Loft & Attic antennas for restricted spaces - M. Ehrenfried – G8JNJ

I've recently been looking at designs for an efficient antenna that would fit in a loft. I hoped to find something that would work on with a 100 Watt HF transceiver on all bands from 80m through to 6m.

Searching the web and emailing other Amateurs who use loft based or stealth antennas provided lots of advice which provided a very good starting point.

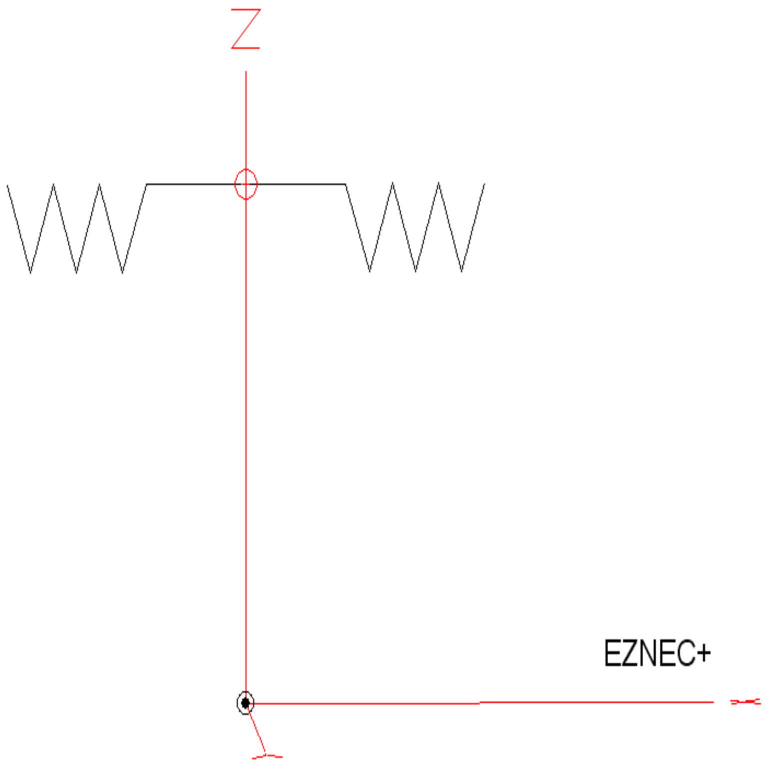
I have an area about 12m long by 4m wide and 1.8m high to play with, so the first suggestions were an open loop running around the outside of the loft, a fan dipole with wires cut to resonate on each of the required bands but trap loaded on the LF bands and a Zigzag end loaded dipole. At this stage I was considering just using resonant antennas, but it soon became apparent that I would only obtain very limited bandwidth operation on 80m, so the use of some form of ATU became inevitable.

Modelling each of these in turn with EZNEC demonstrated an equal number of advantages and disadvantages for each design. They all gave about the same peak gain at about the same elevation angles, the peaks and troughs in the azimuth plots varying slightly with frequency and wire positions.

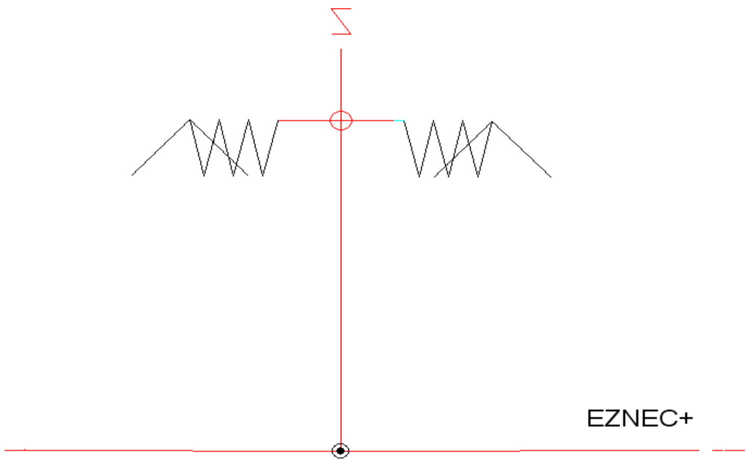
One I had narrowed the options down, I installed some wire and started testing.

The first antenna was a simple Zigzag dipole which I fastened to the roof spars using electric fence insulators. Previous experiences with indoor antennas had demonstrated to me that it's a good idea not to fasten antenna wires directly to any structure. The efficiency improves with 30cm or more spacing away from masonry or woodwork, but even a few inches makes some difference. I think this is due to some sort of close field dielectric coupling, but I've not investigated the effect fully. A further reason for using the fence insulators was to keep high voltage nodes on the antenna away from potentially flammable material, as I didn't want any arcing to create a fire risk.

Here's the first attempt at a design.

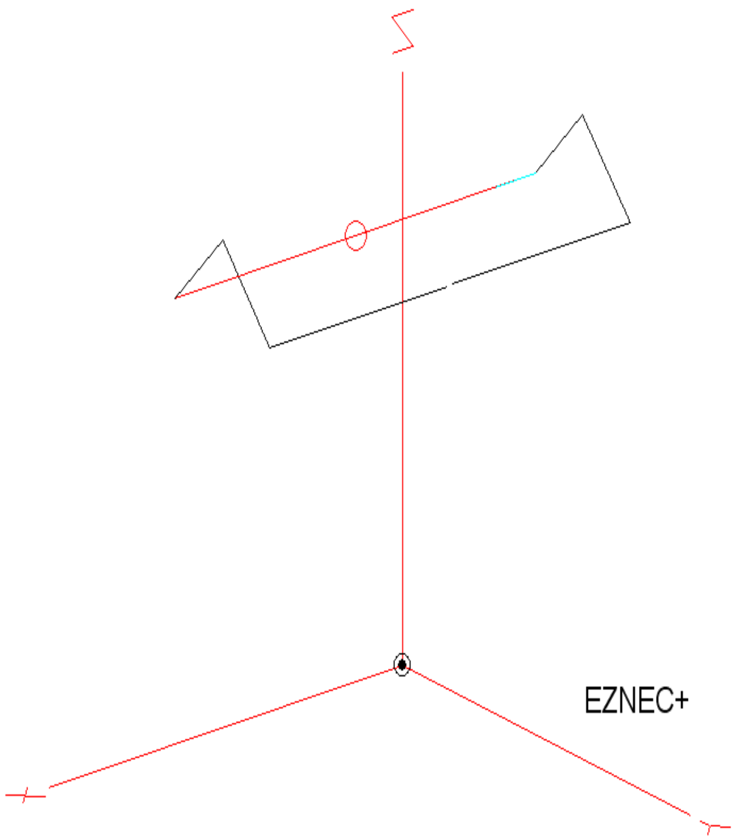


This seemed to work reasonably well on 40m and above. However it struck me that I could add some sloping end loading wires to improve the performance on 80m.



This lowered the resonant frequency which improved the performance on 80m slightly; however it still proved a difficult match on some of the HF bands, where it was approaching ½ wave long.

