A 2 ELEMENT 30 METER PARASITIC VERTICAL ARRAY PROJECT

Having killed off the 5B-DXCC purely using LOTW, it was time for the addition of a new band. 30 meters was selected based on lack of sunspots and a head start of 40 countries on the books already.

From CA, the Country Rich region requiring a bit of a reach is EU and not too many of them were in the log. So the mind turned to something directional, fixed, cheap, easy and interesting that could fit in my space. The answer is - a 2 element vertical array!

A review of the literature reveals a 75 meter parasitic 2 element vertical array by W9QQ (Hulick) has been done so it provides a nice starting point and suggests a potential 6 dB benefit over a dipole for DX.

Some Antenna Book investigation reveals that the spacing of the elements used in the 75 m array is pretty sensible, and not terribly critical, so I settled on the scaled equivalent of 5.5 meters (or 0.185 λ) separation.

The conventional choice for the parasitic element is to make it the reflector, although the differences from a director are modest. In my case I decided to make it either a reflector or director in Phase II of the project, with the ability to switch between them. Still the base design was for a reflector so in the director mode there are some compromises.

The next choice is for a radial system. There is emerging consensus (Severns, N6LF) that a modest number of elevated radials can equal the performance of a rather larger set of conventional radials on the ground. So the design plan was for four elevated radials at 1 meter height for each of the two vertical elements, with the antenna elements also elevated to 1 meter. The two sets of four radials were oriented at 45 degrees from each other to minimize any possible interaction as suggested in ON4UN's book.

The remaining issues are then the selection of the antenna elements and their heights and dealing with the impedance matching issue to the feedline. By way of background, for 30 meters (10.1 MHz) a nominal free space quarter wavelength is 7.43 meters (24.4 feet).

Two sets of four telescoping aluminum six foot tubes (3/4" through 3/8") were purchased from the standard vendor. In addition a ¼" aluminum rod was obtained to provide a potential extension since 4X6 = 24' and the required overlap (say 4") makes four tubes a little short. For reasons lost to modeling history, the radials are each 6.8 meters of insulated zip wire (unzipped) but conventional wisdom is that with several radials, resonance is not very important so the lengths are not critical (and there were some local space limits).

The driven element in this array is not expected to be resonant at the operating frequency as a stand-alone element but its length is more driven by matching needs – more on this later. The reflector length (or really its resonant frequency) is another story. The usual story is that reflectors should be ~ 5% longer than a in-band resonant element (and

directors ~5% shorter). It is really the resonant frequencies that are critical rather than the lengths, of course.

Through the magic of EZNEC is it possible to vary the reflector length to estimate the length for optimal gain. However, it is probably not wise to just take EZNEC's length (it is just a model you know) BUT the reflector resonance frequency should be a better measure and we can construct the real element to have the target resonance. The EZNEC model is pictured here (note that one radial, # 8, does not touch the other element but goes under it) .
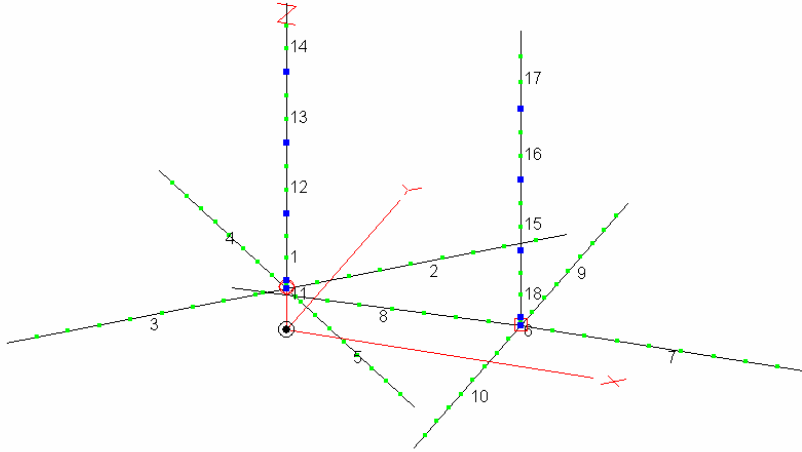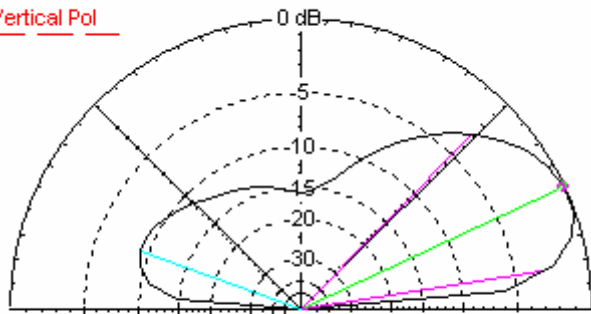

