Capacitor Terminated Loop Arrays

Dallas Lankford, 10/10/2010

The main disadvantage of quad delta flag arrays (see The Dallas File) is their low signal outputs. They require multiple preamps to perform well as weak signal DX antennas and arrays at low noise sites. Moreover, their outputs at the low end of the MW band are about 20 dB less than at the high end, which can cause low band insensitivity. At a test of a QDFA at Grayland I suspected this was the case, but there was no beverage to with which to compare. Later at Kongsfjord, Bjarne and OJ observed definite QDFA low MW band insensitivity compared to a beverage just before and then after sunrise as European stations weakened and the DX splatter to noise ratio improved. And NX4D and N4IS have spent considerable effort improving the weak signal performance of the original Waller Flag (a 160 meter band rotatable dual flag array). Their improvements included multiple common mode chokes, lower noise figure multiple preamps, larger antenna elements, and horizontal Waller Flags. However, there is a limit to the number of preamps which can be used (preamps add noise) and the size of the elements where cost or space is a consideration.

Over the past year I have spent considerable time thinking about how to improve the low band insensitivity of QDFAs. Here are the results to date.

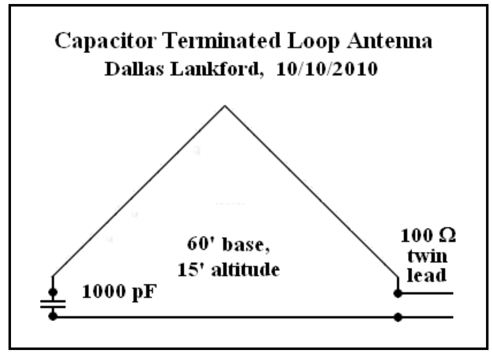
For a long time I considered adding a preamp to each antenna element. But it finally dawned on me that this does not solve the problem of added noise due to multiple preamps. For dual and quad arrays the combiner(s) of the phaser(s) reduce the signal level output of a preamp, but do not reduce amp noise. So it seems to me that there is no advantage to placing preamps at the antenna elements.

Over a year ago I considered replacing the delta flag elements of a QDFA with unterminated loop elements which some said had greater signal output than a flag or delta flag element of the same area and which EZNEC simulations seemed to confirm. But measurements have showed this is not the case; they had more or less the same gain throughout the MW band. I concluded, somewhat wrongly as it has turned out, that the dBi gains calculated by EZNEC were not correct.