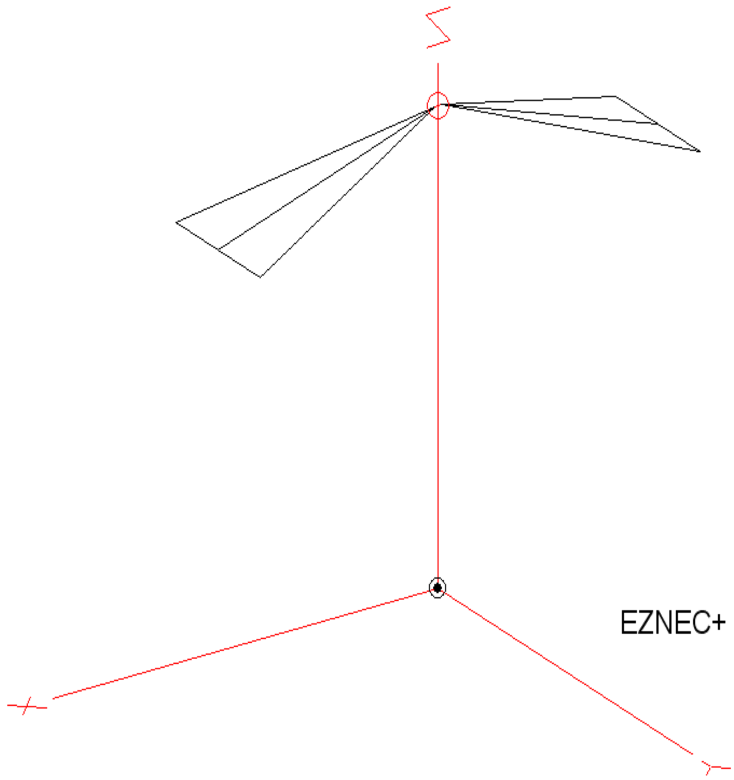
My next attempt was an open loop wrapped around the edge of the loft space.



This was very disappointing. The although it provided a slightly more Omni-directional pattern on the HF bands. The gain was noticeably lower (10dB worse on 80m) in comparison to the previous Zigzag dipole, so it was quickly abandoned. In theory this antenna should have worked much better than it did, I think part of the problem was the close proximity of the wire elements to the structure of the building and the mains wiring.

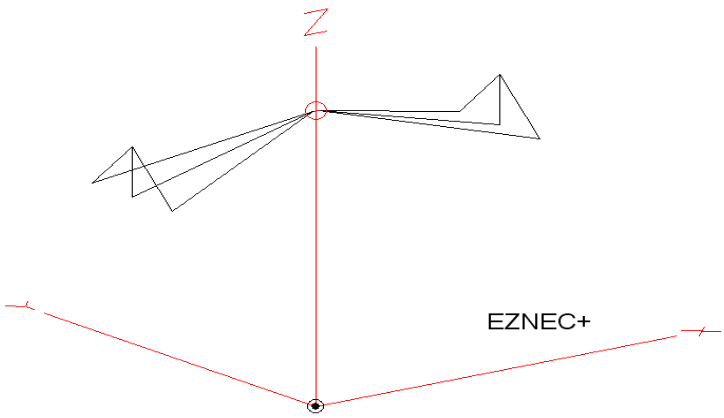
I next tried building a series of parallel connected resonant dipoles in a fan arrangement. However it soon became apparent that I couldn't really get sufficient spacing between the individual wires, and their resulting interaction made it very time consuming to get an acceptable match on all the required bands.

Based on the experience I'd gained so far I decide to try modelling a bowtie antenna.



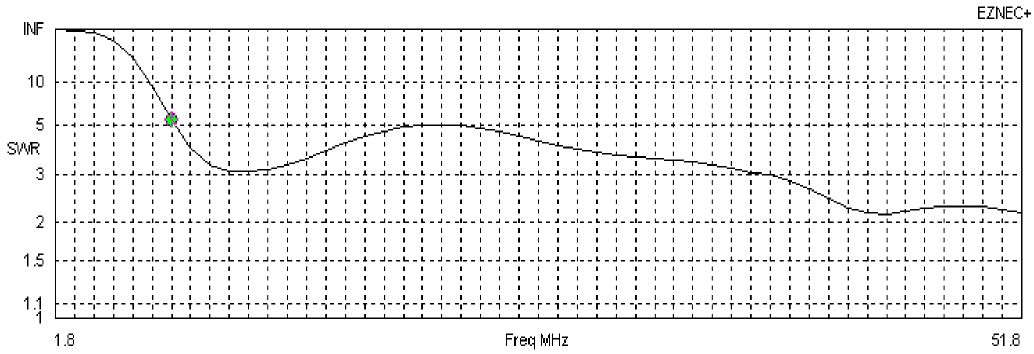
This looked promising, but then I remembered that I'd seen end loaded versions of these and also Biconical antennas being used for EMC testing. I knew they could offer a wide operating bandwidth, but that they had a 200 Ohm feed impedance, however this would be relatively easy to match via a 4:1 balun.

After playing with various EZNEC models, the best arrangement seemed to be like this.



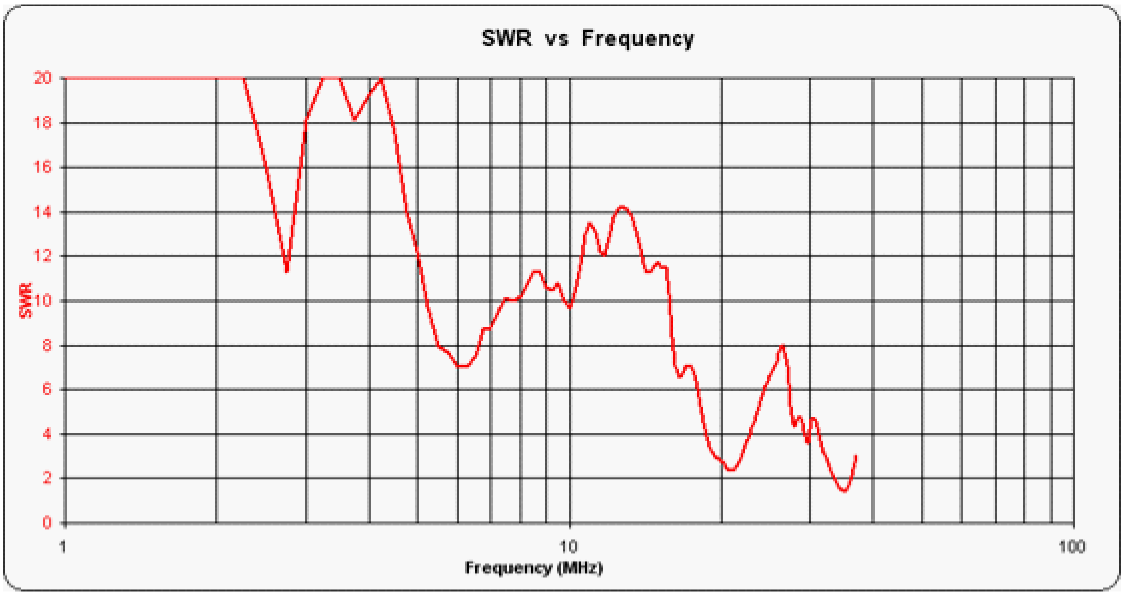
The two up-turned ends fitted nicely into the available space and provide additional end loading.

The modelled SWR when fed with via a 4:1 balun also looked good, and would provide an easy match for the ATU over a substantial frequency range.



As the feed impedance of the antenna never exceed 1Kohm, I decided that it may be more satisfactory to use a 1:1 balun (12 bifilar turns on 4 stacked FT240-61 cores, see next section on page), so that there was less loss when operating into the low resistive component of the antenna input on 80m. I tried adding more wires to see if this made any further improvement, but I felt that it wasn't worth the additional effort. However I did decide to use thicker wire for the elements in order to reduce the resistive losses on the LF bands. I'm not sure exactly how much of a difference this made, but I had a lot of 75 Ohm satellite coax off-cuts which I put to good use for this purpose.

Here's the measured SWR of my first attempt fed via a 4:1 current balun.