It is found that the best forward gain at 10.1 MHz (in reflector mode, shown below) occurs when the reflector (as an isolated element) is resonant (i.e., X=0) at a (model) length of 7.7m giving a stand-alone resonance at 10.05 MHz. This frequency will be the target for response of the isolated real antenna reflector element.


So now we go to a real antenna, but with just the single element, to determine the length needed. Going with the measure/adjust/measure approach with the trusty MFJ-259, we

find that with 24'10" (7.57m) of tubing (plus about 5" of wire lead to attach the SO-239) a resonance at ~10.05 MHz is found with resistance of ~ 43 ohms when used with the four radials.

Next it is time to adjust the driven element. This element, <u>when in the parasitic array,</u> typically has a resistance of ~ 20 ohms before matching and the matching generally involves adjusting the length of this element to get an impedance that makes some form of matching practical. Now we put both elements in position with the parasitic element set as a reflector as discussed above. With the driver length at 23.0', the antenna shows a resonance at 10.0 MHz and R=20 ohms. The model provides generally similar results and allows one to say that below 10.0 MHz, the antenna reactance is capacitive, and above, inductive.

The matching approach was the "hairpin." This consists of adding an inductive shunt across the input with the value of the inductance chosen to match the raw antenna impedance to the feedline impedance. A hairpin match is possible only if the raw antenna impedance has a capacitive reactive component. Beware that what the Antenna Book (ARRL) description of the matching does not tell you is that a reasonable match is possible only for a specific and rather narrow range of this negative reactance and furthermore it depends on the value of the resistive component - the relationship is not simple. Without going into the ugly details, the driver was shortened to make the reactance capacitive at the target frequency of 10.1 MHz. Making the driver tubes 22' provides an impedance for the complete antenna, prior to matching, of about 25-j18 ohms. This is an impedance that, according to calculation, may allow a pretty good hairpin match with the use of a shunt inductance with ~50 ohm reactance.

Now theoretical calculations do not necessarily fully agree with the real world. As a result the driver length and the inductance (a coil of #10 wire) needed to be varied to refine the match empirically by using the theory as a guide for small changes. The final result was a ~ 0.75 µh coil (48 ohms, measured externally) and driver tubes at 22'3" height in addition to the 5" wire from the SO-239 to the tubes. This gave a final Z (the MFJ does not reveal the sign of the reactance) of 63-(+?)j13 at 10.1 and 55-(+?)j7 at 10.15 MHz from the unmatched raw antenna Z of 21-j14. With more fiddling, this might have been improved but with the SWR well under 2 it seems good place to quit. Below is shown the EZNEC SWR estimation for this configuration - it is in the general neighborhood of that measured at the SO-239 feed point.

