Broadband Capacitor Terminated Mismatched Loop Arrays

Dallas Lankford, 10/10/2010, rev. 11/4/2010

Introduction

The main disadvantage of quad delta flag arrays (see The Dallas Files) is their low signal outputs. They require multiple preamps to perform well as weak signal MW DX arrays at low noise sites. Moreover, their signal 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, Washington, I suspected this was the case, but there was no beverage with which to compare it. Later at Kongsfjord, Bjarne and OJ observed definite QDFA low MW band insensitivity compared to a beverage somewhat before, during, and after sunrise as European stations weakened and the DX signal to splatter ratio improved. Low band insensitivity of QDFAs is probably also the case before, during, and somewhat after sunset. It should be remembered, of course, that my dual delta flag and quad delta flag arrays were inspired by the original Waller Flag (NX4D), a 160 meter band rotatable dual flag array, and the Big WF (N4IS). The DDFA is basically a delta WF optimized for splatter reduction, and the QDFA basically two phased DDFAs optimized for splatter reduction. NX4D and N4IS have spent considerable time and effort improving the weak signal performance of the original. Their improvements have included multiple common mode chokes, lower noise figure multiple preamps, larger antenna elements, and horizontal Waller Flags (N4IS). Recently NX4D enlarged his WF with even larger flag elements 17'H x 23'W and a longer boom to accommodate the 29' spacing between centers. He calls it the giant WF, and giant it is. It appears to me that a variant of the Giant WF maximized for splatter reduction and phased for maximum null depth and null width would make an excellent rotatable MW dual flag array.

Broadband Capacitor Terminated Loop Arrays

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 probably would not solve the problem of added noise due to multiple preamps. For dual and quad arrays the combiner(s) of the phaser 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.

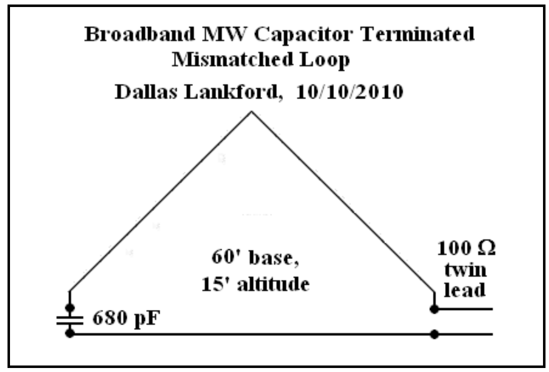
As NX4D and N4IS have shown, increasing the antenna element area improves weak signal performance. Changing the delta elements to flag elements would increase the area by a factor of 2 should in principle increase the signal output by 6 dB. But at Kongsfjord where gale force winter winds are not uncommon, doubling the areas of the deltas would not be cheap or easy because 8 new heavier duty masts would be required. In my case, changing the QDFA delta elements to a bigger flag elements could be done with 8 new heavier duty masts. But I would only use the bigger quad flag array at distant sites, shipping and installing it would not be cheap or easy. So I decided against this approach, at least for now.

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 flag or delta flag elements of the same area and which EZNEC simulations seemed to confirm. But measurements showed this is not the case; they had more or less the same gain throughout the MW band, at least for my implementation of the loop.

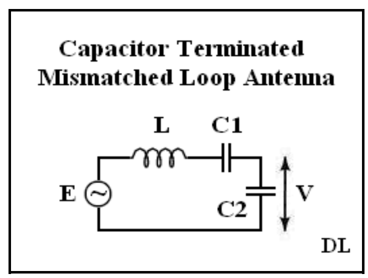
The concept of capacitor terminated loops was inspired in part by a remark made by Doug Waller, NX4D that it would be nice if the resistor noise of flag antennas could be reduced or eliminated.

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? In theory by tuning it to resonance and impedance matching. 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 tried a few fixed capacitors together with impedance matching with a 1:100 ohms broadband step up transformer, but observed no signal increase.

Next I tried a common base amplifier (very low impedance input) in place of the broadband transformer, and seemed to get increased signal output at the low end of the MW band. But it was difficult to determine how much of the increase was due to the capacitor termination and how much was due to the impedance matching (good or not so good as the case might have been) of the common base amplifier. And I did not like using an amplifier at the antenna element, which introduces noise.