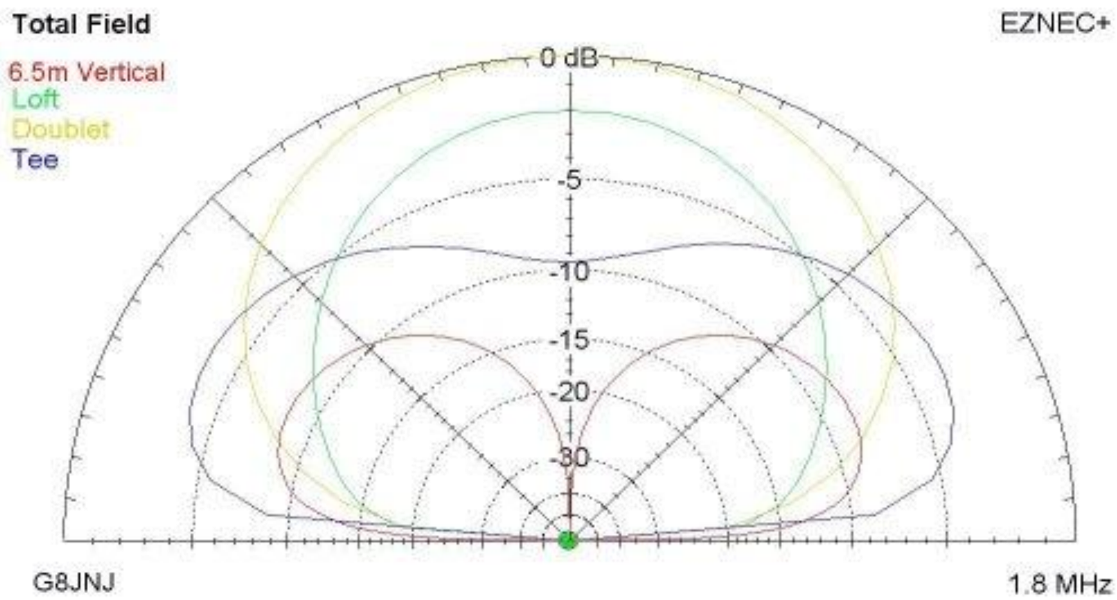


Not quite so good, clearly there is some interaction with the surroundings, but the maximum impedance values are still easy to match to.

One further bonus of this design is that the total antenna current is spread across the three parallel wires forming the antenna element. This seems to reduce coupling from individual wires into nearby house wiring and any associated EMC problems. In fact there is a loft mounted TV antenna actually sitting in the middle of one of the elements, but it seems to have less RF induced into it from this antenna than when the Zigzag dipole was under test.

I decided to perform some gain tests using WSPR. First I modelled all the antennas I'd be using in the tests with EZNEC.

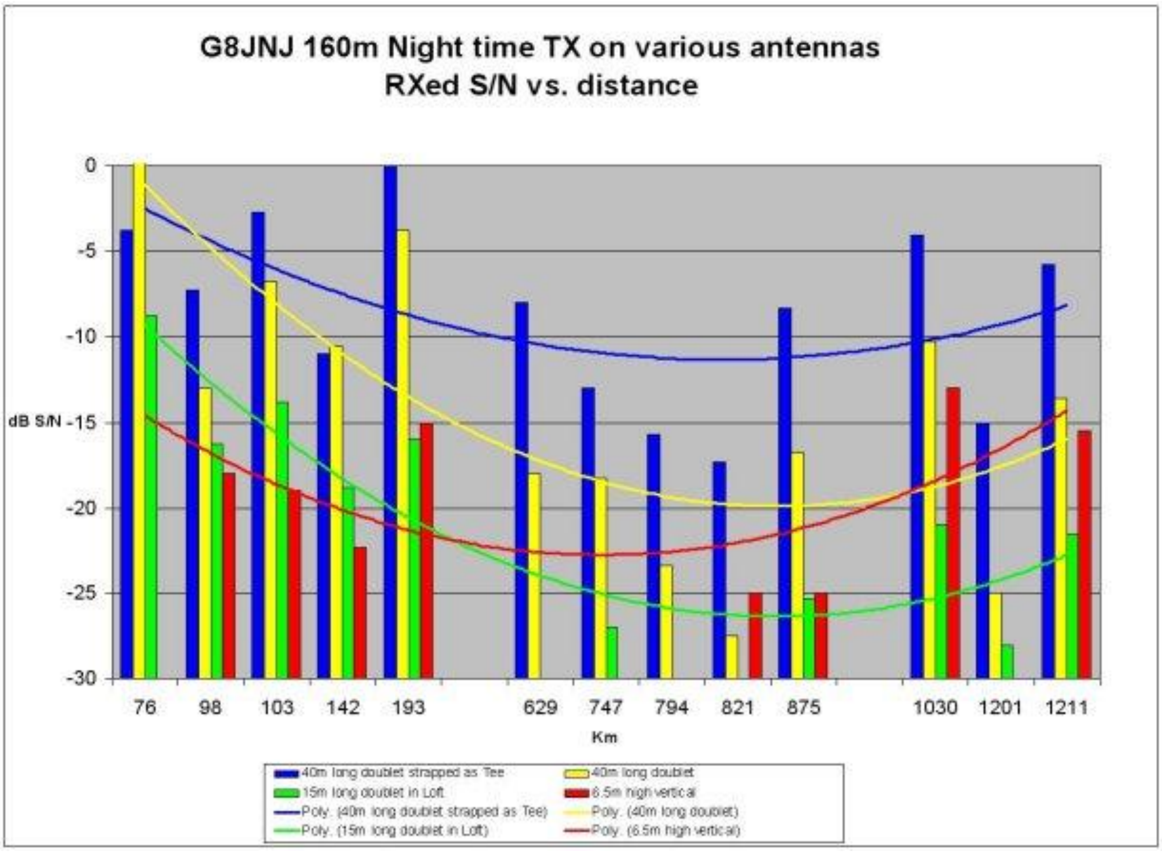
For this example I've chosen 160m.



EZNEC plots I have produced for the four antennas used in the tests.

Red is a 6.5m vertical fed against a large metal roof using a 4:1 unun, 200ft of coax, and an auto-tuner at the transceiver
Green is the 15m long wire bicone antenna mounted in the loft
Yellow is a 40m long doublet fed with 450 ohm ladder line and an auto-atu at the base
Blue is the 40m long ladder line fed doublet strapped as a Tee and fed against 16 ground radials using an auto-atu at the base.

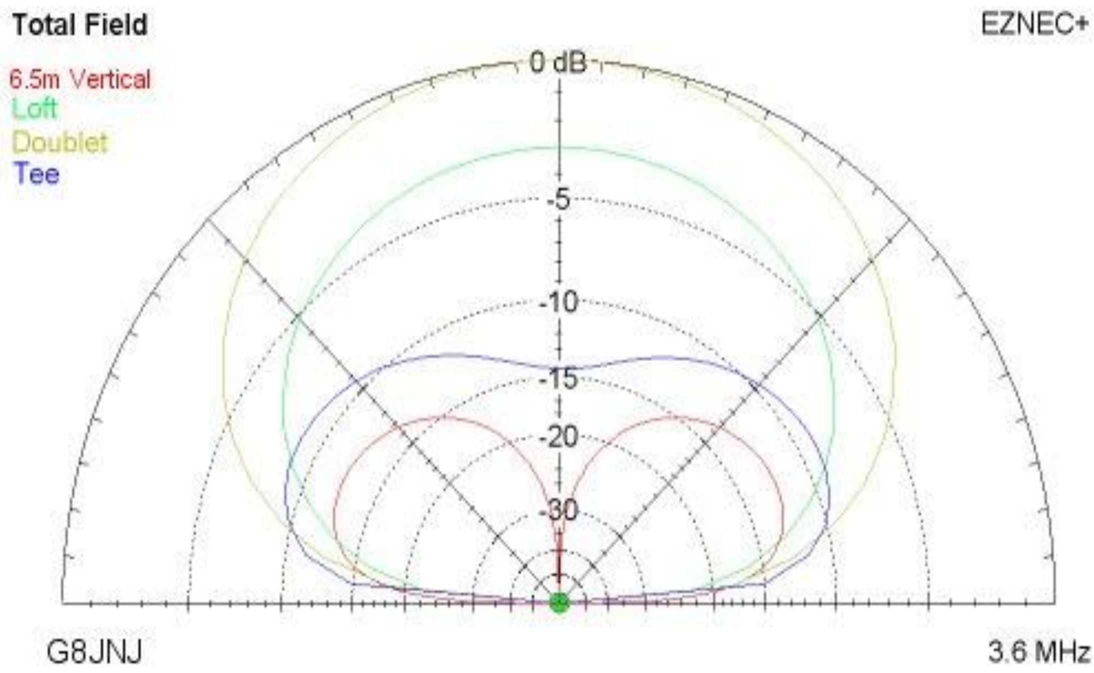
From this model it’s possible to see that the loft antenna should have about 2dB less gain than the doublet on 160m

