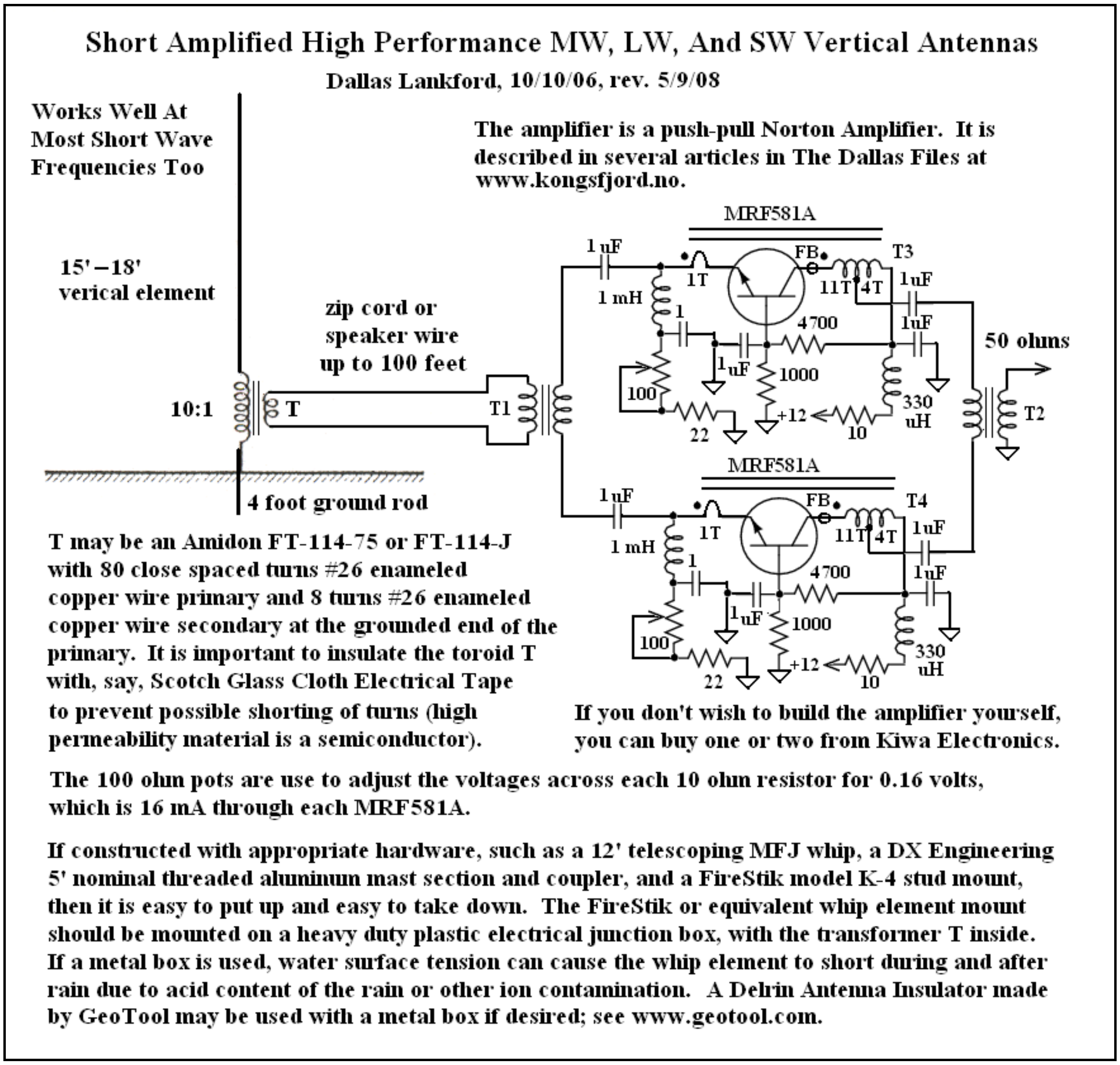
Active MW Vertical Arrays

Dallas Lankford, 7/26/2011

I put the two medium wave vertical array articles (below) together in this single file so that my experiences with MW vertical receiving antenna arrays would be available in a single location. If you are not interested in recording the entire MW band with a receiver like Perseus, then null steering two passive (amplified, but not active) vertical MW antennas (below) is a reasonable way to improve your MW DXing.



