 14 dB. Given the intrinsic low output for LOGs +14 dB is not to be sneered at. With this scheme the feedpoint impedance will be very high. The most direct way to deal with that is to use a high input impedance amplifier at the feedpoint like a K7JTR Hi-Z amplifier for example. The input impedance of these amplifiers is ≈50kΩ and output impedance 75 Ω.

An alternative scheme is shown in (B) where a series capacitor is used to introduce a series resonance at the operating frequency.

Initial LOG tests

Using scheme (B) I resonated it with series 470pF SM capacitor and measured the input impedance shown in figure 6 compared to the untuned impedance (figure 3).

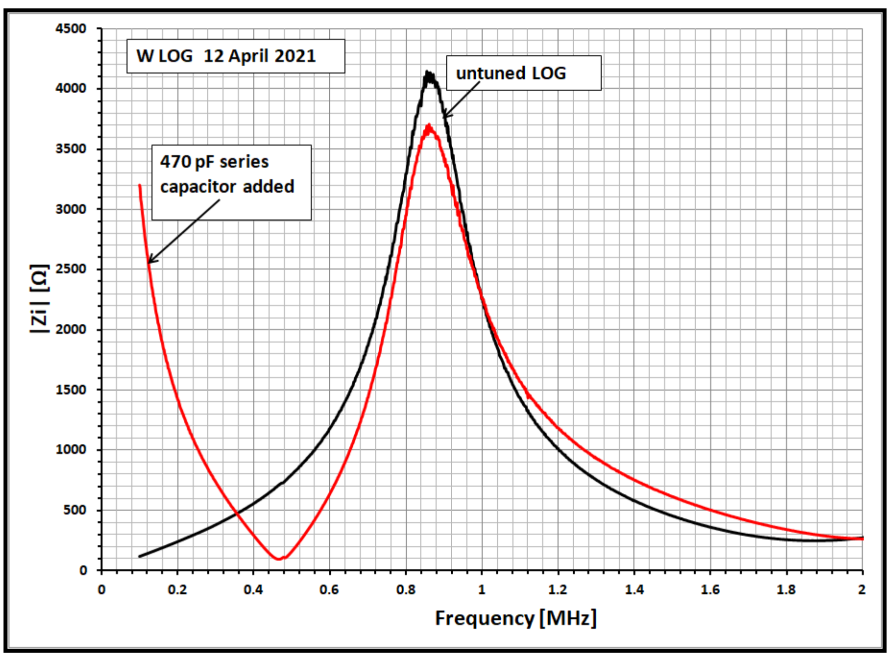

Figure 6 - Zi with and without series 470 pF capacitor.

At 475 kHz adding the series capacitor the input impedance became 123Ω resistive. For the initial tests the match was reasonable for a 75Ω line so I connected the line directly to the antenna though a common mode choke. I could have improved the match with a simple 1.3:1

turns ratio transformer but I didn't bother at this early stage of the experiments. One point to note here is that adding the series capacitor adds a series resonance at the operating frequency but has little effect on the parallel resonance.

Referring to figure 1, the x-axis was pointed north. This meant the vertical polarization maximum was oriented E-W. Figures 7A and 7B show the results of the initial run on April 13th. At first glance the LOG seems to be about equal to the vertical for VK4YB but inferior for K3RWR. This LOG was placed on the west side of my property within 100' of the power lines on my west boundary while the vertical is about 400' from the lines. Induction field intensity usually falls inversely as the cube of distance so one would expect the noise at the vertical should be much lower than at the initial LOG placement.