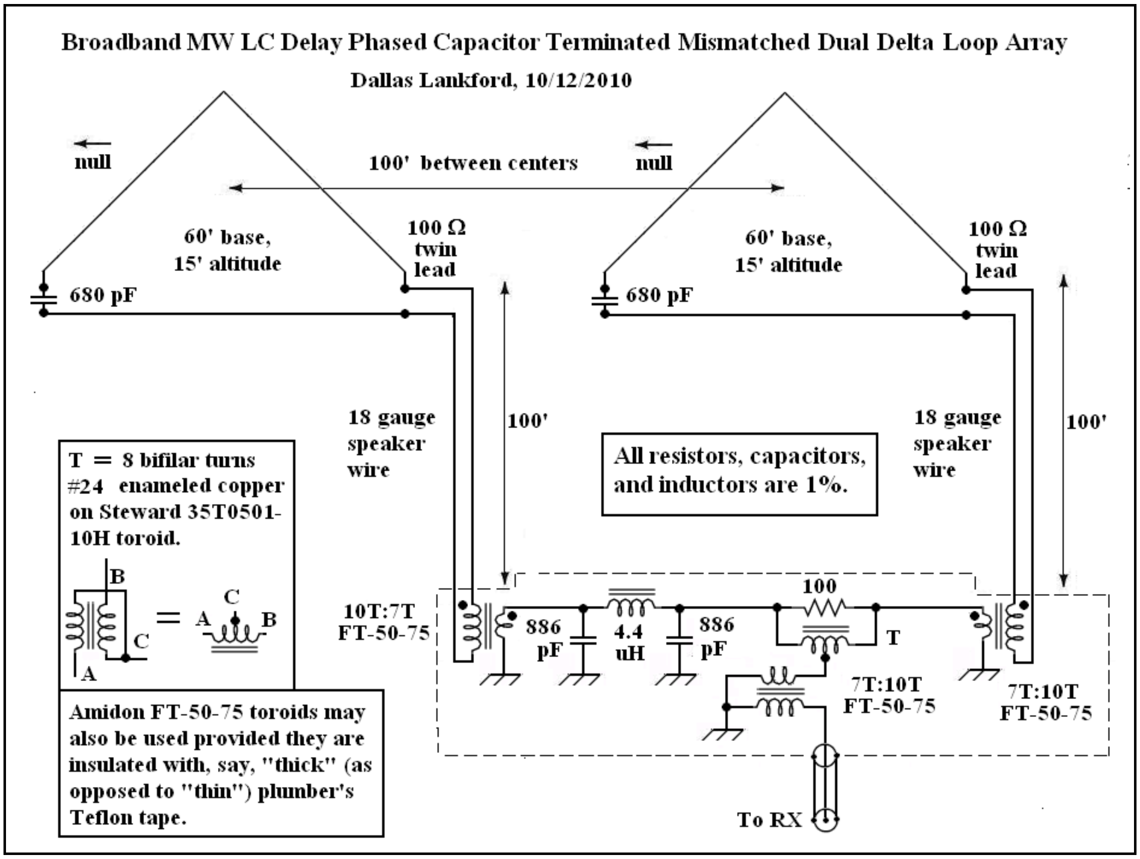
So I decided to connected the 100 ohm twin lead directly to the antenna element shown in the figure at right. The loop was not matched to the transmission line in this case, but the loop output at a given frequency was increased as the terminating capacitor was tuned to resonance. I used Perseus in recording mode, thanks to a suggestion from OJ, and stood at the end of the delta loop with a 1500 pF air variable capacitor and varied the capacitance slowly back and forth through its range. With the variable capacitor adjusted for maximum signal output at 580 kHz kHz there was a 10 dB increase in the signal output compared to a 1000 ohm terminated flag. With this capacitor setting there was a 4 dB increase at 870 kHz and a 2 dB decrease at 1490 kHz compared to a 1000 ohm terminated flag. The measurement frequencies were determined by the availability of signal sources in the direction of the antennas maximum responses. It was found that the capacitor value for a maximum in the 600 to 700 kHz range was about 680 pF.