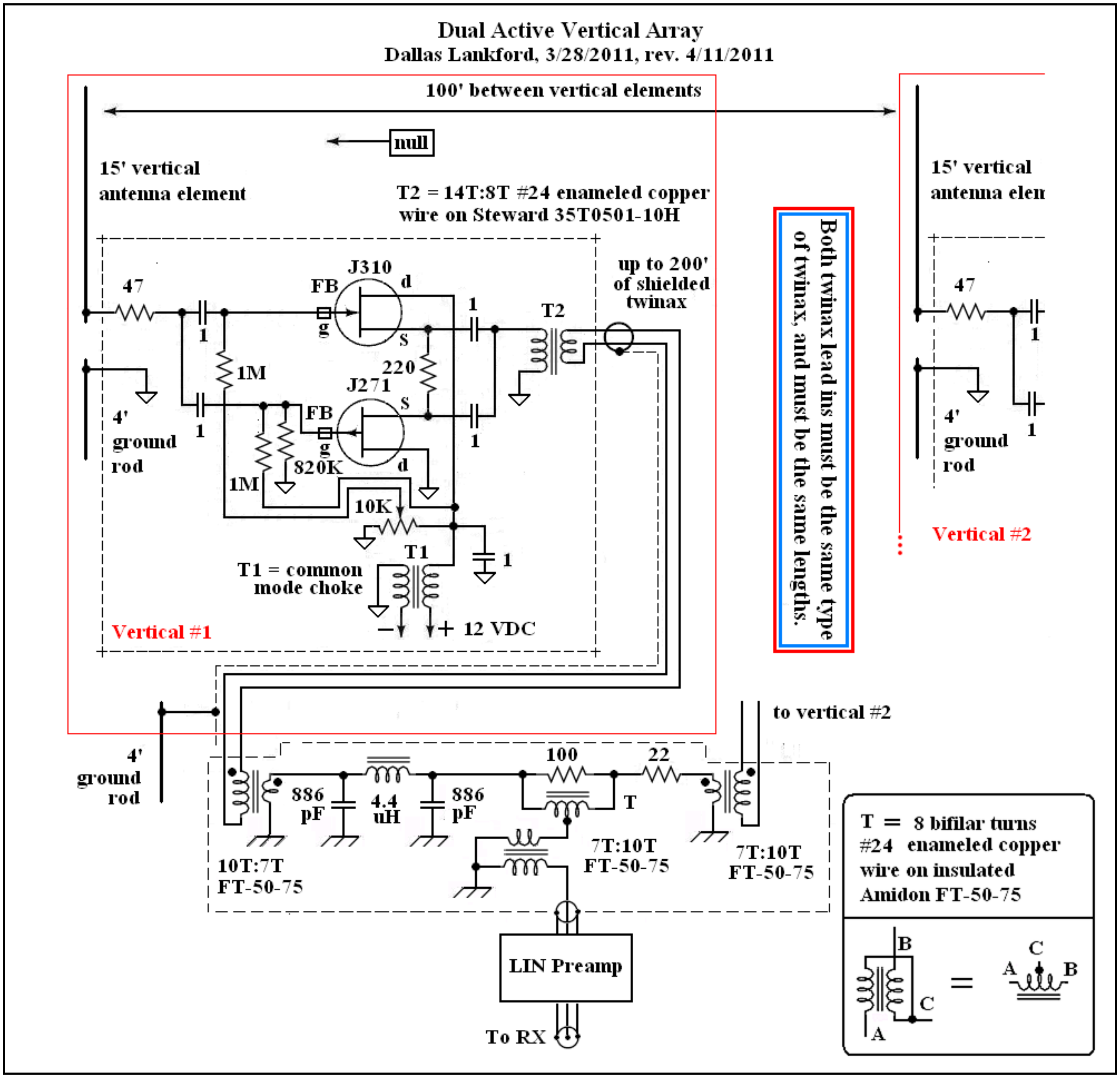
Beyond that, vertical arrays are not good choices for MW DX antenna arrays.

I have spent a lot of time trying to make a good quad vertical MW antenna array for recording the entire MW band with Perseus and similar recording receivers. The articles below suggest that it can not be done.