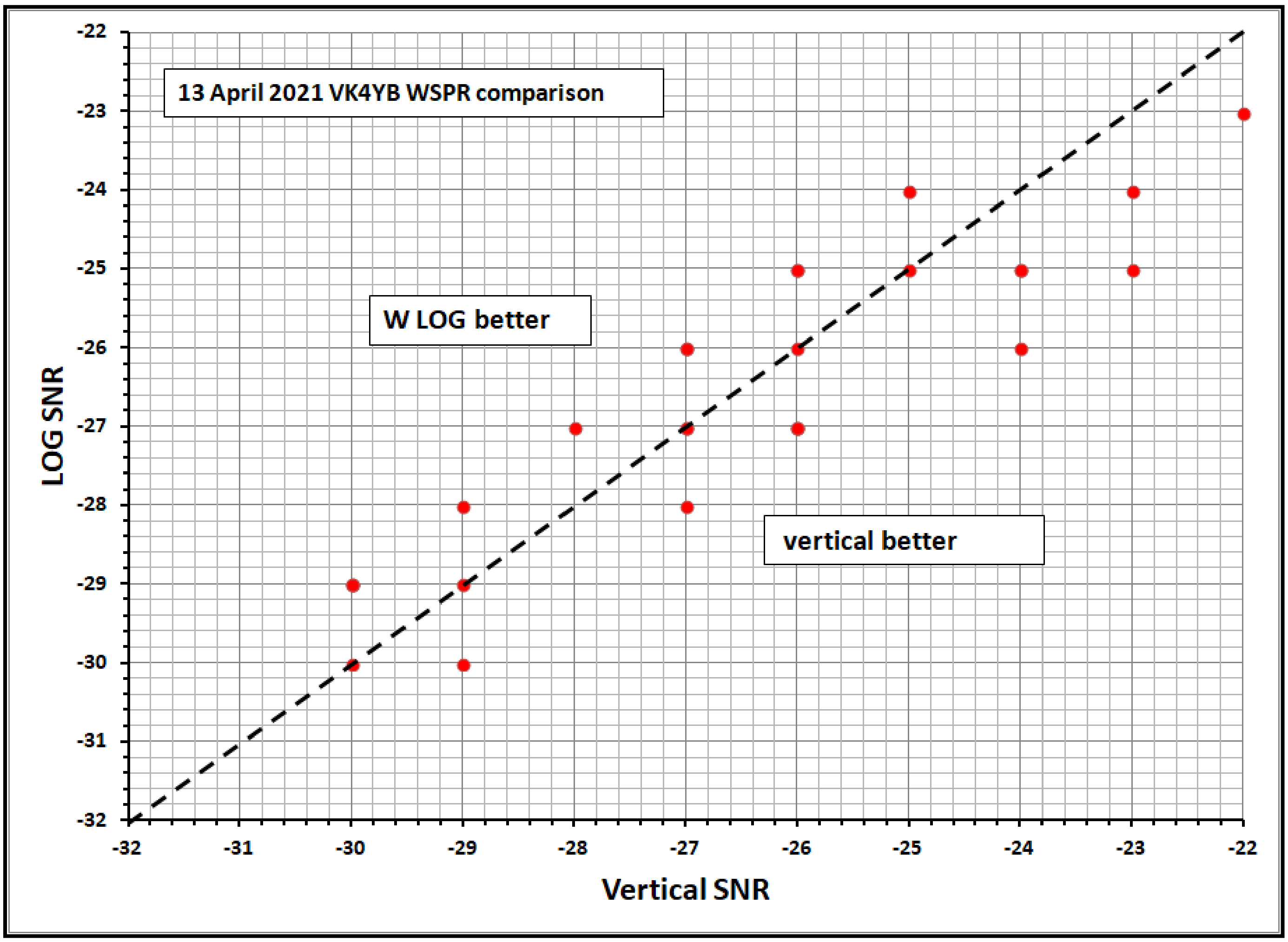

Figure 7A -VK4YB reception.

