High Z PPL's For Loop And Flag Arrays

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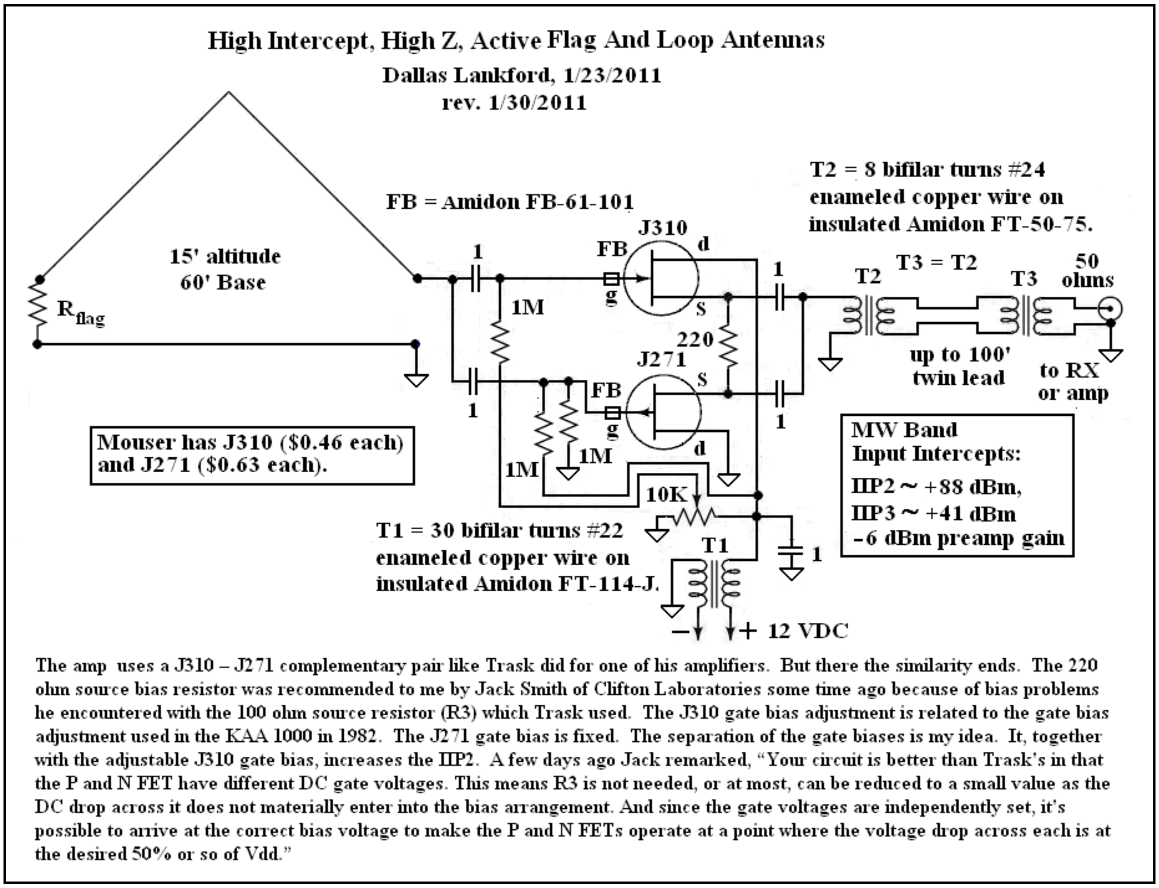
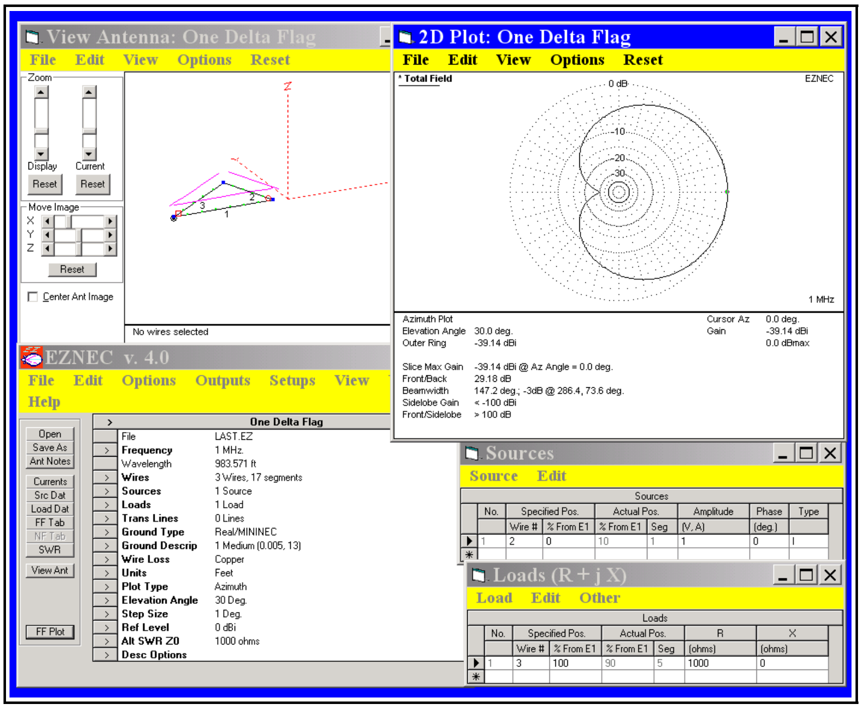
Introduction