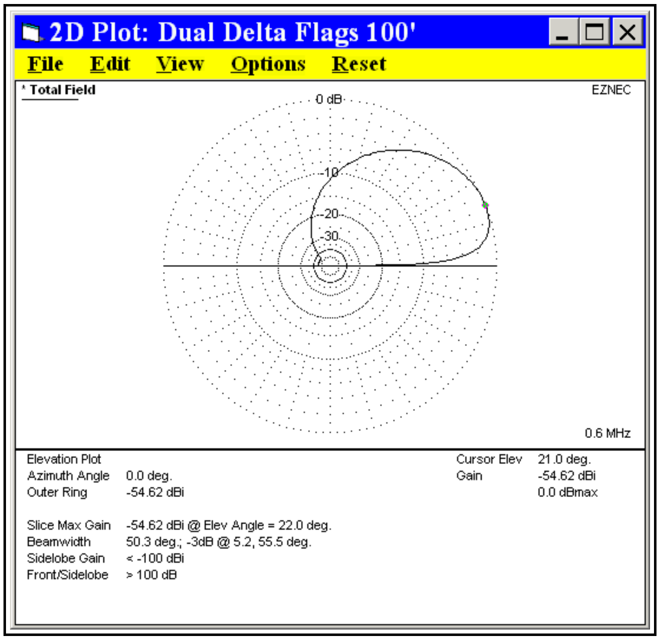
Dual Active Vertical Arrays

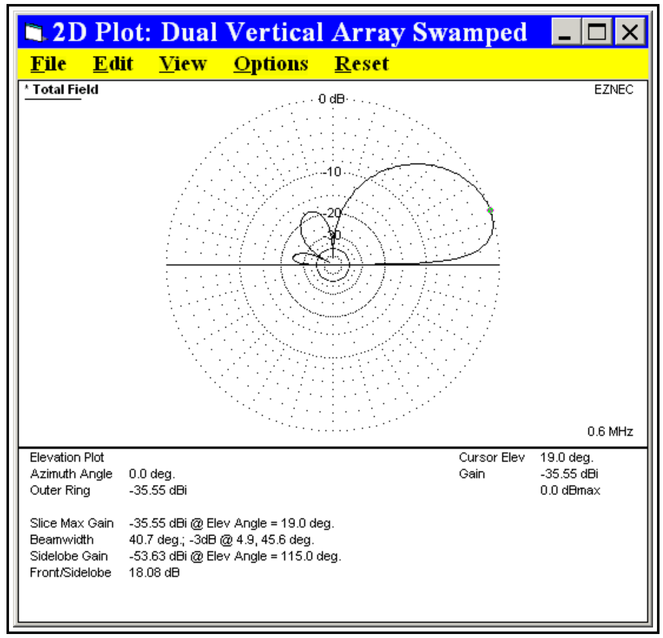
Dallas Lankford, 3/28/2011, rev. 4/15/2011 and 5/18/2011

I had two PPL's which I had been using to test various dual delta flag and dual delta loop arrays using two 15' fiberglass masts, so it was natural to take down the delta elements and replace them with 15' vertical elements. I was also curious if the nulls of dual active vertical arrays would be any better than the poor nulls of the dual and quad passive vertical arrays which I tested about two years ago. The schematic below shows the test setup, except that at first no 47 ohm resistors were used (more about this later below), and the J271 gate to ground resistor was originally 1M (changed to 820K during these tests for about 10 dB greater IIP2).



The tests initially had about the same outcome as two years before with passive verticals, namely poor or nonexistent nulls for most MW frequencies. In the meanwhile I had read about vertical arrays with negative real parts of some of the source impedances, how they were caused by mutual antenna impedance, and how they led to phasing and other problems. The solutions I read about involved resonating the vertical arrays, which did not appeal to me because I wanted broadband arrays. I knew that good nulls could be generated for vertical arrays using variable phasers. Unfortunately, EZNEC phases for the desired patterns did not produce the desired patterns when implemented. The variable phaser also adjusted amplitude, so a rotary attenuator with 1 dB steps was used together with a 1 foot per step switched 15' length of RG-316 and coax jumpers of various lengths. With this somewhat variable phaser reasonably good nulls were generated with 37 additional feet of coax delay and a dB or two or three of attenuation. Moreover, this fixed delay and fixed attenuation gave a reasonably good null (in a particular direction) for all frequencies from one end of the MW band to the other. The null was much narrower than a single flag null, but could be steered with the variable length RG-316 and rotary attenuator to give about as deep a null as the flag could (without null steering). Of course, a dual flag array leaves the dual vertical array in the dust.





The EZNEC patterns above show the difference.

The EZNEC plot of the dual delta flag shows a dBi of –54.52. This is for a traditional dual delta flag array. For my High Z PPL Dual Delta Flag Array, the dBi gain is about –28.62 dBi, about 7 dBi better than the dual vertical array with 47 ohm swamping resistors. The RDF of the dual delta flag array is about 10 while the RDF of the dual vertical is about 9.5.