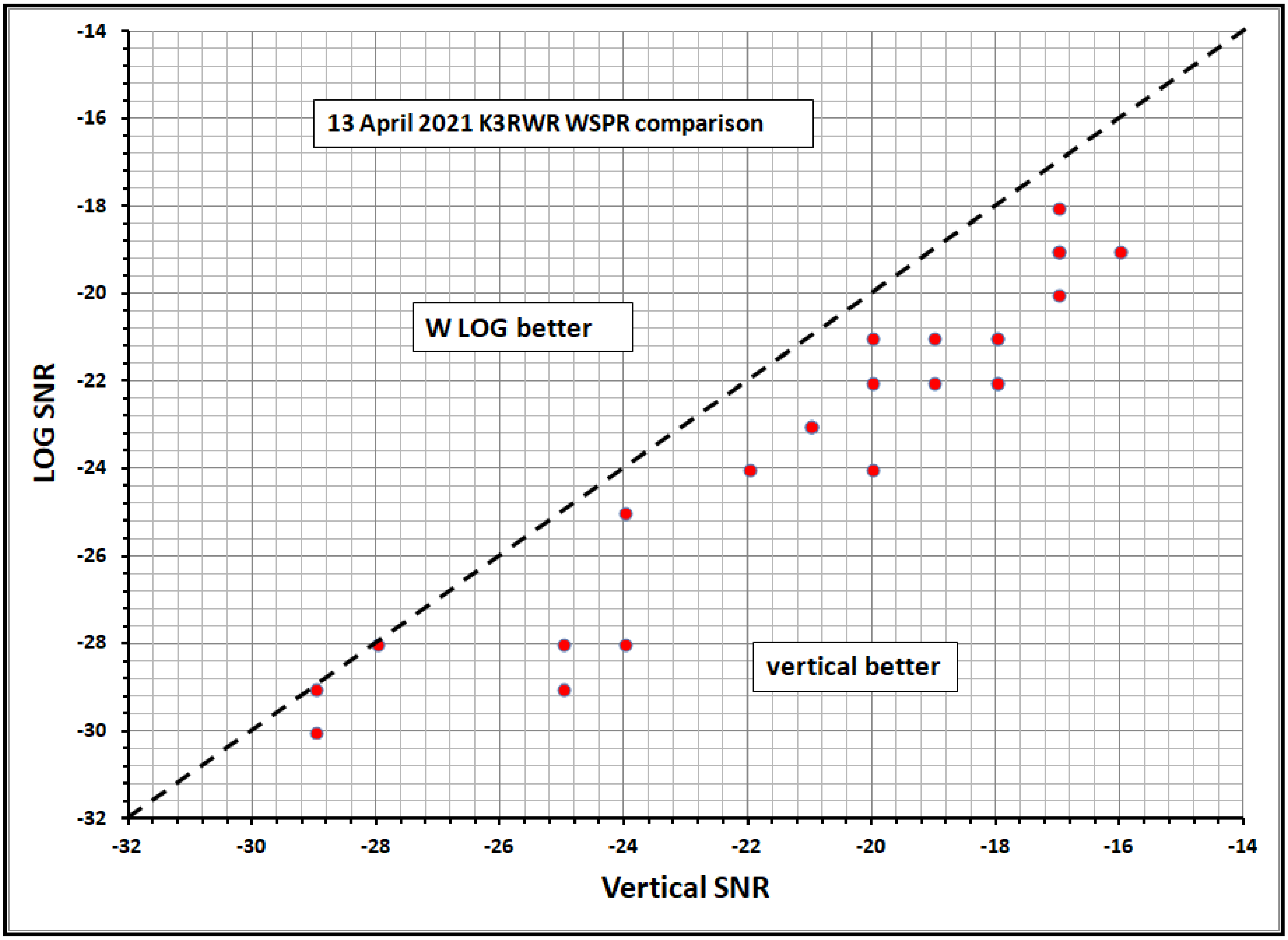

Figure 7B -K3RWR reception.

When working with RX antennas with very low output one of the first things I measure is the noise margin. To do this I connect an RMS voltmeter (HP3400A) to the receiver audio output and measure the output level, first with the antenna disconnected and then with the antenna connected, choosing a frequency with only noise in the passband. The increase in output in dB is the noise margin. Usually a minimum of 10 dB of noise margin is needed to overcome receiver NF. In this case, with the antenna in my west field, there was plenty of noise margin!

The next step was to pull up the first LOG and reinstall it on the east side of my property, just east of the vertical, over 400' away from the power lines. Fortunately I'm on very good terms with that neighbor and in exchange for a bit of grass mowing with my tractor he let me use part of his field to reinstall the LOG. The new results are shown in figures 8A and 8B.

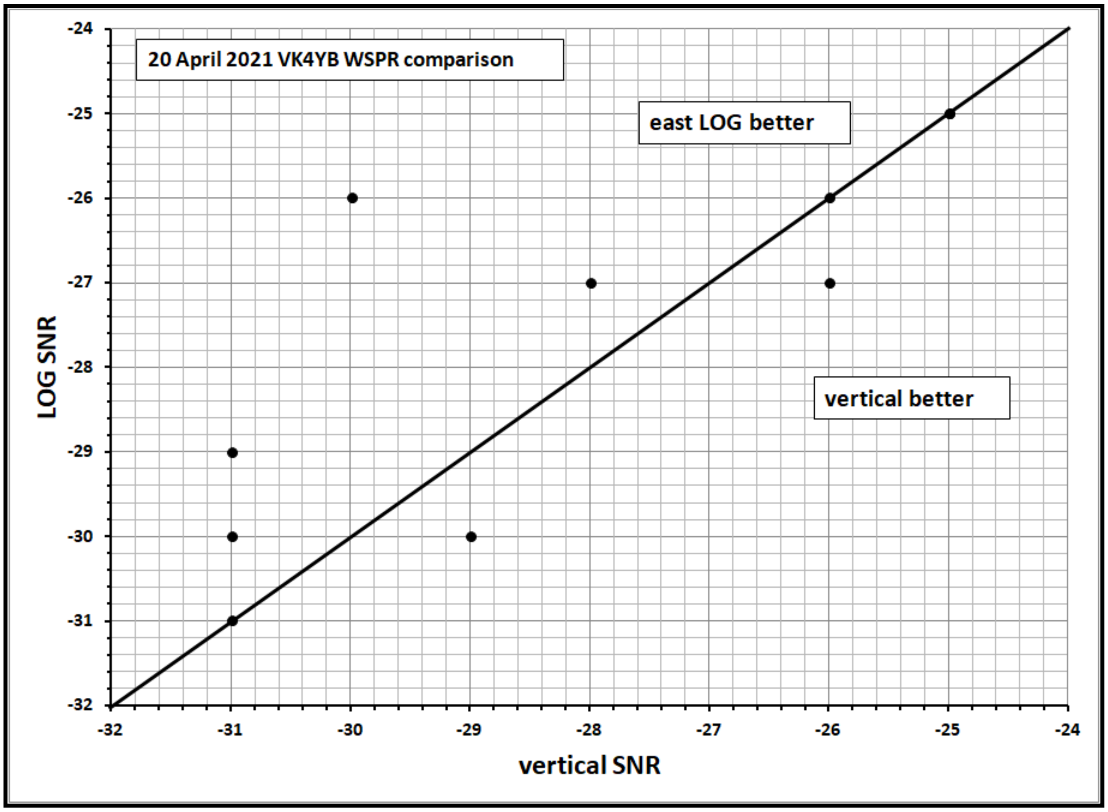

Figure 8A -VK4YB reception.