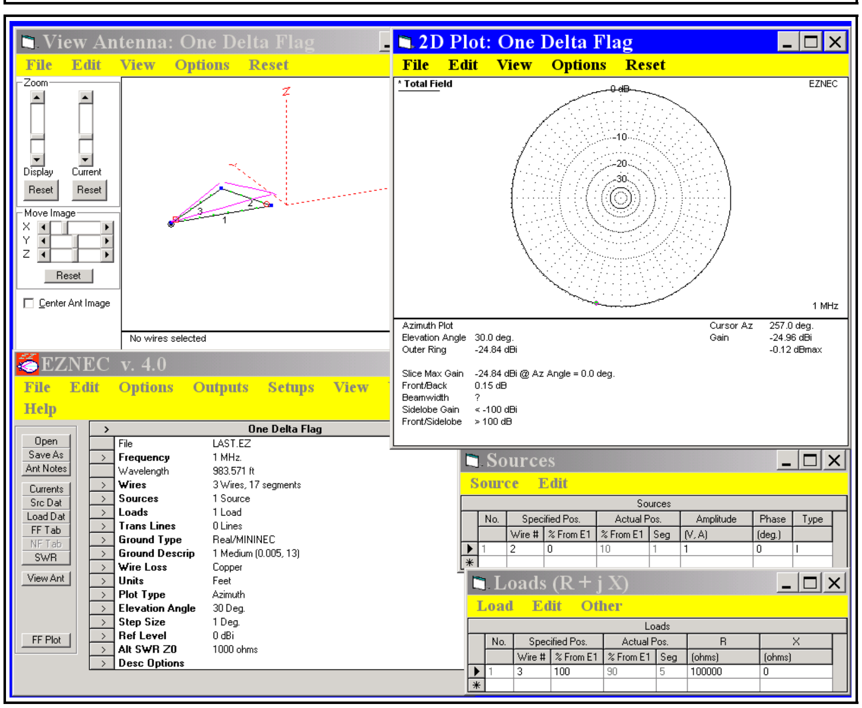
The primary purpose of this development is to eliminate the low (MW) band insensitivity of the QDFA which was discovered at Kongsfjord. A previous method, capacitor termination with mismatch, was proposed, but it provided only 10 dB additional low band signal level output increase, and somewhat decreased the high band signal level output. Capacitor termination of flag arrays may also degrade null depth and null aperture, and so may not be a good idea. The approach introduced here appears to offer signal level output increases of up to 25 dB. The higher gains are probably not needed, which is good because the higher gains are obtained with progressively higher values of terminating resistors, which progressively degrade the flag limaçon (a distorted cardioid) pattern into an omnidirectional pattern.