After Doug Waller, NX4D saw the capacitor terminated mismatched loop diagram above, he remarked that the 100 ohm twin lead was part of the antenna circuit. I had not considered that theoretically, so I used the circuit at right to model the capacitor terminated mismatched antenna. The measured loop inductance was L = 66 μH, the terminating silver mica capacitor was C1 = 680 pF, and the measured 100 feet of 100 ohm twin lead-in capacitance was C2 = 1700 pF. The KVL loop equation was solved for the voltage V across C2, that is the voltage across the 100 feet of 100 ohm twin lead, and a resonance formula $f = 1/(2\pi\sqrt{(LC_1C_2/(C_1 + C_2))})$ was developed. Using the component values above, resonance is f = 889 kHz. This is much too high based on measurements above of signal levels for the actual antennas. So it seems that a more elaborate model is needed for better theoretical agreement with measurements.

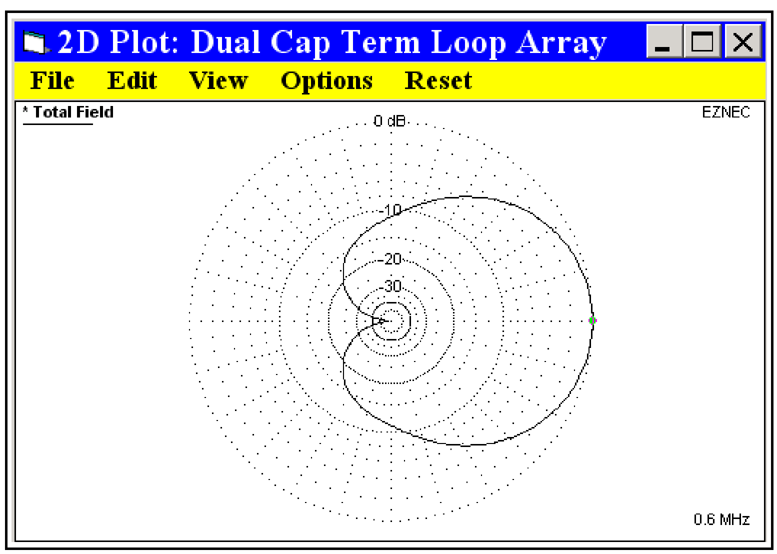
A dual capacitor terminated delta array, schematic below, became operational the morning of 10/12/2010. It was oriented N-S with null center pointed more or less due North. Tonight sky wave nulls will be compared insofar as possible.

The dual capacitor terminated loop array was made from half of a recycled QDFA, modified with connectors on the output ends, so that the change from DDFA to dual capacitor terminated loop (and vice versa) could can be made quickly by plugging in and unplugging the transformers and changing test lead clips on the termination ends. The twin lead was already plug-in since December 2008.



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 capacitor terminated pair is not a cardioid; it has a much wider null aperture than a cardioid. According to EZNEC, a capacitor terminated dual loop array null aperture is not as wide as a DDFA, about 30 degrees versus 90 degrees. According to EZNRC, the quad patterns are identical, except that the quad capacitor terminated mismatched loop array has two or three small blips in its deep null structure. But according to EZNEC, the blips can be eliminated by changing the phaser slightly.