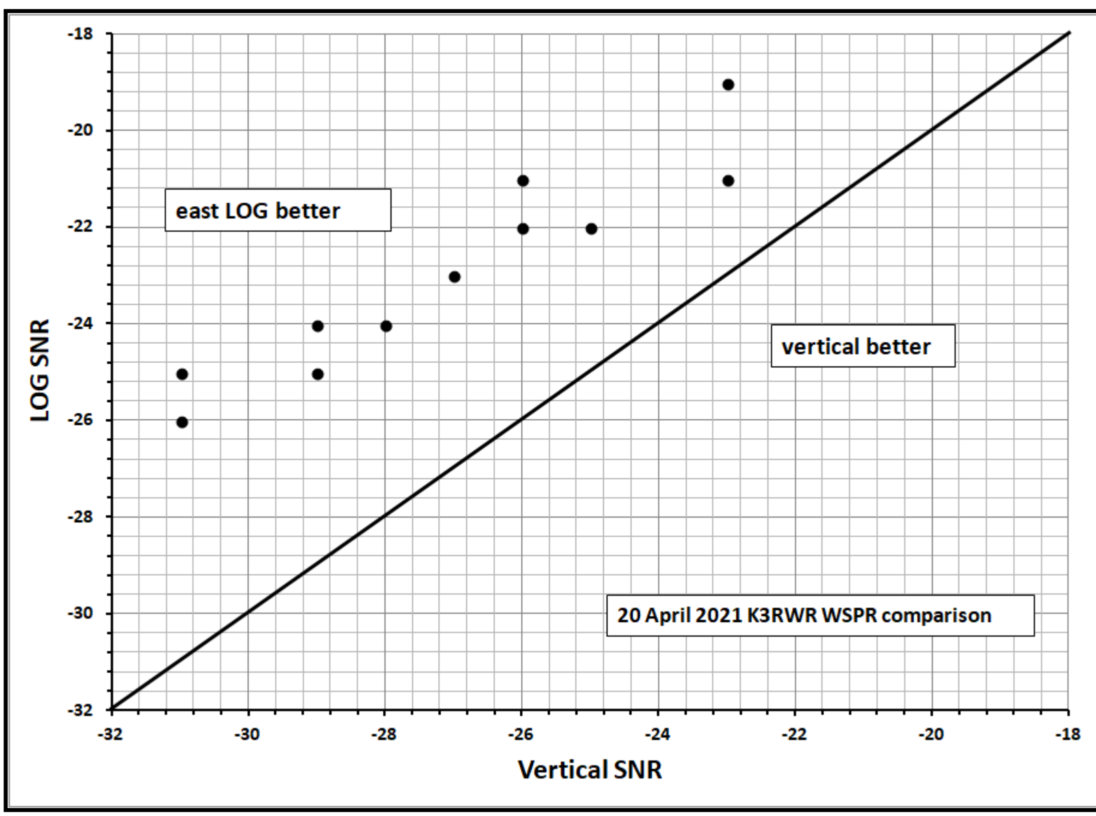

Figure 8B -K3RWR reception.

This is exactly the same antenna, just relocated, the difference is dramatic. The LOG is much better than the vertical for K3RWR and appears to provide some improvement for the path to VK4YB. One comment, after moving the LOG to a new location I remeasured the noise margin, it was 6-8 dB lower! The only problem was the noise margin was now only about 5 dB which is not adequate. As predicted by the modeling, the output from this LOG was low, too low. The cure of course was to make the LOG larger which I did. The message here is that a usable LOG will have to be quite large on LFMF.

The new E Log

A sketch of the new LOG is shown in figure 9. To fit the available space the antenna is a rectangle fed at the center of one side (the south side). The x-axis points N-S and the y-axis E-W so the vertical radiation maximum is pointed E-W. This antenna is larger, 140' X 100', an area of 14,000 ft^2. The first LOG, with 71' side lengths, had an area of 5000 ft^2. I used #14 THHN wire for mechanical reasons because I'll be driving over the wire while mowing the field. Electrically much smaller wire could be used if it's not subject to abuse.