The high Z active delta flag antenna was discovered entirely by accident while trying to find the optimal resistor value to achieve the deepest active horizontal flag antenna null. It was during the horizontal flag tests that I discovered connecting a high Z input impedance amp directly to the horizontal flag increased the signal level output. At that time it was also observed that when the value of the terminating resistor was increased, the signal level output increased. For R_{flag} = 100K, the increase was about 20 dB, and for R_{flag} = 1Meg, the increase was about 25 dB. Originally it was thought that the gain increase was due entirely to the higher values of terminating resistors. This is partially true, but much of the increase turned out to be due to the high impedance amplifier. Because the FET input is very high impedance, it does not load the flag, and so the flag open circuit voltage appears at the FET gate. This gives about a 6 dB voltage gain. And there there is no 3:1 broad band step down transformer, as would be the case for a conventional 1K ohm terminated flag, which gives a 9.5 dB voltage gain compared to a conventional 1K ohm flag antenna. So the (additional) voltage gain with a 1K ohm terminating resistor when the flag is connected directly to a very high input impedance amplifier, as in the figure above, is in principle, 14.5 dB compared to a conventional 1K ohm terminated flag antenna. This 1K ohm case directly connected to the high input impedance amplifier is what I neglected to measure the first time around. Also, it has turned out that while loops do not have the highest signal outputs, the do have the best signal to noise ratios. It is presently unknown whether highest signal output or highest signal to thermal noise ratio is best, but I vote for highest signal to thermal noise ratio. Because of this, the title has been changed again, this time to to “High Z PPL's + Loop And Flag Arrays.” The term PPL (one preamp per loop) was coined by Doug, NX4D some time ago when he, Carlos, and I were having one of our many jam sessions on increasing the signal level output of flag and delta flag arrays. The preamps we considered then and how we considered using them were quite different from the high input impedance preamp used above which is connected directly to the flag element (without any transformer between the flag and amp input). These methods can also be applied to the Waller flag top band rotatable arrays developed by NX4D and N4IS which inspired this work.

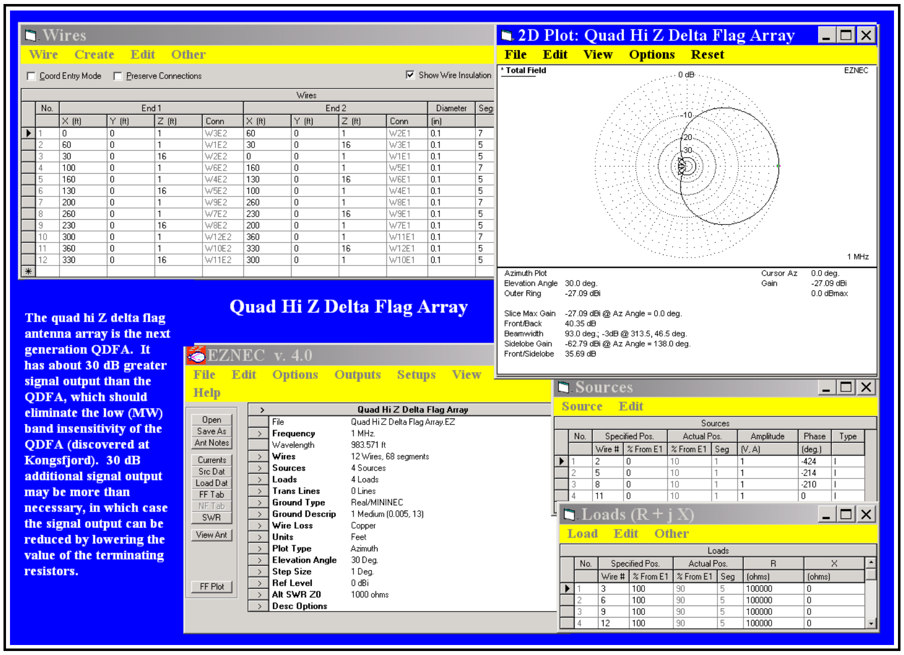
The EZNEC simulations below show how the signal level outputs of a delta flag increase as the value of the terminating resistor is increased. The first simulation is for a conventional 1K ohm terminated delta flag; the second