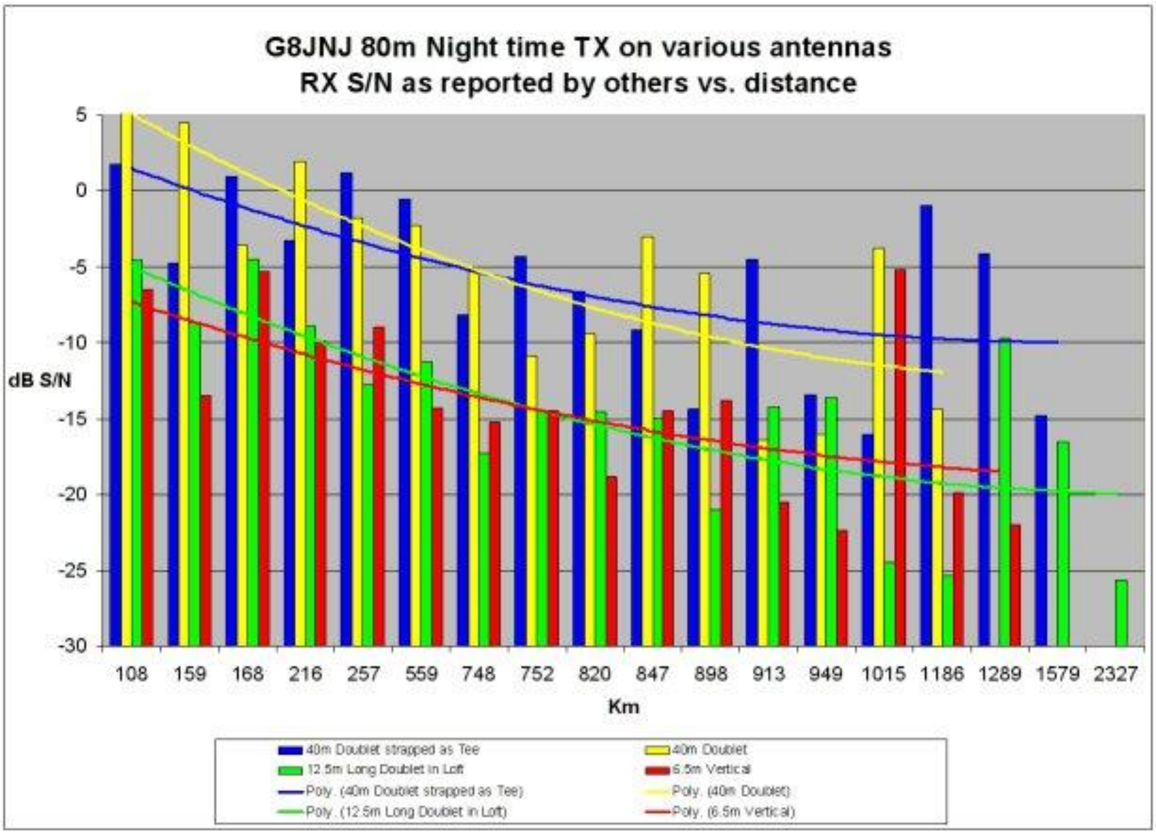


However from the WSPR results it can be seen that it actually has about 8dB less gain than the doublet, or 6dB worse than the modelled value. This loss is also consistent with measurements I made on 80m and the HF bands, and as I'm using the same ATU for both antennas, I've concluded that the loft antenna suffers as a result of coupling a fair proportion of radiated energy into mains wiring, pipe work and other structural components.

Incidentally the 6.5m Vertical is also worse than the modelled values would suggest. EZNEC shows the vertical antenna as being about 5db worse than the Tee. WSPR gives a difference of about 12dB. So the vertical is about 8dB worse than the predicted value. This is probably due to the fact that it's being fed at the base via a 4:1 unun, and brought to an acceptable match match by an auto-tuner connected to the TX at other the other end of a 200ft run of coax !

Some more plots this time 80m





I've improved upon the accuracy of distances between stations this time, as the previous 160m plots used the same distance references for all the sites. This time I've plotted the correct distances between stations.

As before the spots were captured over a period of 1/2 hour in the early evening. By using continuous TX for a short period I was able to obtain over 500 spots. I sorted these into groups by TX antenna in use, and reporting station. I then averaged typically four spots from each station for each antenna. This is graphed in Excel to show the RX S/N against distance between my TX and the spotter.

The measurements were made using 10 watts of transmitter power measured in a 2.4KHz IF bandwidth. As a guide SSB contacts are just about possible with S/N ratios of around 0 to +3dB, PSK at about -12 to -10dB and CW somewhere around -15 to -12dB.

So as an example, if I'm using the 6.5m vertical on 80m using 50 watts of SSB. Then I'd expect to be able to have contacts at distances of up to about 100 to 150 Km. If I used PSK I'd be able to increase the range to about 800Km, CW would extend the range to 2,000 Km or more.

Note that there will be a large variation in S/N measurements between stations because they will be using different equipment and antennas and have differing background noise levels. So wherever possible I have tried to ensure that I have spots for each of the four antenna combinations from each of the stations. This should help to average out differences between plots, because each individual station will still be using the same RX system to for each of the four antenna spots at a given distance. Although overall accuracy is not brilliant, the general trend is still a very good indicator of performance.

From this information I can determine that the loft antenna is about 8dB worse than the doublet, looking at the EZNEC plots it should only be about 3dB down. So it looks like I'm losing about 5dB somewhere in the building structure.