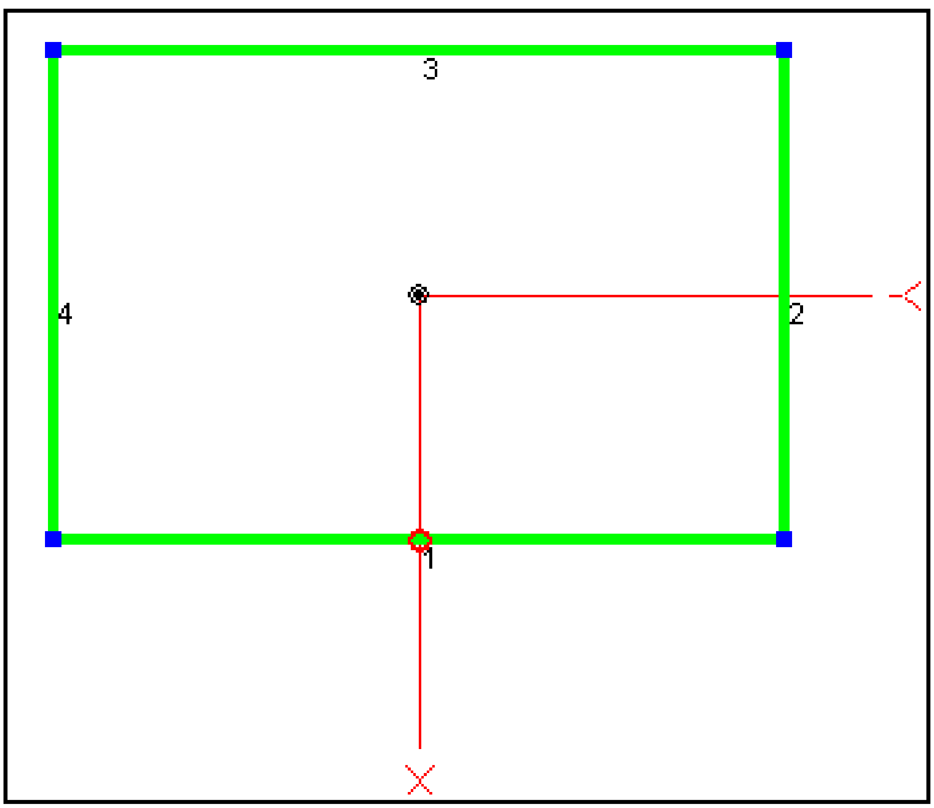

Figure 9 - Final version of the E LOG.

Figure 10 is a graph of |Zi| for this LOG compared to the initial version.

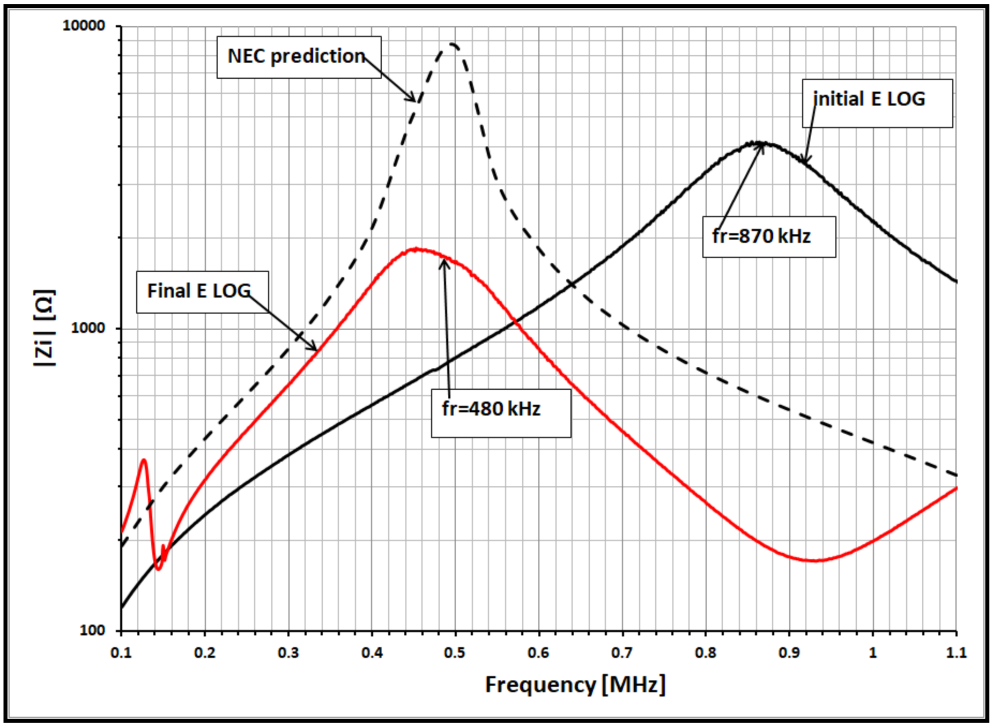

Figure 10 - Feedpoint impedance comparison between initial and final LOGs.

The first parallel resonance is now at 480 kHz compared to 870 kHz for the smaller initial E LOG. Note that increasing the perimeter by 1.7X has reduced the parallel resonant frequency by a factor of 1/1.8. At 475 kHz Zi≈1800Ω I elected to use a Hi-Z amplifier at the feedpoint isolated with a common mode choke without any additional tuning arrangements. Other arrangements are for future experiments!

A contour for the EZNEC prediction is Included in figure 10. The wire was modeled at 1.2" above average ground. The calculated Q is higher but the calculated first resonant frequency is very close. The second resonance (series) is not as close. Looking at the lower end of the measured Zi graph (red) for there appears to be a peak at ≈130 kHz which the modeling does not replicate. I suspect is due to an interaction with the common mode choke?

A quick check of noise margin on 630m showed well over +10 dB. Plenty of margin to override the receiver NF.

Some reception results

One of the things I noticed throughout the tests was a larger number of decodes on the LOG as apposed to the vertical. Here is an example for VK4YB.

3 spots: VK4YB Timestamp	vertical N6LF SNR	8 spots: VK4YB Timestamp	LOG N6LF/A SNR
		2021-04-29 08:54	-30
2021-04-29 10:20	-29	2021-04-29 10:20	-26
		2021-04-29 10:22	-29
		2021-04-29 10:26	-30
		2021-04-29 11:08	-27
		2021-04-29 11:14	-29
2021-04-29 11:16	-29	2021-04-29 11:16	-27
2021-04-29 12:42	-30	2021-04-29 12:42	-30

This was a consistent pattern for both VK4Yb and K3RWR . For the A-B comparisons only the time simultaneous decodes were used. Reception results over several nights are summarized in figures 11A and 11B.