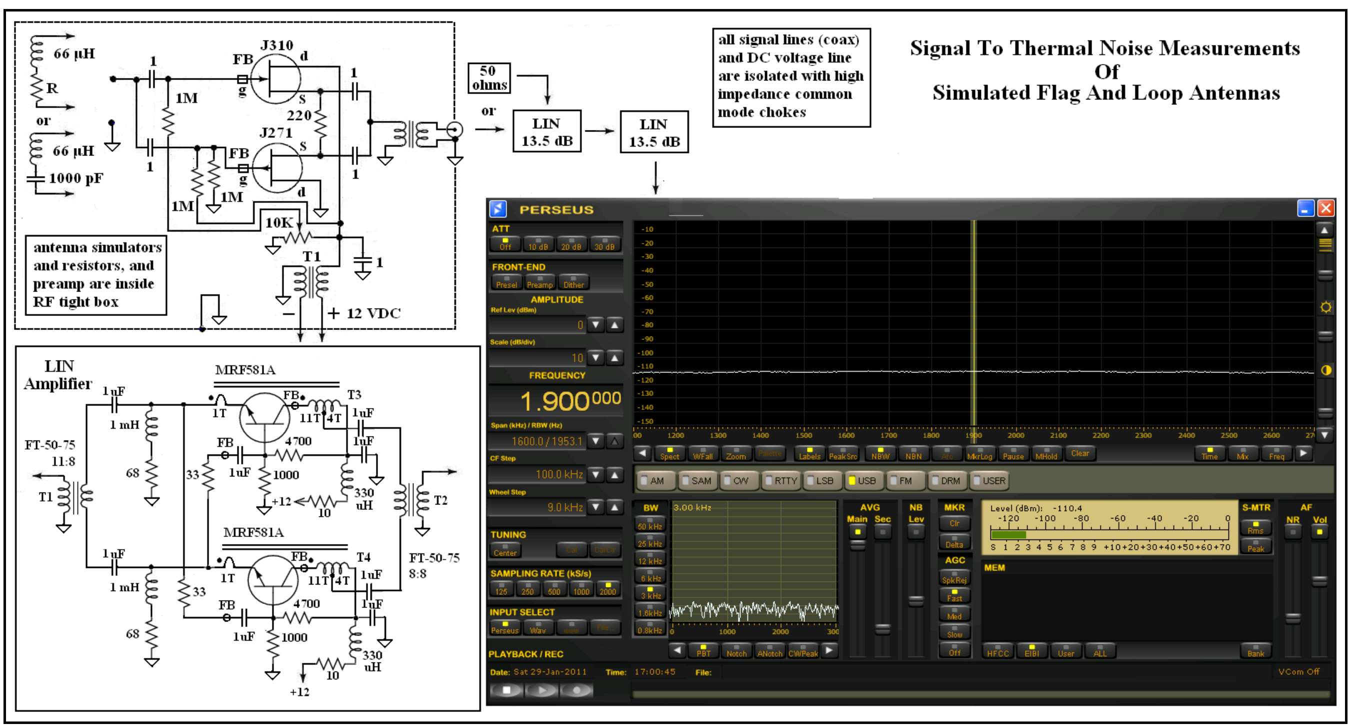


for a 100K terminated delta flag. EZNEC shows a 14 dB signal level output increase; the observed measured increase was 20 dB. The EZNEC patterns above also show the transition from limaçon to more or less omnidirectional (some null in the vertical direction). For better viewing, magnify the figures.

The RDF of the single very high Z delta flag is 4.7, rather pathetic, but improves to 8.8 for a dual high Z delta flag array, and to 10.47 for a quad high Z delta flag array. The null depth and null aperture for a quad high Z delta flag array are about the same as for a standard QDFA according to EZNEC simulations such as the following.



Note that the EZNEC simulation above with 100K ohm terminating resistors has 30 dB greater signal level output than the standard QDFA. My opinion is that this is higher than will be achieved in practice. But maybe EZNEC is right... a quad PPL + high Z delta flag array has not yet been implemented and measured.



To determine if loops ($R_{flag} = 0$) or flags ($R_{flag} \sim 1000$ ohms) have better signal to noise ratios, noise measurements were made of a cascade complementary J310 - J271 amp with resistors and also with resistors in series with 66 µH inductors connected to the input of the amp. The cascade complementary J310 - J271 was later replaced with the single complementary amp shown in the first figure at the beginning of this article. The test setup is shown in the figure above. To get higher resolution in the figure below, use magnification.