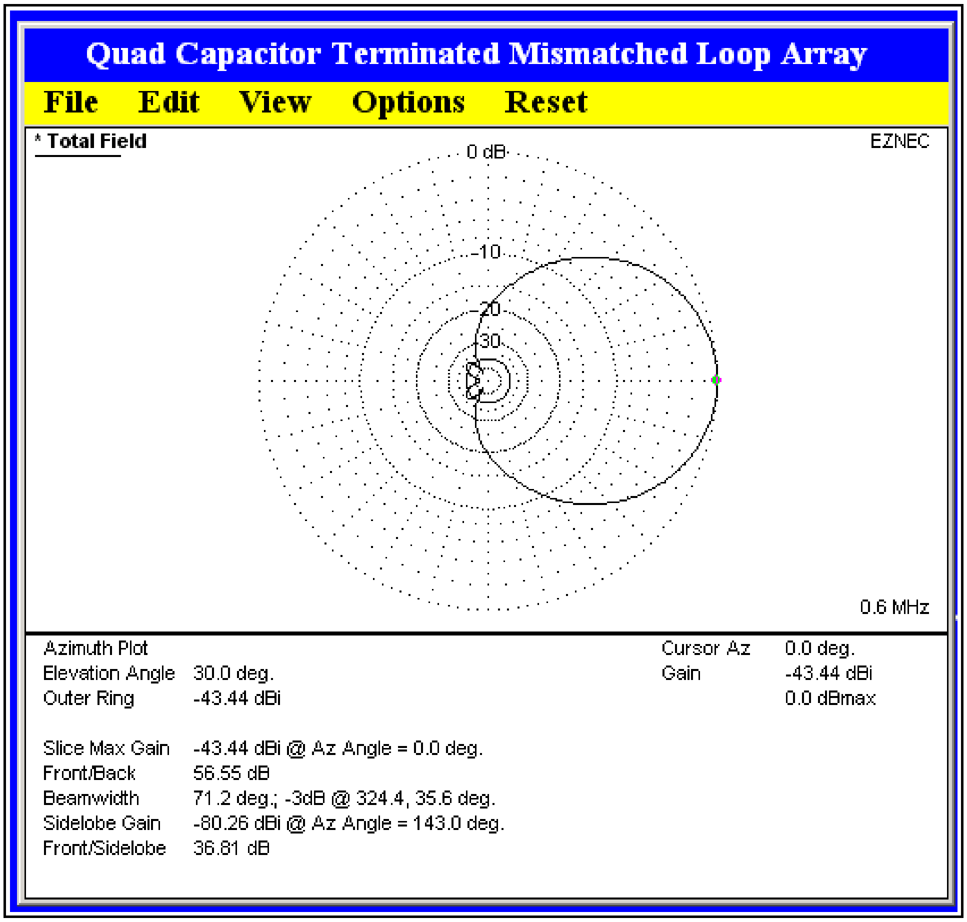
Below is an EZNEC pattern of a capacitor terminated mismatched dual loop array. Tests commenced about an hour after sunset because as usual during sunset transition nulls were non-existent or transient.



According to the EZNEC simulation at right, the 30 dB null aperture of a capacitor terminated mismatched dual loop array is about 40 degrees (the same pattern as a dual ALA-100 array). Because of this, not surprisingly, the capacitor terminated mismatched dual loop array 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 45degree azimuth (the direction of Nashville from my location, Ruston, LA), a DDFA pointed due North (as mine is) has a 12 dB deeper null than a capacitor terminated mismatched dual loop array (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 broadband capacitor terminated mismatched dual loop array performance has been declared a success. A broadband Quad Capacitor Tuned Mismatched Delta Loop Array may 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. But that remains to be seen because a quad array version has not been implemented and tested.

The Objective



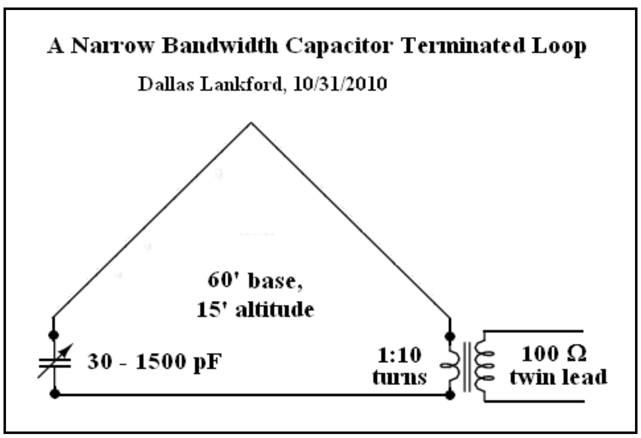
More Sensitive Close Spaced Dual Flag Arrays