The 30 dB null aperture of the dual delta flag is about 0 to 55 degrees, while the dual vertical is about 21 to 36 degrees. Clearly the dual vertical array is inferior to the dual flag array wrt splatter reduction in the MW band. A dual ALA-100 array is equally inferior to the dual flag array wrt splatter reduction in the MW band. I have no idea how quad active vertical arrays or quad ALA-100 arrays would perform wrt splatter reduction in the MW band. By using non-standard phasing, EZNEC predicts that a quad ALA-100 array would perform almost as well as a QDFA. But a quad active vertical array, because of negative resistance issues, would have to be adjusted by trial and error for best splatter reduction in the MW band, an unenviable task.

But then I came across a brief discussion of his 4 square array by W8JI where he said two things which caught my attention. (1) "2.) Elements must be heavily swamped with loss. Mutual coupling effects must not change element impedance." (2) "This structure is base loaded with a series L/R combination of approximately 30uH and contains a total loss resistance of 75 ohms. This resistance includes resistive losses related to inductor Q, as well as ground system loss resistance. I used small molded choke inductors, although other components will work. My system requires only 56 ohms of lumped resistance to bring base resistance to 75 ohms."

Incredibly, even after an "intergalactic" search, I found no vertical array schematics or EZ files which include swamping resistors.

I immediately opened EZNEC with my dual vertical array EZ file, added two 47 ohm resistors, one to each vertical antenna element near the sources at the bases of the verticals, and looked at the Src Dat after doing a FF Plot with this modified dual vertical model. Previously one of the sources had a negative real part (negative resistance), but now both real parts were positive. This suggested to me that by adding resistors of suitable values at suitable places in the array the negative resistances due to mutual antenna element impedances could be eliminated and that the EZNEC predicted phases for the swamped dual vertical array would be the actual phases needed in practice. The schematic at the beginning of this article shows where I placed the 47 ohm swamping resistors. In lieu of the rotary step attenuator, a 100 ohm pot was inserted in the non-delayed signal path and found to produce just as deep nulls. In preparation for implementing a quad active vertical array, a 22 ohm attenuating resistor shown in the schematic at the beginning of this article was used for the “average” of the pot values which produced the deepest nulls at various frequencies.

Yes! With the 47 ohm swamping resistors, the swamped dual vertical array phases predicted by EZNEC were the phases needed to generate good nulls (modulo some null steering due to the narrowness of the vertical array null). The extra 37' of coax delay required for the vertical array sans swamping resistors was no longer needed.

The narrowness of the dual vertical null was obvious on nighttime sky wave signals because on the average the dual vertical nulls were not nearly as good as a dual delta flag array nulls unless the dual vertical array nulls were steered by using a 100 ohm pot and a variable length (switched) RG-316 delay.

It remains to be seen if a quad active vertical array with 47 ohm swamping resistors will now produce a good pattern where in the past a quad passive vertical array without swamping resistors did not. According to EZNEC, a quad vertical array should have a pattern almost as good as a QDFA. If so, it might make a simpler (if you don't count building the PPL's) portable quad array for MW DXpeditions.