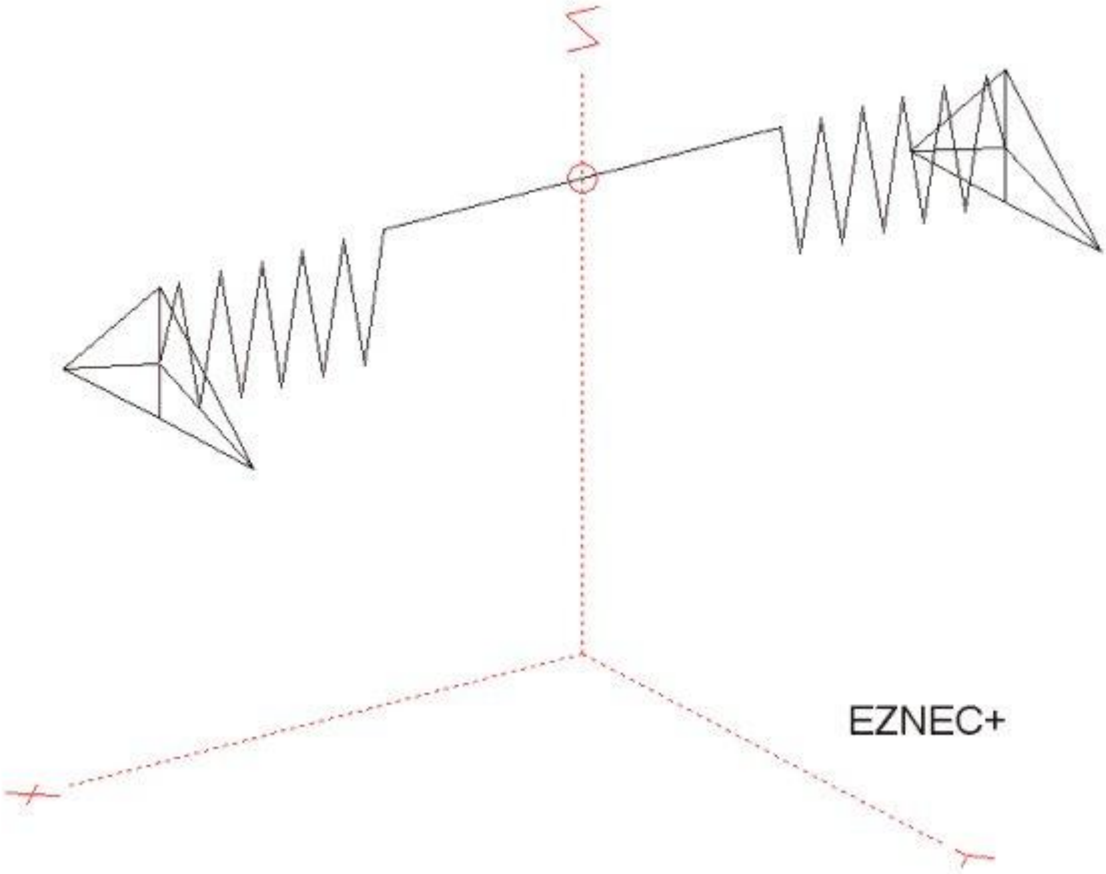
The vertical is about 8dB worse than the Tee. EZNEC says it should be about 4dB down. So it looks like I'm loosing 4dB in the 4:1 Unun, coax and remote tuner.

Notice that in this case the crossover point between the Doublet and Tee is much less noticeable. The EZNEC plots show the doublet gain to be comparable to the Tee at low angles of elevation, mainly because on 80m the doublet height above ground level (12m) is starting to become a greater proportion of a wavelength, improving its overall efficiency.

For stations closer to my TX site (NVIS) I'm a bit surprised that there is only about 5dB difference between the Doublet and Tee, as the EZNEC plots suggest it should be more like 15dB. However this may be due to night time propagation and an unbalance in the horizontal sections of the Tee resulting in more upward gain than predicted.

The high level of loss I was experiencing with the loft antenna worried me, so I thought I'd try another type of Zig Zag antenna. This time I increased the number of Zig Zags, reduced the spacing between them in order to maximise the 'straight' part of the antenna and added extra spokes to the end loading 'hats'.

Careful adjustment of wire length ensured that any 'difficult' feed point impedances remained well outside the amateur bands.

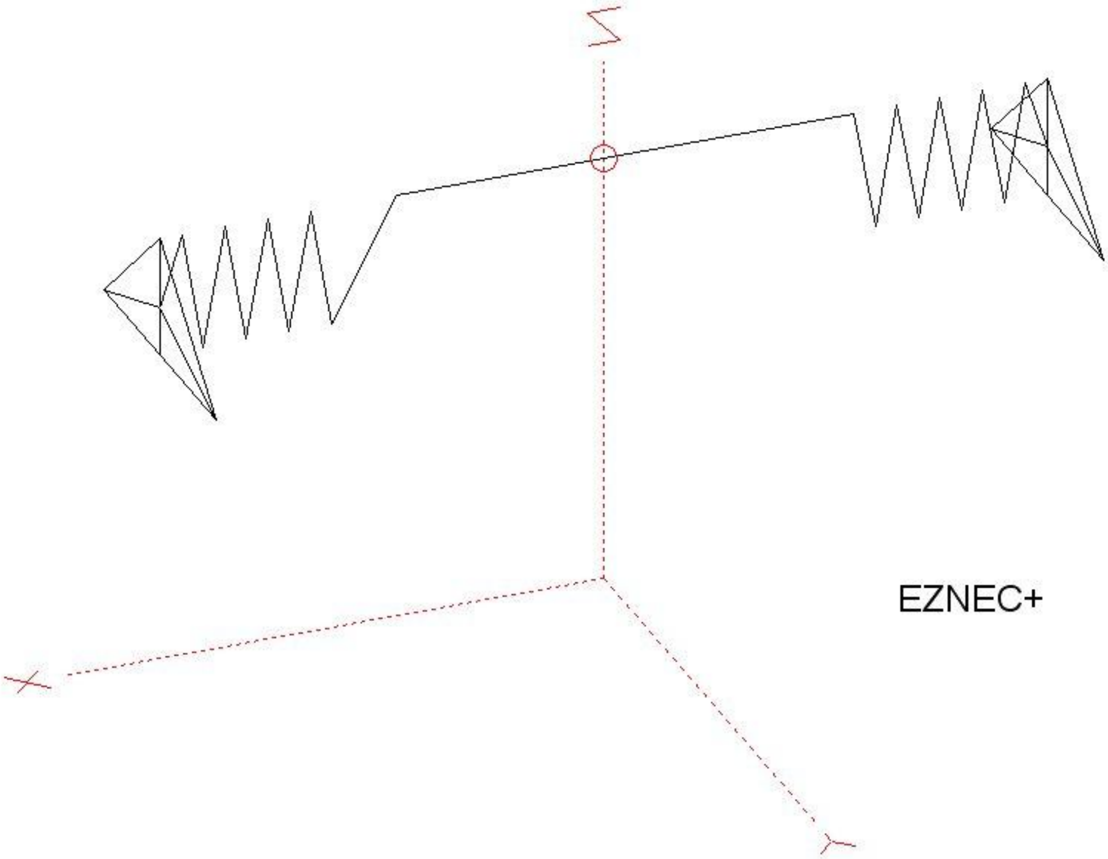


This improved the performance on 160m and 80m by about 2dB. It also seems to have improved performance on the HF bands slightly, perhaps by about 1dB, although this is much more difficult to quantify. The antenna model suggests that this design should have slightly less gain on 160m and 80m than the previous skeleton Bicone. So some form of loading definitely helps improve the matching efficiency on these bands. This is primarily because it raises the resistive component of the feed point impedance, which is only in the region of a few ohms. However this is counteracted by the current distribution of the zigzag wire section which reduces the overall gain slightly.

After some further modelling I thought that it would be worthwhile trying some loading coils in place of the Zigzag section. EZNEC suggested that this would provide about 1dB further improvement. So I wound some coils using 2.5mm wire along an 18” section of 2” plastic pipe. These provided about 200uH at 1.8MHz and with the end loading resonated the loft antenna on 1.9MHz.

On 160m I couldn’t measure any difference between Zigzag and inductor loading, however on 80m the performance was about 10dB worse than the Zigzag. So this was quickly abandoned. Investigation of the loading coil later revealed that it was self-resonant at about 2.5MHz, so it was presenting a capacitive reactance on 80m rather than the required inductance.