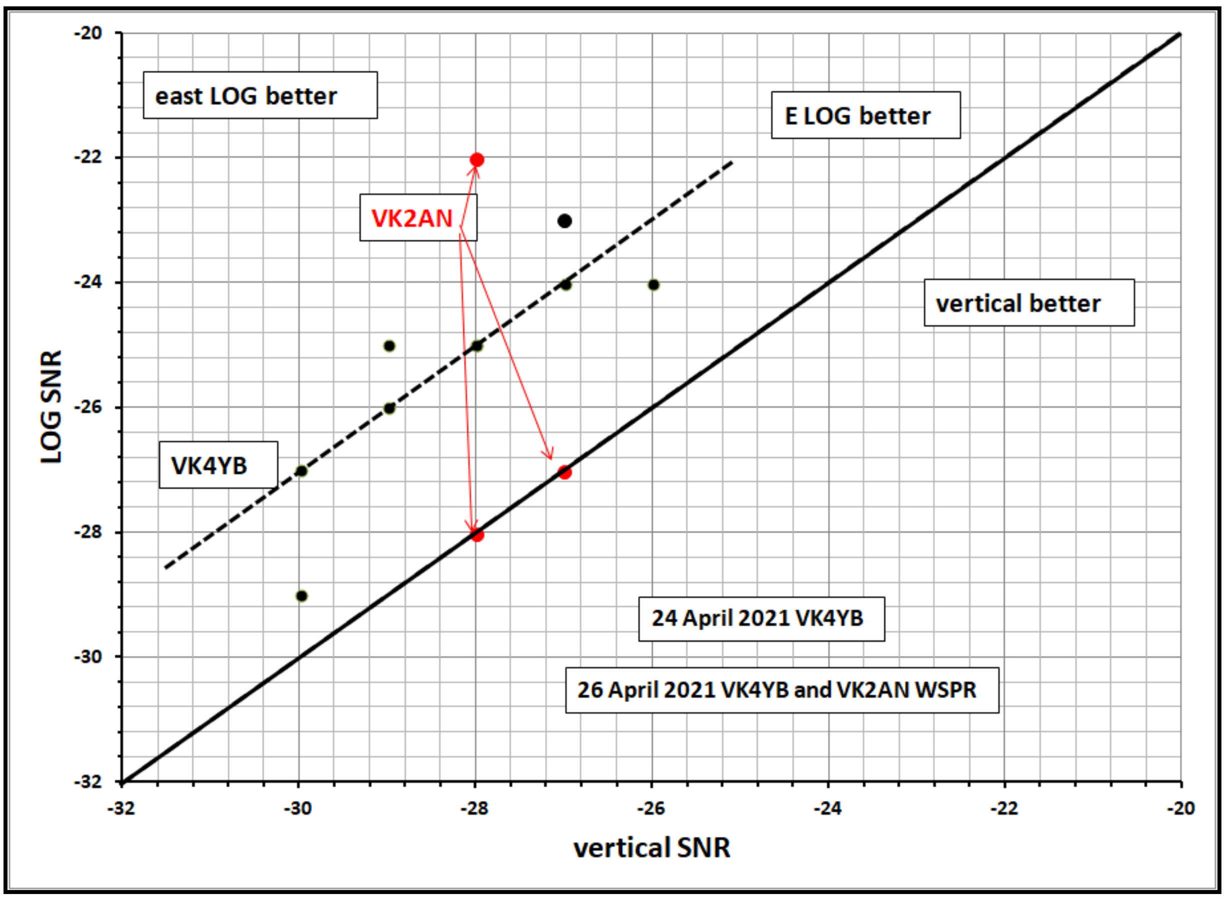

Figure 11A - WSPR decodes for VK4YB and VK2AN.