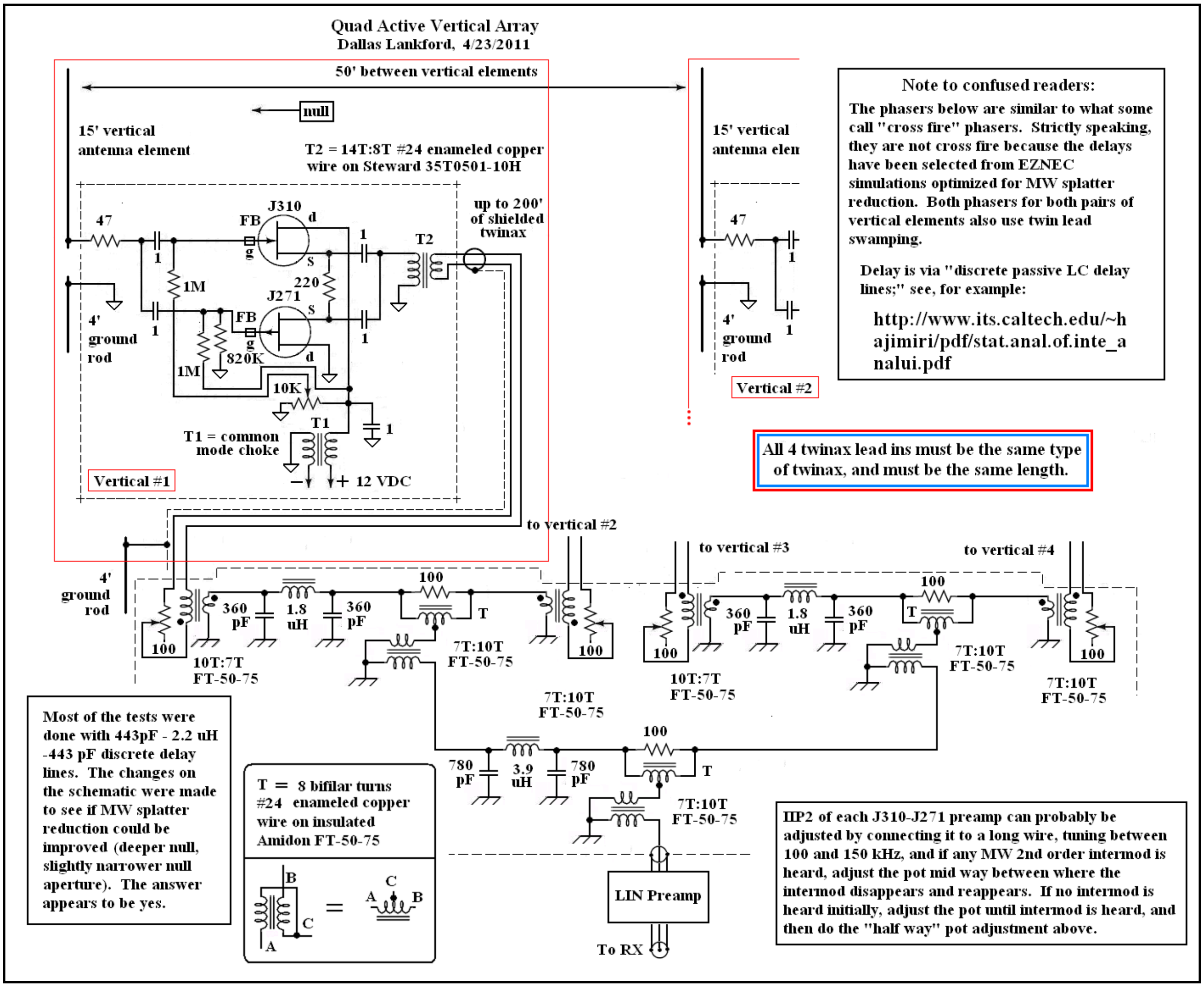
The 47 ohm swamping resistors reduce the signal to thermal noise ratio of a dual 15' vertical array (without swamping resistors) by about 24 dB, which is not good because a “barefoot” dual 15' vertical array already has a lower S/tN ratio than a dual delta flag array. So for best dual vertical array performance we are again faced with the unenviable task of adjusting the “barefoot” dual vertical array by trial and error. A “barefoot” quad vertical array is unfeasible. But a “barely swamped” vertical array may be feasible because EZNEC indicates that swamping resistors as low as 2.2 ohms (for a 100' spaced dual vertical array) eliminate the negative real parts of the sources which apparently cause the phase problems. I used 10 ohm resistors during part of my tests and they seemed to work as well as 47 ohm resistors for the 100' spaced vertical array. For substantially closer spacings higher value swamping resistors may be required.

These dual vertical array tests were in one way irrelevant because a dual flag array is a much better MW splatter reducing antenna than a dual vertical array. But these dual vertical array tests were a crucial first step towards developing quad linear vertical arrays because they have shown that W8JI's discovery of vertical element swamping as a key ingredient for obtaining good 4 square patterns also applies to dual linear arrays. And further testing has shown that vertical element swamping is also a necessary part of quad linear vertical arrays in order for them to realize a pattern similar to the one which EZNEC predicts for them.

Quad Active Vertical Arrays

Dallas Lankford, 4/12/2011, rev. 4/25/2011, and 5/18/2011

Below is a schematic with diagram of a 50' spaced quad (linear) swamped vertical array which became active about 9 pm CDT 4/13/2011. Total linear space required was 150', 10' more length than the 140' diagonal length of a 100' side dimension 4 square array, but 140' less than the diagonal width of the 4 square. EZNEC calculated an RDF of 12.5 and a gain of –47 dBi at 0.6 MHz which is 11 dBi greater than my original 100' spaced QDFA.