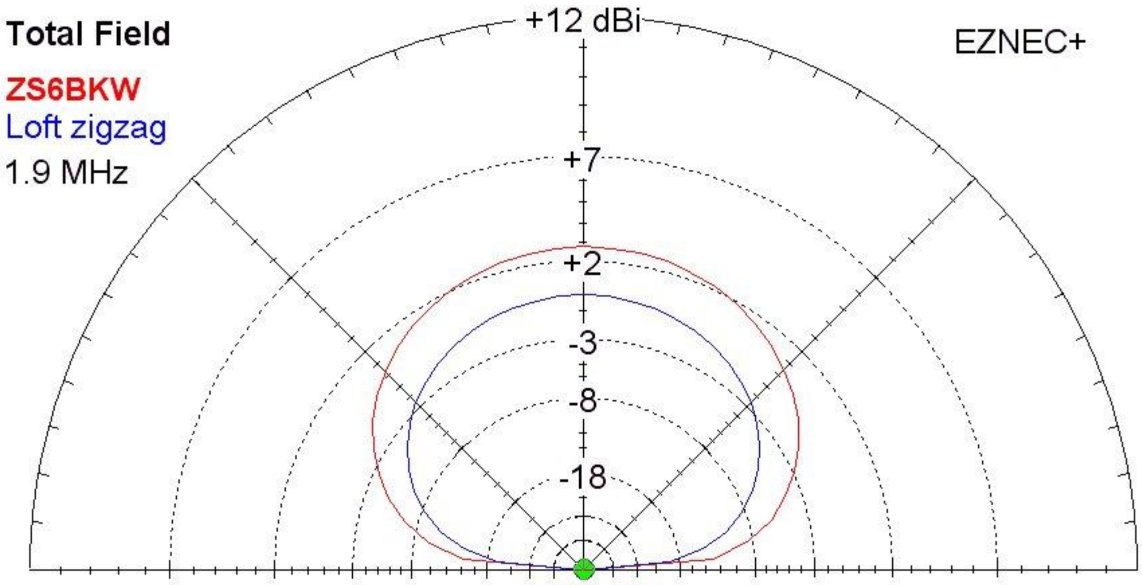
So as the loading coil didn’t seem to offer any advantages on 160m, where it was actually working correctly. I decided to revisit the Zigzag loading. This time when I reinstalled the wire I added some extra spokes to the end loading sections. This lowered the resonant frequency still further, so I was able to remove one of the Zigzag sections on each leg and still achieve resonance on 80m.

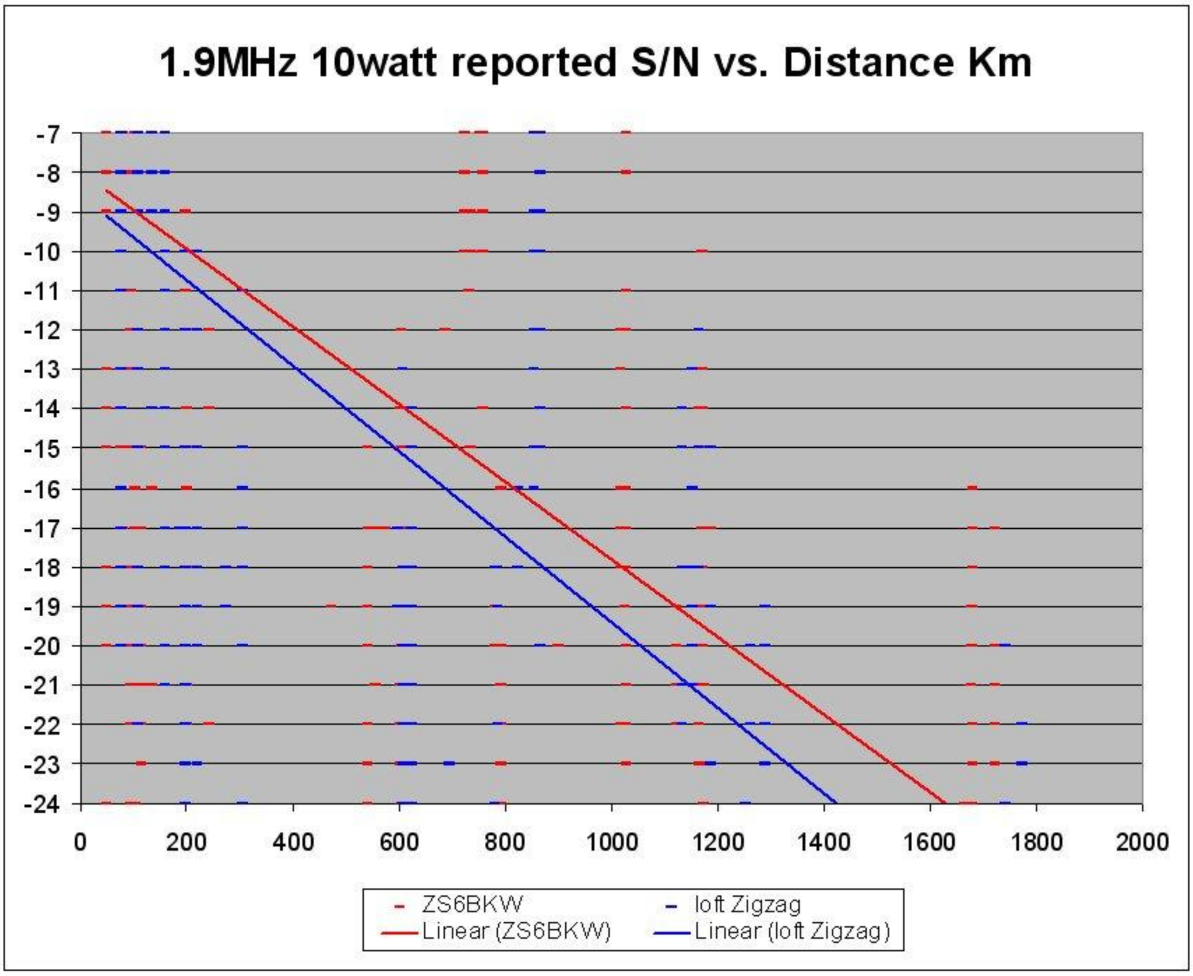


This time I used a different graphing method which gave much more accurate results.

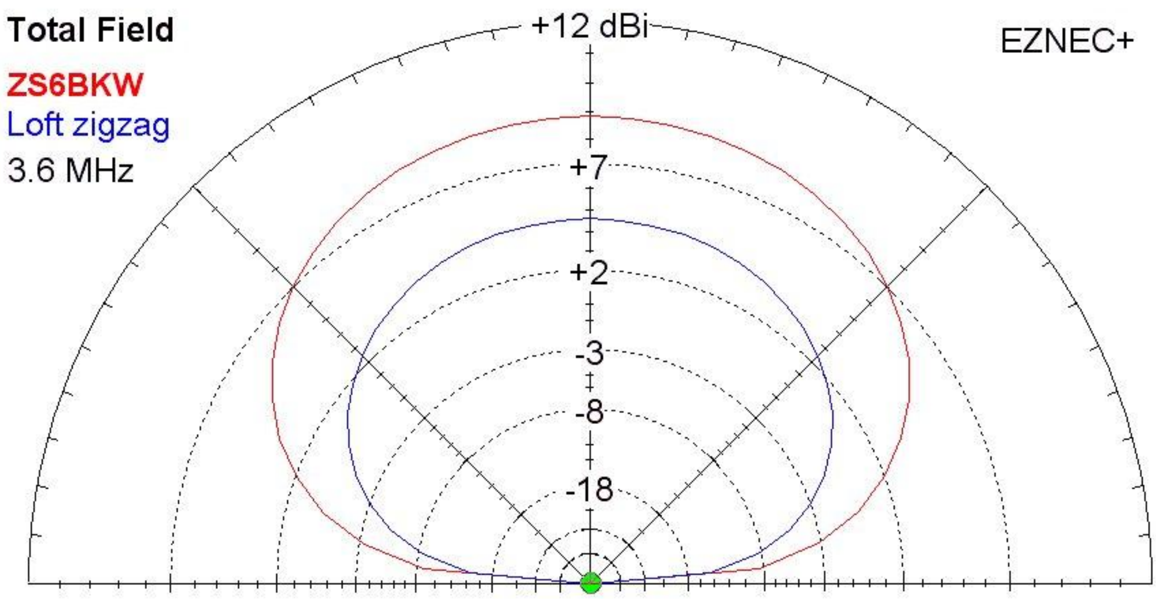
By comparing these results against values for each antenna obtained from an EZNEC model, I was able to determine that the revised loft mounted Zigzag now had approximately the same gain as the predicted value.