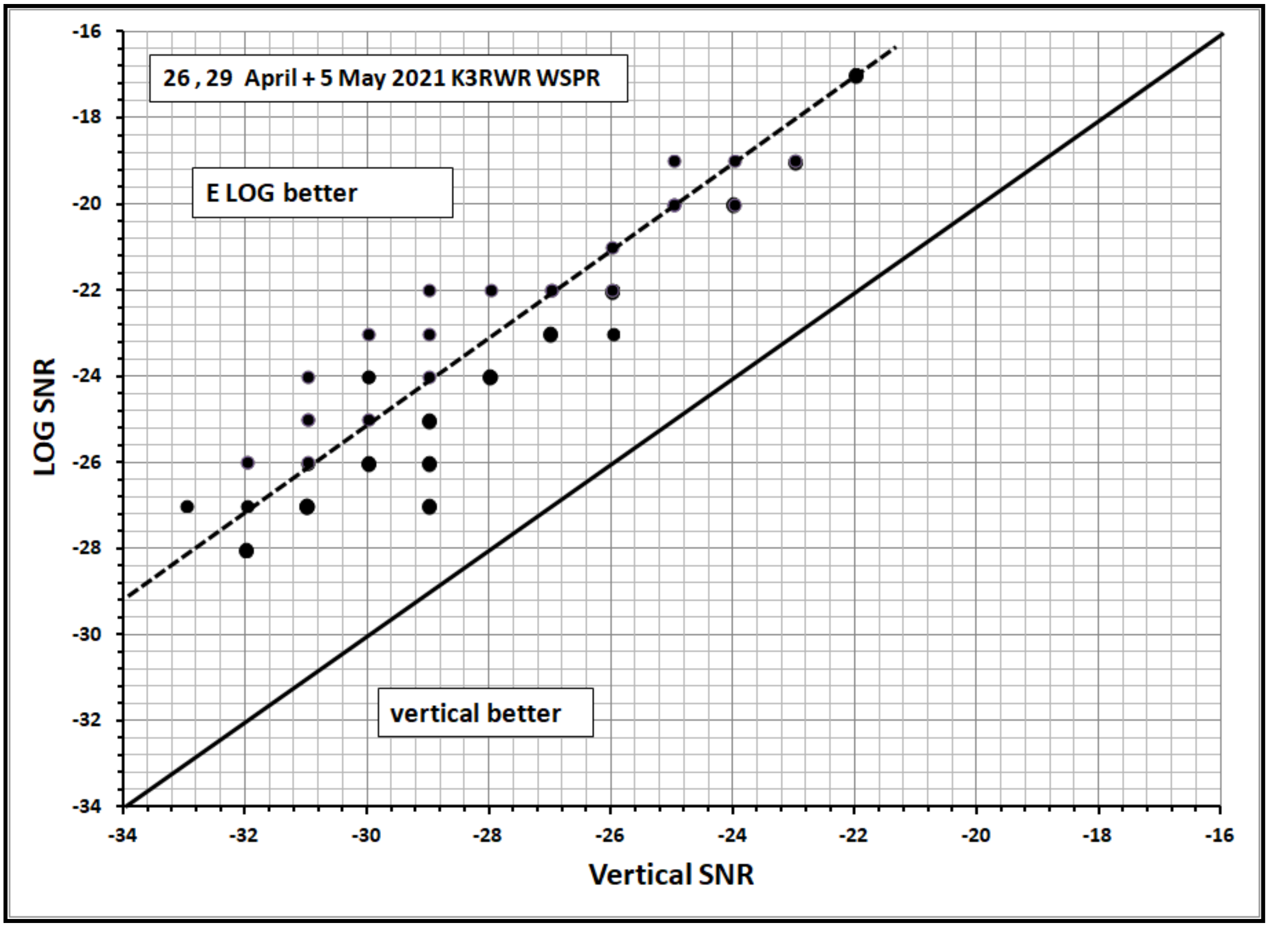

Figure 11B -K3RWR WSPR decodes.

For both the VK and K3RWR paths the new LOG is clearly the winner. In both graphs I've added linear trend lines to approximate the data. For the VK path the average improvement for the LOG over the vertical is 3-4 dB. For the K3 path the improvement is somewhat larger 5-6 dB. These are very worthwhile improvements and the E LOG is now my working RX antenna for 630m.

Null in vertical polarization pattern

The vertical polarization null was pointed N-S. From my QTH KL7 is ≈325⁰ so I would expect the E LOG to be inferior to the vertical on this path. For the paths to KL7 and JA the relative worth of the LOG is still TBD. We can however, use signals from US stations to see the effect of the null. Figure 12 compares WSPR reports for W7XU on two nights separated by about two weeks with quite different propagation, the LOG was consistently better. W7XU is to my east and KR6LA is almost due south. Comparing the two as shown in figure 13 illustrates the effect of the N-S null in the vertical polarization pattern.