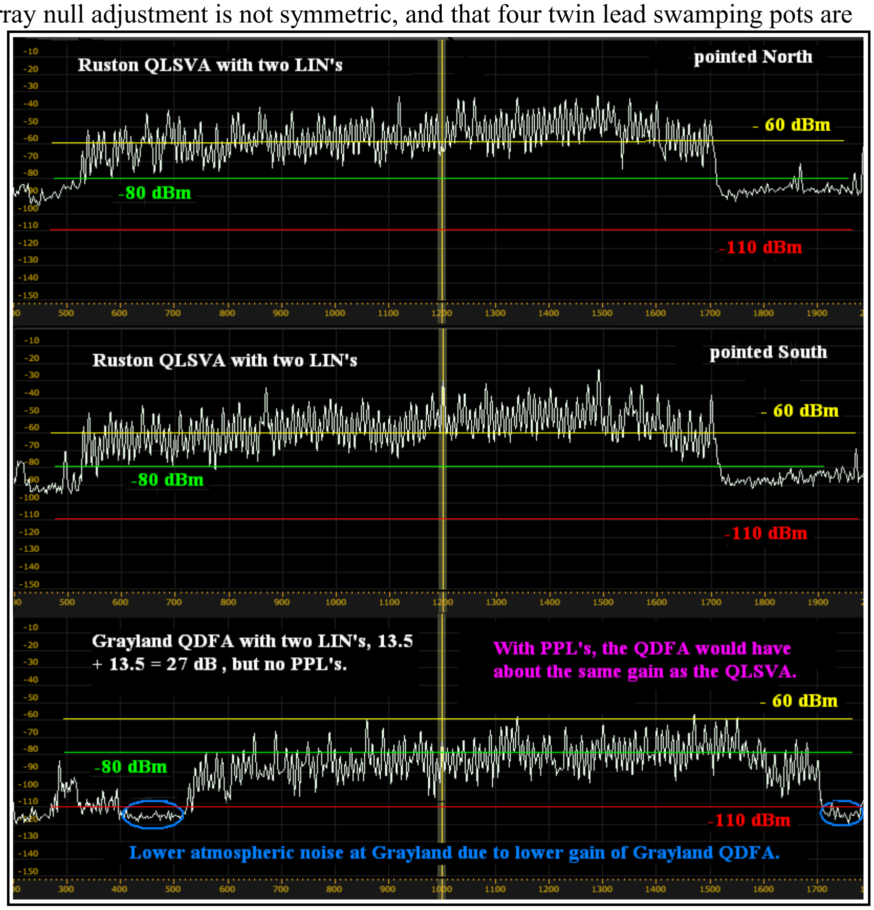


There were some differences between the schematic above and the tested quad vertical array. The PPL's were not shielded. The twin lead was not shielded twinax, but instead 120' of 20 gauge speaker wire. No attenuators were used (as were used for the dual array tested previously) because only occasionally did they significantly enhanced the null for daytime ground wave signals, and slightly, if at all, did they enhance the null for nighttime sky wave nulls. Twin lead swamping pots were not used at first because the need for twin lead swamping was not know until later in the testing; more about this later below. Phasing has been changed from earlier versions for better splatter reduction.

The phaser-combiner used for these tests was the 3 module phaser-combiner used for the April 2009 Grayland DXpedition with the QDFA with LC delays changed for 50' spacing. One LIN preamp was usually used between the phaser and receiver as shown in the diagram above. Sometimes two LIN's were used. The receivers used for these tests were an R-390A and Perseus . R-390A audio was enhanced with my elliptic low pass audio filter and a 7 watt mono high fidelity Velleman audio amplifier. The photo below shows the indoor components for the tests.

Initial tests were quite promising. With an attenuator in the 1st phaser-combiner similar to the 22 ohm attenuator used in the previous dual vertical array tests, daytime nulls of ground wave signals could be made almost as good as a QDFA. Nighttime nulls of sky wave signals seemed to be good on the first two nights of testing, but difficult to rate precisely because of high static levels. On the 3rd night, with static gone, nulls of the quad vertical array were rated poor to nil. I was stunned. I replaced the 3rd phaser-combiner with a variable passive phaser and the nulls were very good, but dBi gain was down about 20 dB. I replaced the 22 ohm attenuator with a variable attenuator, but there was no improvement in the null. By then it was well after midnight, so testing was terminated.