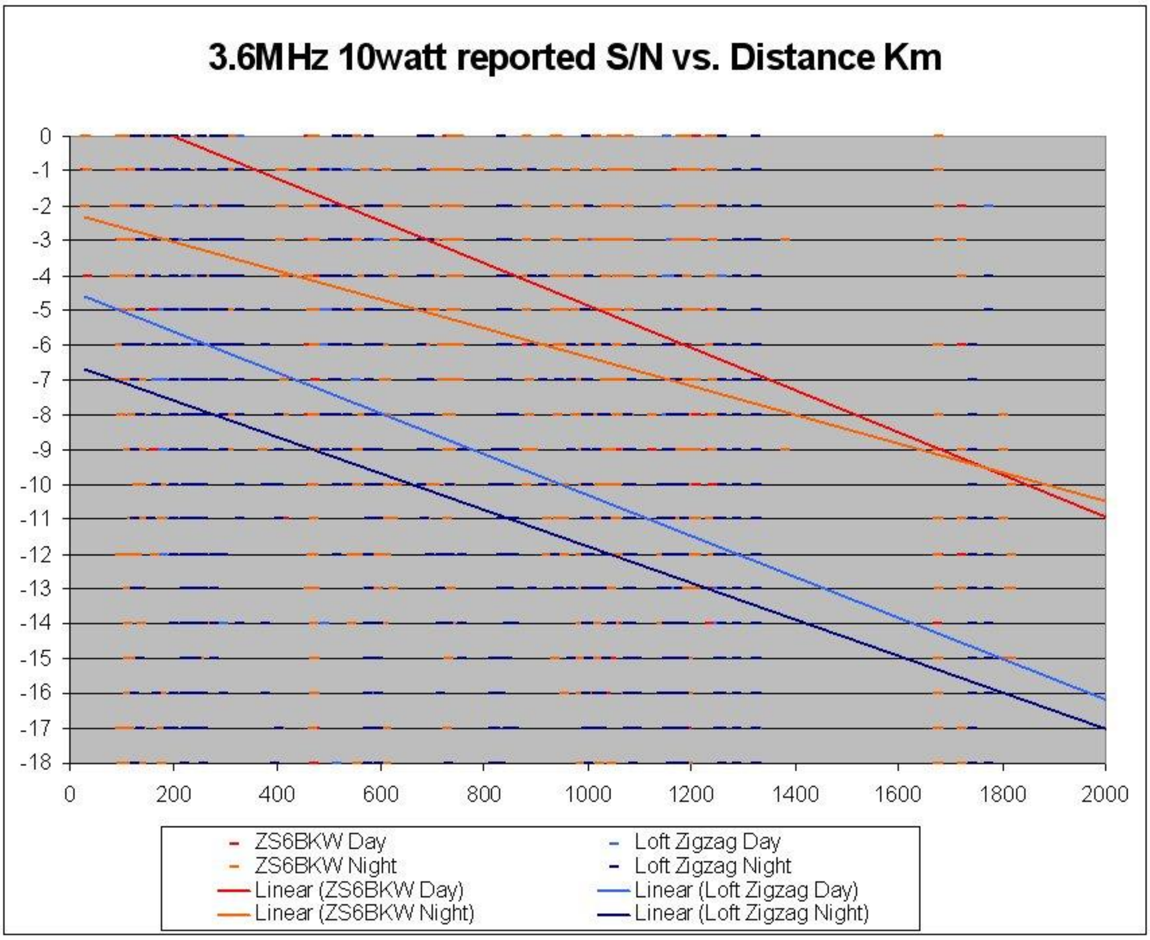
160m



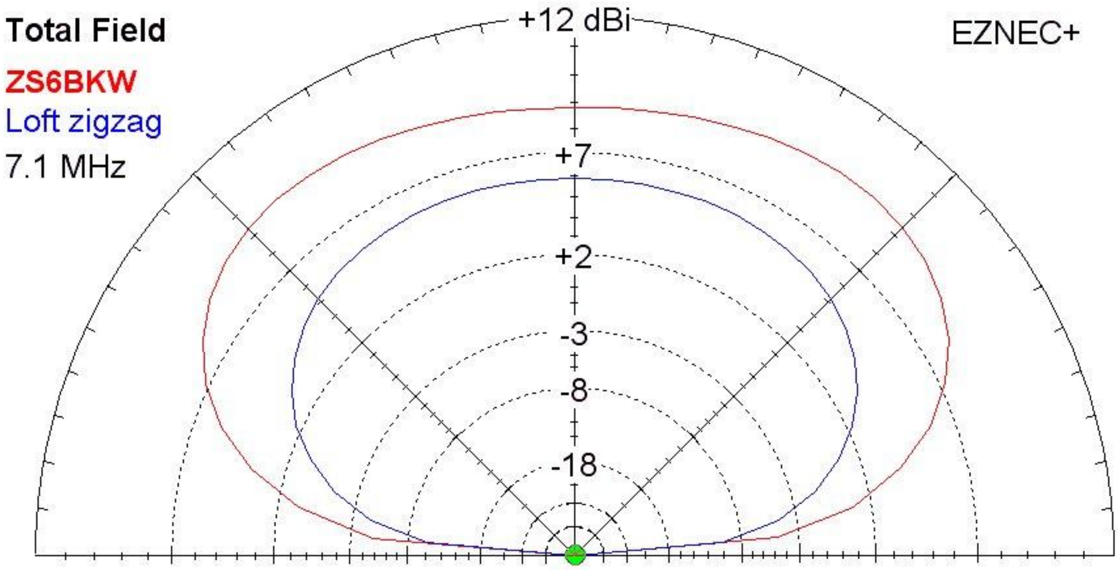

1.9MHz 10watt reported S/N vs. Distance Km
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
-17
-18
-19
-20
-21
-22
-23
-24
0
200
400
600
800
1000
1200
1400
1600
1800
2000
ZS6BKW
loft Zigzag
Linear (ZS6BKW)
Linear (loft Zigzag)