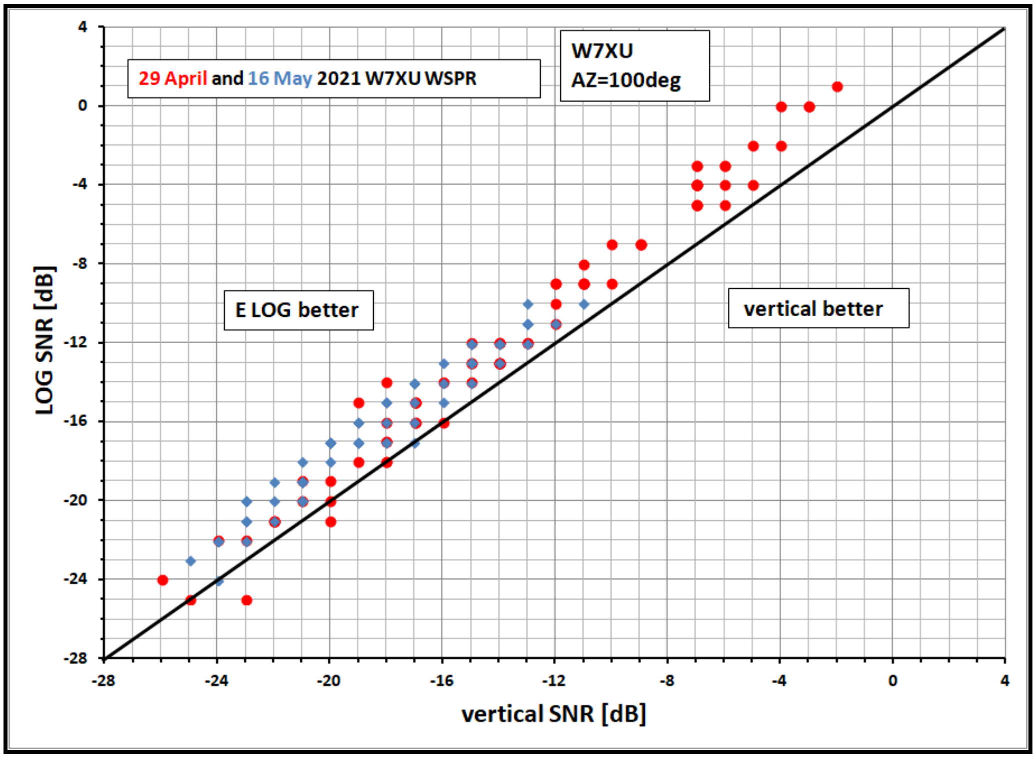

Figure 12 - W7XU comparison.

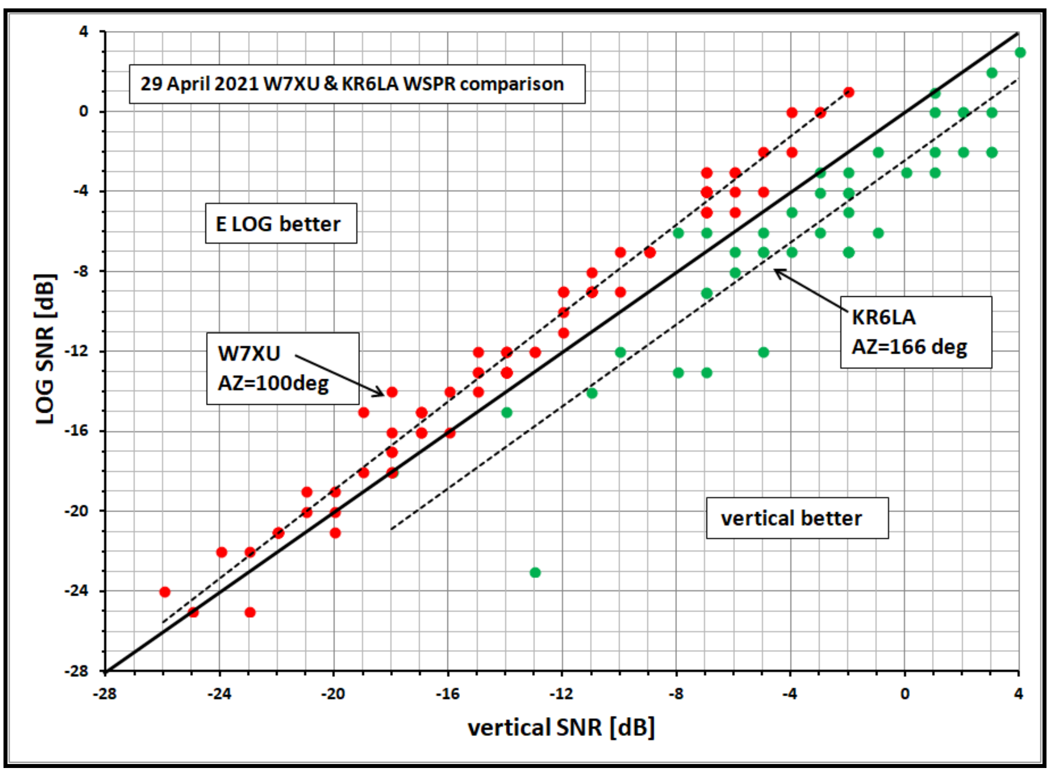

Figure 13 - Comparison between W7XU and KR6LA.

To date 2200m experiments have been limited to reception of W7IUV and WH2XND. Both stations lie almost directly N-S of me in the N-S vertical polarization pattern null. Limited measurements showed the LOG to be about -10 dB from the vertical for W7IUV. SNR reports for XND were even lower.   I've not had time to compare signals on other paths where the results might be quite different. Again, that's for the future.

Summary

At my QTH the LOG appears to be a winner. However, I suspect at least part of this is due to my particular RFI environment so I can't promise equal results at other sites but at the very least the antenna is worth considering if space is available.

The work reported here is very preliminary and far from complete. In particular the analysis of feedpoint schemes is casual at best. Much to be done there. Other than switching from a diamond to rectangular shape, there is no discussion of the effect of shape on patterns, especially the ratios between vertical and horizontal polarity. Some preliminary modeling, holding the area constant and varying the aspect ratio (length to width), indicated that a long narrow shape could reduce the horizontal response but much more needs to be done before drawing conclusions. The only thing I can say for sure is size matters, you have to have enough area to get sufficient noise margin and on LFMF that area will likely be large.

References

[1] KK5JY.net

[2] KG3V ham radio blog, wordpress.com