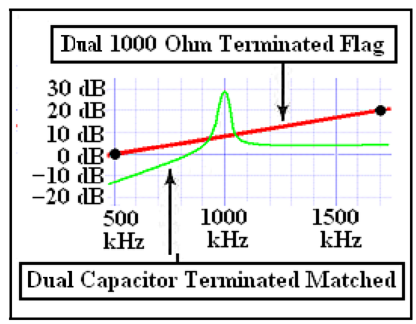
Recently NX4D enlarged the Big WF for still better 160 m band sensitivity: 17'H x 23'W flag elements, spaced 29' apart; see also the information in the figure below. It is optimized for RDF. He calls it the Giant WF, and giant it is compared to the original WF. I do not recall the boom length, maybe about 50'. EZNEC simulation (see below) suggests that by optimizing the Giant WF for splatter reduction and making other changes it might be a very good fixed or rotatable MW splatter reducing MW flag array only 52' long. In principle, based on EZNEC simulation, the modification should be relatively easy. As is well known, a dual flag array does not have as wide 30 dB null aperture as a quad flag array, but tests at Grayland with a DDFA showed that in practice a dual flag array can be a very good performer, almost as good as a quad array. It would, however, probably have low band insensitivity. Also, a close spaced quad version has not been found after many EZNEC simulations, and may not exist. Building one of these would not be an easy or inexpensive proposition. Nevertheless, it holds the promise of being the first high performance broadband splatter reducing rotatable MW antenna, and for that reason alone it deserves our attention. A fixed version would be much easier and less costly to build, and would be attractive for small yards at potentially good MW DX locations, like seashore locations, especially in the northeast and northwest. Finding enough open land and reasonable accommodations by the sea to put up a QDFA or worse yet (gasp) a long beverage is becoming more and more difficult. A capacitor terminated mismatched version of the Giant WF MW variant for more low MW band signal output is a distinct possibility.

Concluding Remarks

In general it was found that the closer the transmission line (lead in) was matched to the capacitor terminated loop, the greater the signal output increase was at resonance, but the greater the signal output loss was away from resonance compared to a 1000 ohm terminated flag.. Mismatching the capacitor terminated loop directly to the 100 ohm transmission line, which was discovered accidentally, was found to give the most low MW band signal increase consistent with the least high MW band signal loss compared to a 1000 ohm terminated flag antenna. Thus it appears that mismatching the loop to the 100 ohm twin lead is the best way to improve the low MW band signal output of a QDFA. Of course, in that case it would no longer be a QDFA, but instead a Quad Capacitor Terminated Mismatched Delta Loop Array. Of course, rectangular loop elements could also be used if it turns out that greater signal output is needed.

Appendix
Narrow Bandwidth Capacitor Terminated Loop Arrays





The experimental narrow bandwidth capacitor terminated loop in the figure above left was designed to be tuned to any frequency in the MW band as well as some frequencies above and below the MW band so that comparisons could be made with a 1000 ohm terminated flag of the same size.. The loop output was (approximately) impedance matched to 100 ohms twin lead with a broadband transformer, assuming a loop impedance of 1 ohm real. The transformer was 3 turns : 30 turns #22 enameled copper wire on an insulated Amidon FT-114-J (high permeability, $A_L \sim 3000$). In a previous version, split capacitor matching was tried but it had about 15 dB loss. The air variable capacitor was 3 sections, 10 – 500 pF, wired parallel. Tuning was so sharp that this narrow bandwidth capacitor terminated loop was not sufficiently sensitive in the MW band except at and very near resonance. At resonance, the signal output of the narrow bandwidth capacitor terminated loop was about 20 dB more than a 1000 ohm terminated flag of the same size, but about 20 dB less then the flag away from resonance. This is unsuitable for use in the MW band with very broad bandwidth recording SDR receivers such as Perseus. Also, the remote tuning which would be required for use as a MW antenna is problematic and perhaps not practical for narrow bandwidth arrays. For these reasons only a prototype dual MW capacitor tuned matched loop array was built. Approximate graphs of the relative signal outputs of a dual 1000 ohm terminated flag array and a dual matched capacitor terminated loop loop array are given in the figure above right.

A three element capacitor terminated loop array with binomial feed and 81 square feet (9' x 9') rectangular loop elements has been designed and implemented by K3NA for top band (160 m) and excellent performance has been reported. I believe that the K3NA array elements were split capacitor matched with 14 dB matching loss rather than broadband transformer matched.

If you do not require a broad bandwidth array, a narrow bandwidth capacitor terminated impedance matched flag array might be a good choice.