INF

10

5

SWR

3

2

1.5

1.1
1

9.7   Freq MHz   10.5
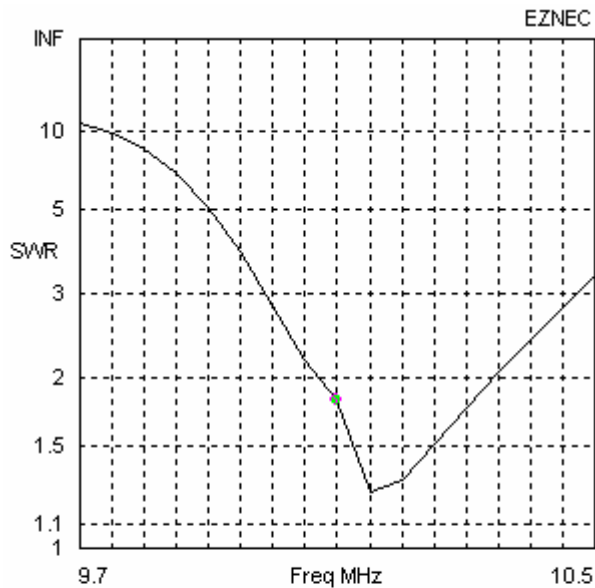
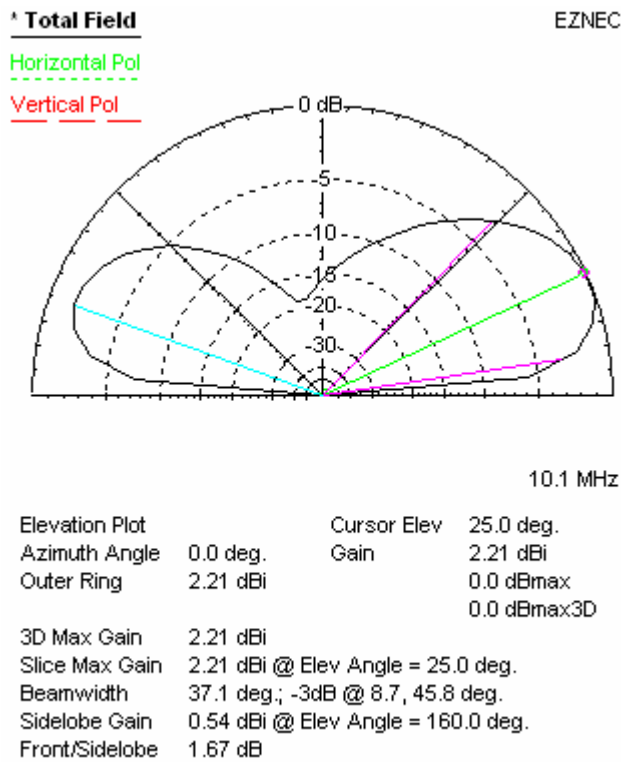| Freq	10.1 MHz	Source #	1
SWR	**1.82**	Z0	50 ohms
Z	78.65 at -21.05 deg.		
	= 73.4 - j 28.25 ohms		
Refl Coeff	0.2898 at -37.48 deg.		
	= 0.23 - j 0.1763		
Ret Loss	10.8 dB		

The benefits of this 2 element vertical, aimed NE, were subjectively evaluated by comparison with a Cushcraft R7000 multi-band trap vertical. On average, stations in the general direction of EU, including AF and the Caribbean, showed about one S-unit stronger for the K3 meter on the array compared to the trap vertical. Stations roughly perpendicular to the array in western SA showed a lower strength compared to the R7000. This may have been biased by the location of the house which is just south of the array (while the R7000 is elevated). Stations off the back of the array were comparable in strength with those using the R7000.

A number of new EU countries have been worked and probably some of them would not have been possible (at least at that particular time) without the array. In other cases, the benefit may have been in getting through the pile up sooner. On the whole, it seems a modest success. Some EU stations have been raised by calling CQ DX. However I do not really "feel strong," as they say.

Reversing the Direction

A further plan, largely for education, to be able to switch the reflector to a director, (and thus get some gain in the VK/ZL direction) was accomplished by first shortening the parasitic element to a length to make it perform as a director and then adding a switchable loading coil at the base of the element.   EZNEC indicates that the element must be shortened from 7.7 m to about 7.2 m to become a director. The gain available with a director, according to EZEC, is not as high as for the reflector mode. This probably

results from the non-optimal director spacing. The reflector feature can then be restored by adding in a series 30 ohm inductor as a load, according to EZNEC. This coil can be shorted out to reverse the direction of the array. The selection of the 7.2 m director length may have been somewhat longer than optimal for that mode but a consideration is the resulting antenna impedance when switched into director mode. Since the hairpin impedance matching was done for the reflector mode so there is no assurance that a decent match will occur in director mode without additional (and undesired) adjustments.

Total Field   EZNEC

Horizontal Pol

Vertical Pol

10.1 MHz

Elevation Plot		Cursor Elev	25.0 deg.
Azimuth Angle	0.0 deg.	Gain	2.21 dBi
Outer Ring	2.21 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	2.21 dBi		
Slice Max Gain	2.21 dBi @ Elev Angle = 25.0 deg.		
Beamwidth	37.1 deg.; -3dB @ 8.7, 45.8 deg.		
Sidelobe Gain	0.54 dBi @ Elev Angle = 160.0 deg.		
Front/Sidelobe	1.67 dB		