Averaging of the Perseus display and SLOW AGC were used when making measurements (this gives ± 0.2 dB measurement accuracy). If you look at the figure below, you will see that Perseus is measuring – 110.4 dBm. This measurement is for a 50 ohm resistor connected to the first LIN amplifier (the simulated antenna and its preselector are not connected to the first LIN). The – 110.4 dBm is the noise power output of the two cascaded LIN's. The noise figure and gain of each LIN was previously measured as NF = 0.9 (± 0.4) dB and 13.5 (± 0.1) dB respectively. We will take the high values 1.3 and 13.6 so from

$N(dBm) = NF + 10 \log(G) + 10 \log(B) – 174$

it follows that

$N(dBm) = 1.3 + 27.2 + 10 \log(3000) – 174 = 1.3 + 27.2 + 35 – 174 = –109.6$ dBm

which is within 1 dB of the measured value.

At right are two measurements with the 50 ohm resistor replaced by the simulated antenna and preamp, the first simulating a 60' base by 15' height delta loop, the second simulating a 60' base by 15' height delta flag with 1000 ohm resistor termination.

For the first simulation, the open circuit noise voltage induced in the 66 µH loop is

$e_n(\textbf{loop}) = 2\sqrt{(kTrB)}$

where $k = 1.37 \times 10^{-23}$ J/°K is Boltzmann's constant, T = 290 degrees Kelvin, B = 3000 Hz, f = 1.9 MHz, L = 66 µH, and r is taken as 2 ohms,

$e_n(\textbf{loop}) = 0.01$ µV.

The loop amp gain is –6 dB, so

$e_n(\textbf{preamp output}) = 0.005$ µV = –153 dBm.

The LIN cascade has 27.2 dB gain, which gives –125 dBm at the input to Perseus which is considerably lower than the –108.4 dBm measured. Apparently what was measured in this case was equivalent short circuit input noise of the J310 – J271 FET follower.

For the second simulation,

the open circuit noise voltage induced in the 66 µH loop in series with a 1000 ohm resistor is approximately

$e_n(\textbf{1K flag}) = 2\sqrt{(kT \times 1000 \times B)} = 0.$ µV = – dBm.

With the –6 dB preamp gain,

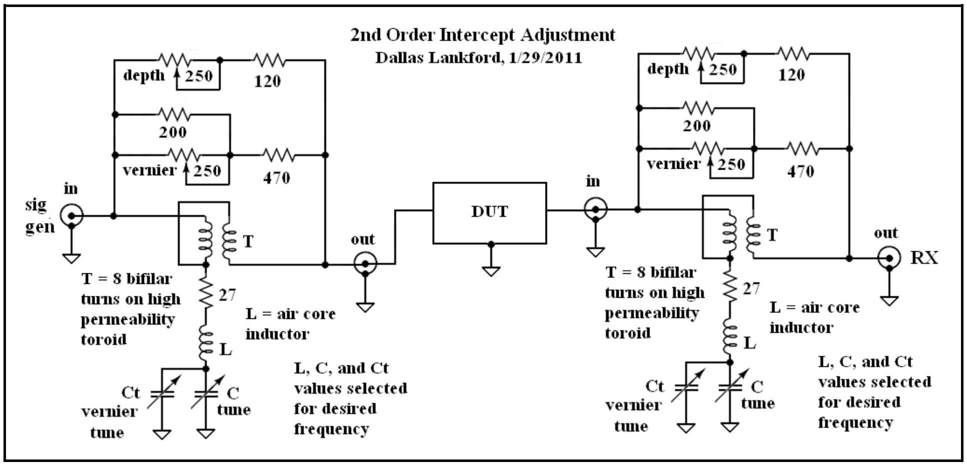
$e_n(\textbf{preamp output}) = –126.2$ dBm,

to which the LIN cascade of 27.2 dB gain is added, giving –99 dBm at the input to Perseus. This is within 0.5 dB of the measured value of –99.5 dBm.