The next day I decided to try a different approach and made two 100 ohm variable “plug-in” twin lead swamping pots which could be easily and quickly inserted in the twin leads of the banana jack and plug connector set up of the vertical pair combiners. I also removed all metal from a nearby storage shed, and installed 4 more ground rods connected in parallel with the original ground rods. Whether these changes had any effect on the null problem is unknown. The 100 ohm twin lead swamping pots were set using 1120 kHz St. Louis. With one swamping pot set to 0 ohms and the other to near 100 ohms a very good null was generated for 1120 St. Louis, after which nulls were good from one end of the MW band to the other. The values of the swamping pots did not seem to be frequency dependent, but more testing is need to be sure of this. The next morning around sunrise sky wave nulls were observed again and again they were excellent, with no additional adjustments of the pots required. All 3 Chicago clears on 720, 780, and 890 kHz were gone with Latin Americans in their places, and 1120 St. Louis was also gone. This is excellent nulling during sunrise transition when nulls for any phased array are often not good. It was later found that swamping pot values depended on whether the null was adjusted for one or the other of the two possible null directions 180 degrees apart. The null directions 180 degrees apart could be changed by reversing the order of the twin leads and changing the swamping pots from the first pair to the last pair (from left to right in the diagram above). This means that the array null adjustment is not symmetric, and that four twin lead swamping pots are required. Initially all 4 swamping lead in pots are set to 0 ohms. A mid band nighttime sky wave several hundred miles away in (or near) the plane containing the verticals and passing through the center of the earth is selected for null adjustment. Each of the 4 twin lead swamping pots is adjusted (with the other 3 set to 0 ohms) to determine which one of the 4 gives the greatest null improvement. Then without changing its setting, each of the other 3 twin lead swamping pots is adjusted in (with the other 2 set to 0 ohms, and the 1st adjustment not changed), and the 1 of the 3 which gives null improvement (probably very slight improvement) is left adjusted, and the other 2 are left set to 0. This completes the lead in swamping pots adjustments. Well, not quite. Later I discovered that the null can be made a little deeper... and the null aperture probably a little wider... if the two null deepening pots above are adjusted alternately, back and forth, for a deeper null. For my quad vertical array the two pots which need to be adjusted are either the two even # lead in pots (for N null) or the two odd # lead in pots (for S null).



Above right are Perseus displays of the QLSVA in Ruston last night about 11 pm CDT, the 1st with maximum gain pointed due North, the 2nd pointed due South. The 3rd Perseus display at right is for the full size 100' spaced Grayland QDFA about midnight PST two years ago. It is seen that the QLSVA has about 30 dBi more gain than the full size 100' spaced standard QDFA (without supercharged PPL's). This is about 20 dBi more than EZNEC calculated. Measurements have shown that the 47 ohm swamping resistors do not reduce dBi gain as predicted by EZNEC, which appears to account for the higher QLSVA gain than predicted by EZNEC.

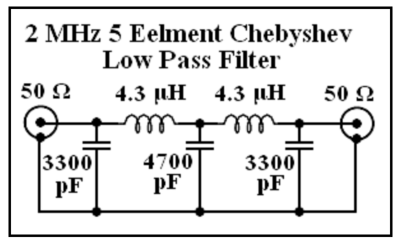
It is not expensive to build a prototype using “dead bug” construction methods, cheap 18 gauge speaker wire, pairs of 6 volt lantern batteries, taped together, and so on. If you like it, you can put together a permanent QLSVA later.

After the above tests, the phaser discrete LC delay lines were changed to the values shown on the schematic for somewhat better splatter reduction. The two EZNEC simulations for the two sets of values are shown below. To save space they are reduced in size; magnify them for satisfactory viewing.

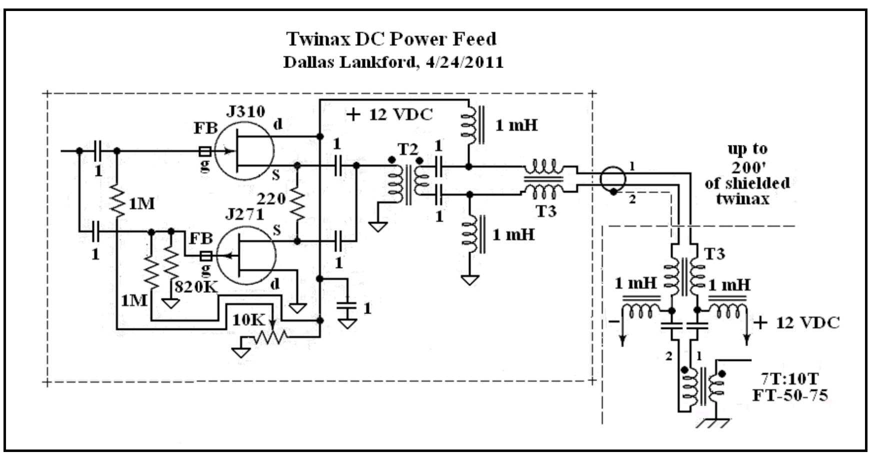
According to EZNEC, much better splatter reducing vertical arrays are possible as shown by the EZNEC simulation of a 16 element array below.