With the parasitic loading coil in for the reflector mode the impedance is about 69-(+?)j18 (which is comfortingly close to the result for the original reflector length) and with the coil shorted out for the director mode it is about 101-(+?)13 which gives an SWR of about 2 at 10.1 MHz. The parasitic element, taken alone, in the EZNEC model is designed to be resonant at about 10.05 MHz in the reflector mode and it is about 10.5 with the coil shorted for the director mode. The model shows the impedance plot below for the director mode which is similar to the measured result. As with the reflector result, it appears that with some additional cut and try, the SWR could have been improved but the benefits probably would not be very big. (Since the reversible aspect was carried out after the array was in place, the physically changed parasitic element was not directly measured to determine its stand-alone resonances.)
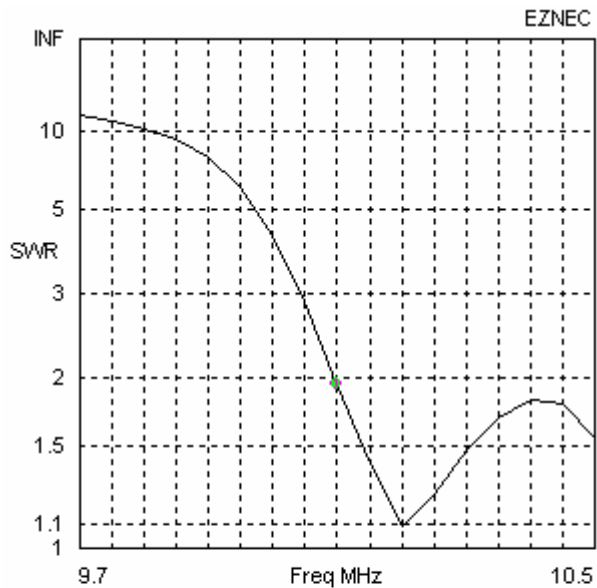
Freq	10.1 MHz
SWR	**1.96**
Z	97.44 at -4.96 deg.
	= 97.08 - j 8.425 ohms
Refl Coeff	0.3247 at -6.87 deg.
	= 0.3223 - j 0.03882
Ret Loss	9.8 dB

Source # 1
Z0   50 ohms

Additional observations for on-the-air performance compared to the R7000 for the director mode indicated that there may be as much as one S-unit benefit in the design direction for the director mode over the R7000. Again the F/B seems to be modest and maybe around the one S unit level, which is nominally 6 dB.

In about a month over 80 countries have been worked on 30 m. Whether it is the antenna or "just showing up" that is important is hard to sort out. As always, YMMV.

Construction Notes

The elements were mounted on 6' 2X4s held in the ground by post holes packed with rocks to hold the 2X4s upright. This works very nicely for a temporary arrangement.

The tube elements are supported by simple and cheap hardware using ¾" ID plastic conduit as the insulator.

The finished array. The elements are not guyed. Once during winds approaching 50 mph the elements were flexed over to about 60 degrees off vertical. No damage was done but before the next winds, the tubes were taken down to wait out the weather.

The feed system with shunt inductor and 4 radial supports. Not shown is a portion of the coil in the coax feedline that is coiled to suppress common mode currents on the outside of the coax braid for this unbalanced feed. Note that the radials are held in place by eye screws but the wire is not actually looped around the eyes like a transformer core, they are just doubled back through. This may not matter but it didn't seem wise to risk it.
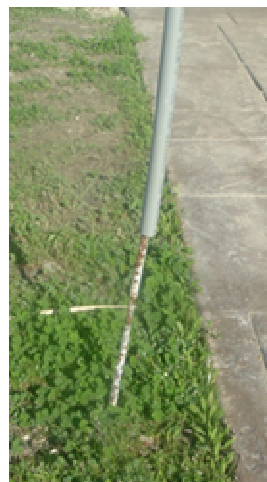
The manually switchable 3 turn loading coil to reverse the direction for the parasitic element is shown here in shorted (director) mode.

The 4 radials for each element are elevated to about 1 meter using 4' lengths of ½" plastic conduit that are placed over rebar stakes. Being a bit short on small insulators, nylon fishing line holds the radials in tension.

References

Hulick, T.P.,W9QQ, "A Two-Element Vertical Parasitic Array for 75 Meters," QST December 1995.
Antenna Book, ARRL, 21st edition.
Low-Band DXing, ARRL, ON4UN, 4th edition.
Severns, R., N6LF, "An Experimental Look at Ground Systems for HF Verticals," QST March 2010.