To eliminate all external signal ingress for the inductor (loop) simulation, the inductor had to be double shielded, first with a shield around only the inductor grounded to the ground plane of the amp PC board, and with a second shield enclosing the amp and shielded inductor.

The noise measurements above suggest that a loop ($R_{flag} = 0$) may be better than a flag ($R_{flag} \neq 0$) for weak signal performance because the thermal noise floor of a loop is much lower than the thermal noise floor of a flag. Also, flags with high R_{flag} values may be unacceptable at sites with low man made noise because of their high thermal noise floors.

The schematic at right shows how to adjust the preamps for maximum IIP2. Details will be provided in a future revision. If you have made intercept measurements before, the schematic at right should provide you with enough information to maximize IIP2 for the J310 – J271 PPL's.



Dual Flag And Loop Arrays With High Z PPL's

There are a number of ways to implement high Z PPL's with dual flag arrays: (1) PPL's at the antenna elements with (a) flag (resistor termination) and standard flag antenna transformer preceding the PPL's, (b) flag and 1:1 balun preceding the PPL's, (c) flag and 1:1 Guanella balun (common mode choke balun) preceding the PPL's, and (d) flag and no antenna transformer, (2) PPL's at the receiver end of the lead-in with (a) flag (resistor termination) and standard flag antenna transformer, (b) flag and 1:1 balun, (c) flag and 1:1 Guanella balun (common mode choke balun), and (d) flag and no antenna transformer.

Previously loops were included in this list, but issues with dual loop array phasing have resulted in deletion of discussion of dual active loop arrays in this article.

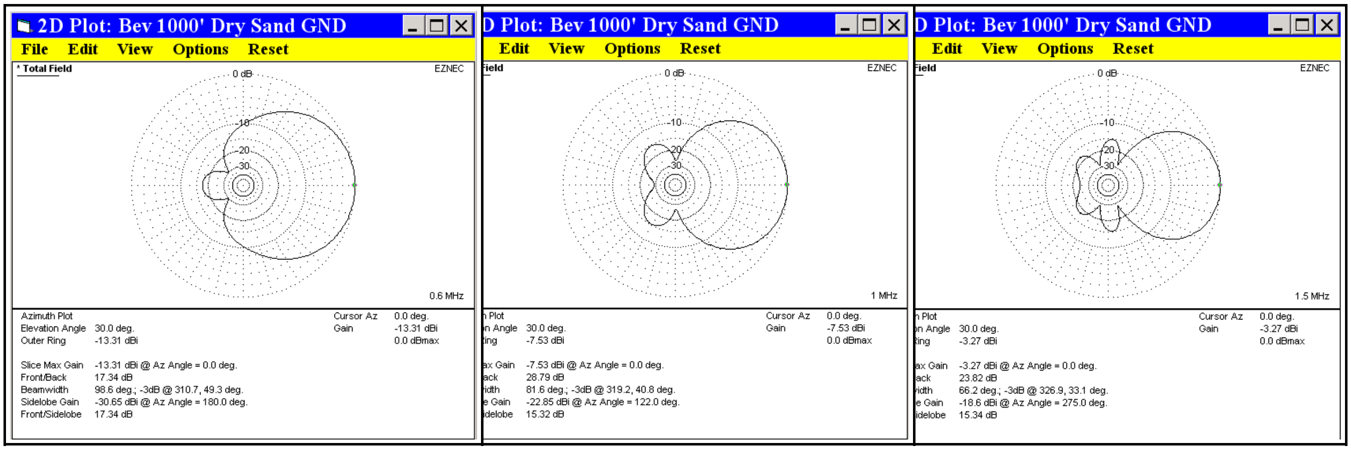
It is necessary to test all of these potential ways of implementing high Z PPL's with dual flag arrays to determine which may be more suitable for implementing high Z PPL's with quad flag arrays. All of these cases have been tested and measured, unless some were accidentally omitted. Some of the most promising measurements are given in graphics below. To save space, the graphics below have been inserted in compact forms. For better viewing, you may magnify the page.