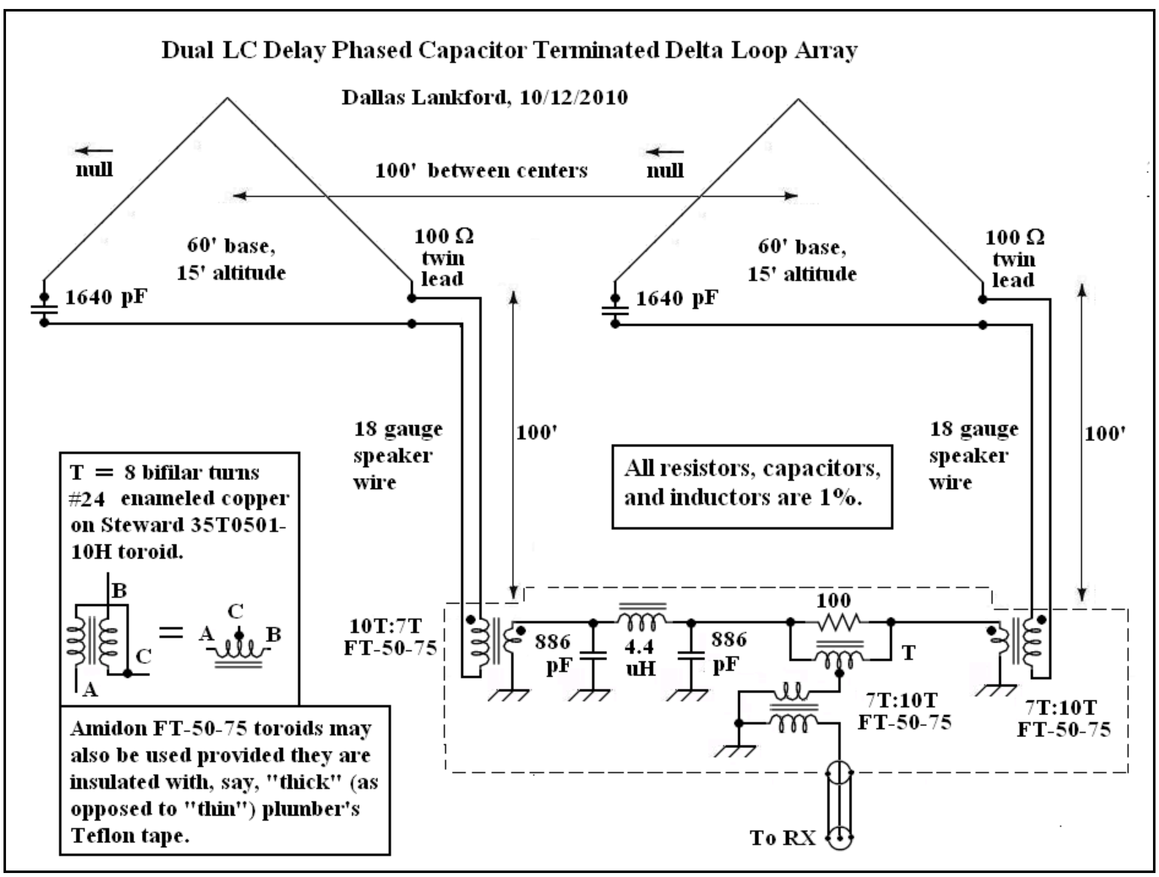
Recently, while playing with EZNEC, I noticed that the SWR of the unterminated loops I was using (and presumably that everyone else was using) had an extremely high SWR, greater than 100:1. This suggested to me that perhaps unterminated loops had considerable loss due to the extremely high SWR. How can the SWR of an unterminated loop be lowered? More or less by tuning it to resonance. With the EZNEC 4.0 SWR window one can estimate the value of a series capacitor required to reduce the SWR to near 1:1 at the low end of the MW band (presumably this also tunes the loop to resonance). I did this, but got no increase in signal output. An antenna transformer was used, and this suggested that the primary inductance of the transformer was added to the loop inductance.

To eliminate any added inductance, the antenna transformer was replaced with a push-pull common base amplifier which has a very low (non-inductive) input impedance. To my satisfaction the signal output of the loop was increased at the low end of the MW band. However, the common base amp had a terrible noise figure, and so was abandoned.

Then I decided to connect the 100 ohm twin lead directly to the antenna element. I don't think the SWR in this case is as low as possible, but the loop was still tuned to resonance by a termination capacitor. I used Perseus in recording mode, thanks to a suggestion from OJ, and stood at the end of the delta loop with a 600 pF air variable capacitor and varied the capacitance slowly back and forth through its range. When I replayed the recording one of my semi-locals on 1680 kHz its signal strength (mid day so there was a steady ground wave signal) varied from about 10 dB less than a standard delta flag (1000 ohm termination and 9:1 Z step down antenna transformer) to about 10 dB more than a standard delta flag. The measurements were repeated at the low end of the MW band on a 540 kHz semi local using switched discrete silver mica capacitors, and again its signal strength varied from about 10 dB less to about 10 dB more than a standard delta flag. That's the good news. The possible bad news is that with a 10 dB increase at the low end of the MW band, there is a 10 dB decrease at the high end of the MW band, and vice versa. But is this really bad news? Based on my limited experience at Grayland, I believe that 10 dB loss at the high end of the MW band will not the sensitivity degrade sensitivity of a capacitor terminated quad loop array. So if a capacitor terminated loop is adjusted to maximum output at the low end of the MW band, say 700 kHz, this will provide about 10 dB gain over a QDFA from about 600 kHz to 800 kHz, with the additional gain slowly falling off outside its range (the "bandwidth" of increased gain is quite wide). If if all of this is true, then the low MW band insensitivity has been solved. Otherwise 3 switchable capacitors could be use to select the desired third of the MW band to be enhanced. Or the delta elements could be replaced with "house" flag elements which are being tested at Kongsfjord. EZNEC simulation suggests that an additional 6 dBi output results from the slightly larger elements, and measurements seem to confirm this. For a narrower band of frequencies, such as the 160 meter ham band, this approach should provide 10 dB additional gain throughout the entire band, improved loop signal to noise ratio, and in turn better weak signal performance, such as for the Waller Flag and its variants. The sizes, spacing, and capacitor values will, of course, need to be changed in this case.