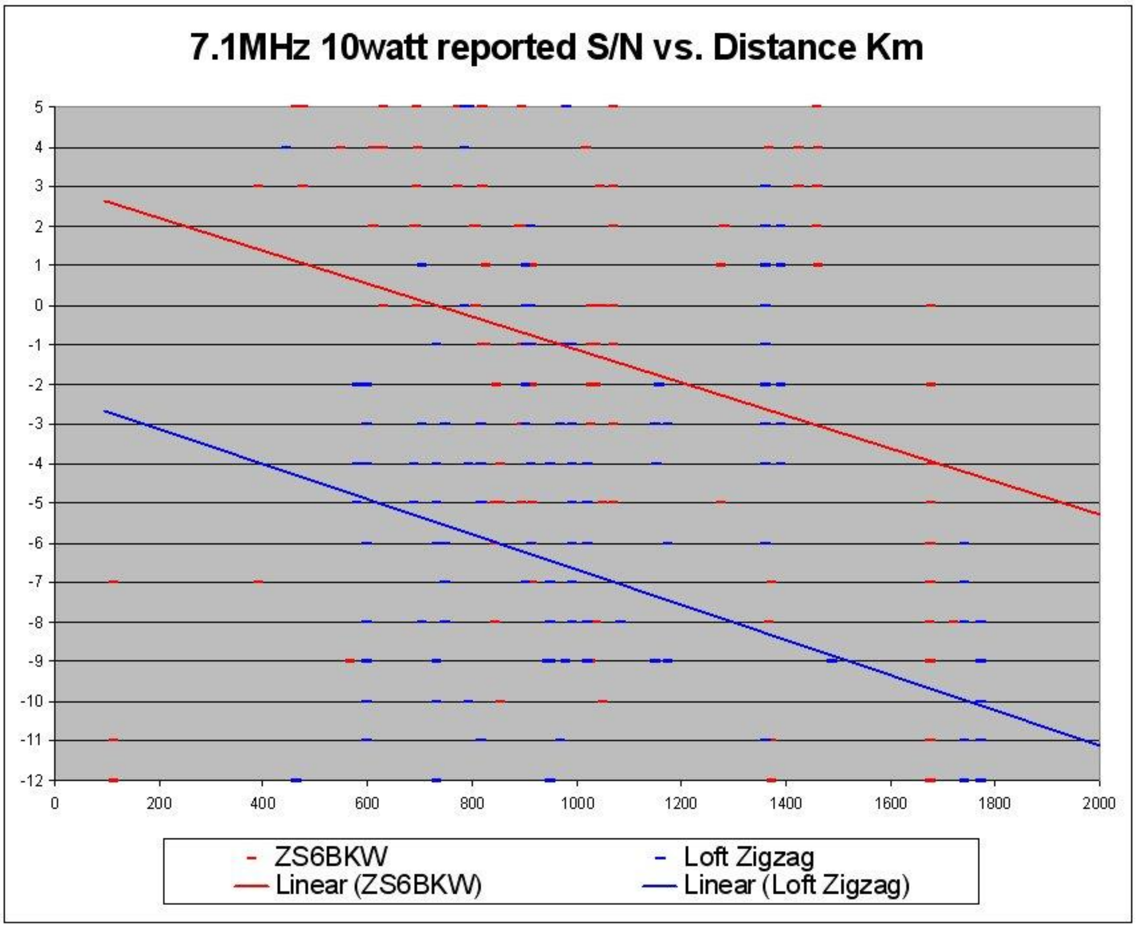
80m


Total Field
ZS6BKW
Loft zigzag
3.6 MHz
+12 dBi
EZNEC+
+7
+2
-3
-8
-18

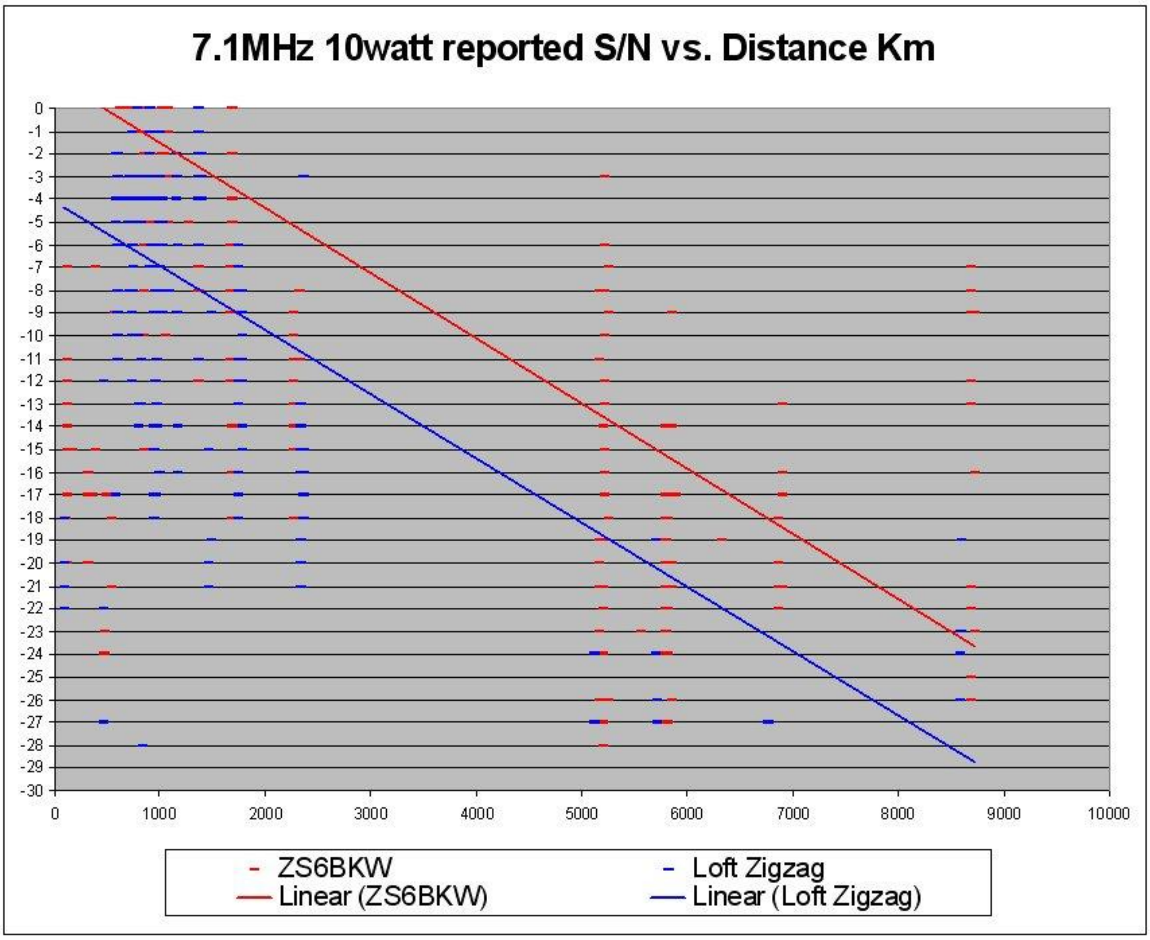

3.6MHz 10watt reported S/N vs. Distance Km
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
-17
-18
0
200
400
600
800
1000
1200
1400
1600
1800
2000
ZS6BKW Day
ZS6BKW Night
Linear (ZS6BKW Day)
Linear (ZS6BKW Night)
Loft Zigzag Day
Loft Zigzag Night
Linear (Loft Zigzag Day)
Linear (Loft Zigzag Night)

40m


Total Field
ZS6BKW
Loft zigzag
7.1 MHz
+12 dBi
EZNEC+
+7
+2
-3
-8
-18



7.1MHz 10watt reported S/N vs. Distance Km
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
0
200
400
600
800
1000
1200
1400
1600
1800
2000
ZS6BKW
Loft Zigzag
Linear (ZS6BKW)
Linear (Loft Zigzag)



This is substantially better than the 5dB loss I originally measured when using the Bicone antenna and is within a dB of the modelled values.

I conclude that this is the best result I am likely to obtain from a loft mounted wire antenna within the space available.

However at some stage I would still like to perform tests with a screwdriver antenna for comparison purposes.

M. Ehrenfried – G8JNJ - V1.5 – 08/12/2009