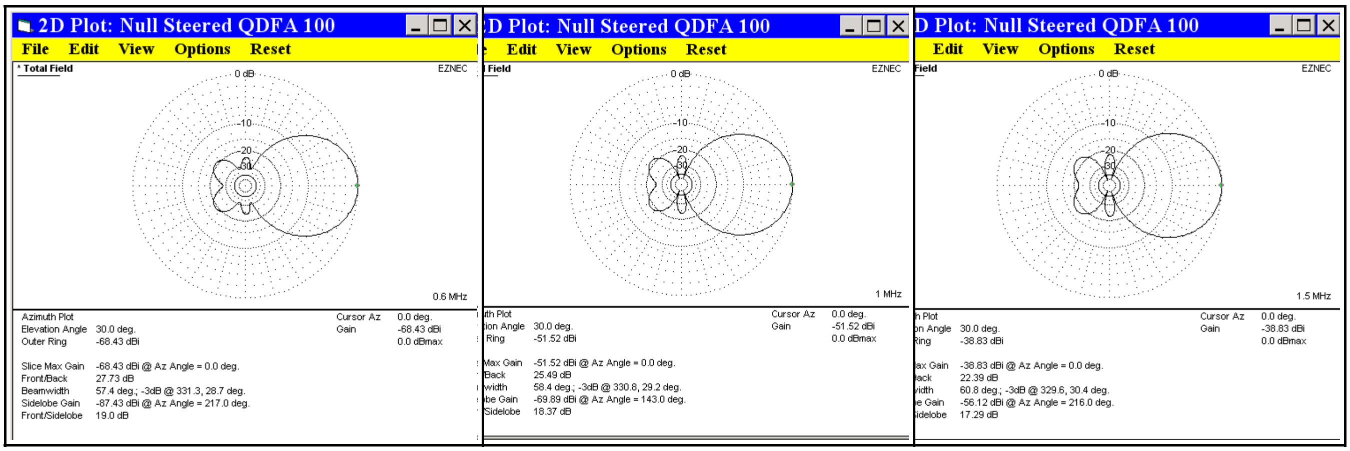
Quad Flag And Loop Arrays With High Z PPL's

No quad PPL arrays have been tested due to inadequate space at Ruston, LA. ADC clipping of Perseus was experienced while testing the dual PPL array. The cause was identified as very strong European 41 meter band signals, and tamed with a 2 MHz 5 element Chebyshev low pass filter.

MW Band (and higher frequency) Beverage Killers?

Some MW DXers with their long beverages wince when I say “beverage killer.” But my original QDFA already killed some of their beverages some of the time, and my new high Z PPL quad arrays will likely kill more because (1) pre sunset and post sunrise low MW band QDFA arrays sensitivity should be fixed with the gain increase provided by the PPL methods developed in this article, and (2) narrow beam width MW QDFA arrays should now be a reality, again because of the gain increase provided by the PPL methods developed in this article. My article “Null Steered QDFA's,” November 2009, developed the basic methods for designing narrow beam width QDFA's. In the past null steered QDFA's were mere curiosities because of their high losses until the discovery of the low noise methods of this article for increasing the signal level outputs of flag and delta flag arrays by 20 dB or more. According to EZNEC, a QDFA with fixed null steering can be designed with a pattern which is much better than a 1000' terminated beverage in the MW band. It requires less than 400 linear feet of space. Below are low band, mid band, and high band patterns for both a fixed null steered single QDFA and a 1000' terminated beverage. If a picture is worth a 1000 words, then the 6 pictures below are worth 6000 words.





Much shorter (~150 total linear feet) versions of this fixed null steered QDFA with greater than 13 RDF can be designed for higher frequencies, such as for the 160 through 40 meter ham bands (and all frequencies in between).

My null steered QDFA's were never really intended to be implemented with a variable phaser because it is virtually impossible to generate the desired patterns with a variable phaser. A Wellbrook variant of my null steered QDFA with variable phaser was tested at Grayland, but the nulls were disappointing, not nearly as good as the standard QDFA. This is not surprising because of the difficulty of adjusting the variable phaser for the desired null, and because the splatter reduction of a typical pattern like 1000' beverage patterns above is not nearly as good as the standard QDFA. But for top band where splatter is not an issue, a 13 RDF pattern in less than half the space of a 1000' beverage would likely be an entirely different matter.

An EZNEC graphic with design information for the QDFA 1000' beverage killer above is given at right.