A dual capacitor terminated delta array became operational the morning of 10/12/2010. It was oriented N-S with null center pointed more or less due North.



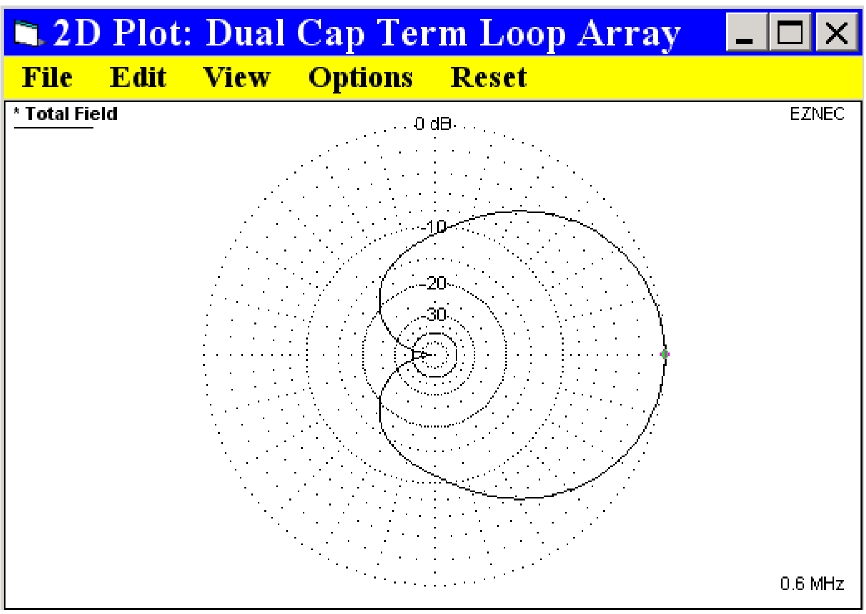
The DCTDA was made from half of a recycled QDFA, modified with connectors on the output ends, so that the change from DDFA to DCTDA (and vice versa) could can be made in less than two minutes by plugging and unplugging the transformers and changing test lead clips on the termination ends. The twin lead was already plug-in since December 2008. High band gain loss could not be compared due to lack of a suitable high band station.

Tonight sky wave nulls will be compared insofar as possible.

Note that a single capacitor terminated delta loop has the same figure 8 pattern as any other loop. It is only when you phase two or more of them that you get a cardioid-like pattern. The pattern of a phased CT pair is not a cardioid; it has a much wider null aperture than a cardioid. According to EZNEC, a dual CT null aperture is not quite as wide as a DDFA, about 30 degrees versus 90 degrees. According to EZNRC, the quad patterns are identical, except that the QCTDA has two or three small blips in its deep null structure. According to EZNEC, the blips can be eliminated by changing the phaser slightly.

Little, if any, difference was noted for two 1000 pF or two 1640 pF fixed capacitors during the dual array tests.

Below is an EZNEC pattern of a DCTDA. Tests commenced about an hour after sunset because as usual during sunset transition nulls were non-existent or transient.



According to EZNEC (above), the 30 dB null aperture of a DCTDA (aka DCTLA) is about 40 degrees (the same as a dual ALA-100 array). Because of this, not surprisingly, the DCTDA nulls on Nashville 1510 kHz were observed not to be as deep as the DDFA nulls with its 30 dB aperture of about 90 degrees. At 45 degree azimuth (the direction of Nashville from my location, Ruston, LA), a DDFA pointed due North (as mine is) has a 6 dB deeper null than a CCTDA (also pointed due N). Little difference was noted on other big hitter nulls to the North because all of their azimuths are much closer to 0 degrees (due N).

The DCTDA performance has been declared a success.

I expect the Quad Capacitor Tuned Delta Array will be an even better success because EZNEC predicts its 30 dB null aperture is the more or less the same as a QDFA, about 150 degrees.