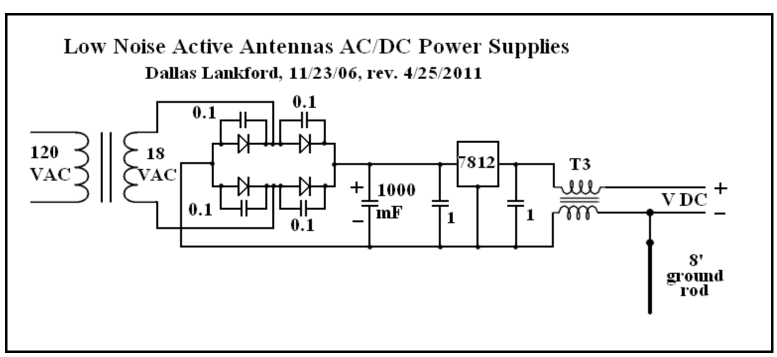
An 8 element version, which would fit in the same space as a standard QDFA, has almost as deep and wide null aperture, almost as narrow beam width, and 13.2 RDF. But such arrays may be difficult, if not impossible, to implement because of the necessity of identifying which lead ins to swamp, and how to adjust the swamping resistors correctly. EZNEC gives no hints about how to do that. The only reasons I was able to identify the QLSVA lead in swamping resistors and adjust them correctly was because only one lead in swamping resistor was required for the due North null and only one (though different) for the due South null, and I adjusted the due North null correctly using multiple “clear channel” nighttime sky wave MW signals. In my opinion, based on my experiences over the past 2 years, a quad vertical array which does not have swamped vertical elements, or which does not have adjustable swamped lead in pots which are adjusted correctly using a MW band “clear” to optimize the null aperture and null depth for splatter reduction will not have the pattern attributed to it by EZNEC.

If you use an SDR receiver like Perseus, which clips (ceases to operate) when signal levels are too high, then you would probably be well advised to used a low pass filter such as the 5 element Chebyshev 2 MHz low pass filter at right. This will prevent disappointment from lost segments of MW DX recordings. It may also be useful for use with analog receivers which will almost certainly not have adequate IIP2 for such an array. Receiver designers sometimes use high pass filters to protect their receiver SW reception from the MW band, but usually don't use a low pass filter to protect their receiver MW reception from SW bands.



The DC power for the vertical array can be provided in several different ways. Four batteries can be used, one at the base of each vertical element. Or two batteries can be used, one battery for each adjacent pair of vertical elements, with each battery at the bisector of the line connecting its two vertical elements, and about 30' of twisted pair power feed from the battery to each of the two vertical elements. Or the verticals can be powered remotely using the signal twin lead. Shielded twinax is not really needed as far as I have been able to determine. Unshielded speaker wire is just as good. Common mode chokes are used both at the preamps and at the phaser-combiners. Then a single battery can be used at the phaser-combiners, or a low noise power supply like the one at right can be used.





You should use battery power for a few weeks until you are familiar with ambient man made noise at your location. After that you can change to AC power and determine if your AC power supply introduces any additional noise (which will be most evident just below the low end of the NDB band).

As you can see by what I wrote above, I really wanted quad vertical arrays to work well. Unfortunately, it appears that I am not immune to The Emperor's New Clothes syndrome. Fortunately, I have recovered.

Quad active vertical arrays have finally earned a thumbs down from me. They have too many problems, namely, they must have good grounds, they have mutual impedance problems which are difficult, if not impossible, to solve completely, it is blatantly obvious that their null depth and null aperture are not as good as a 100' spaced dual delta flag array at the top end of the MW band, and it appears to be impossible to develop a good LORAN C notch filter for active vertical antenna elements. After putting back up a 100' spaced dual active delta flag array yesterday, I was astonished last night at how much better it was than the quad linear vertical array at the high end of the MW band. It requires only 10' more linear space than the 50' spaced quad linear array. There is no phased MW array better than the dual active delta flag array which will fit in such a small space.