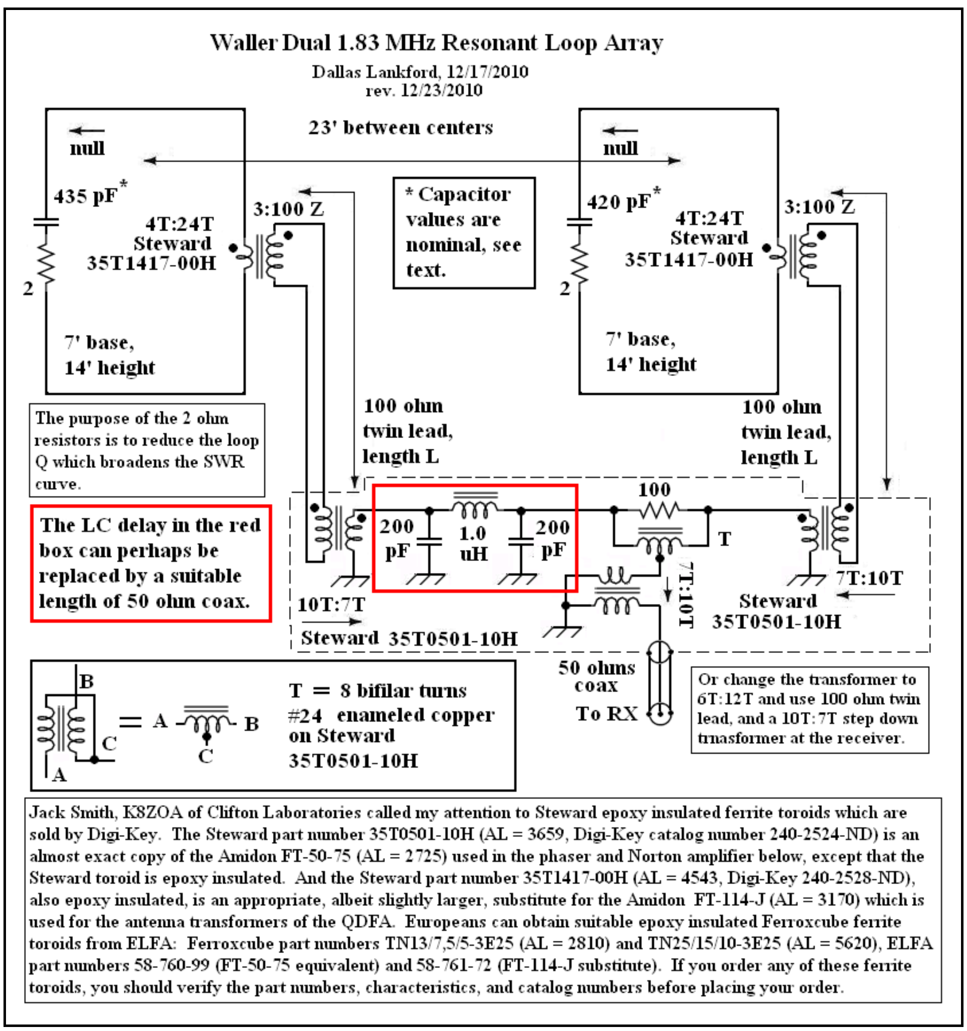
Waller Loop Arrays

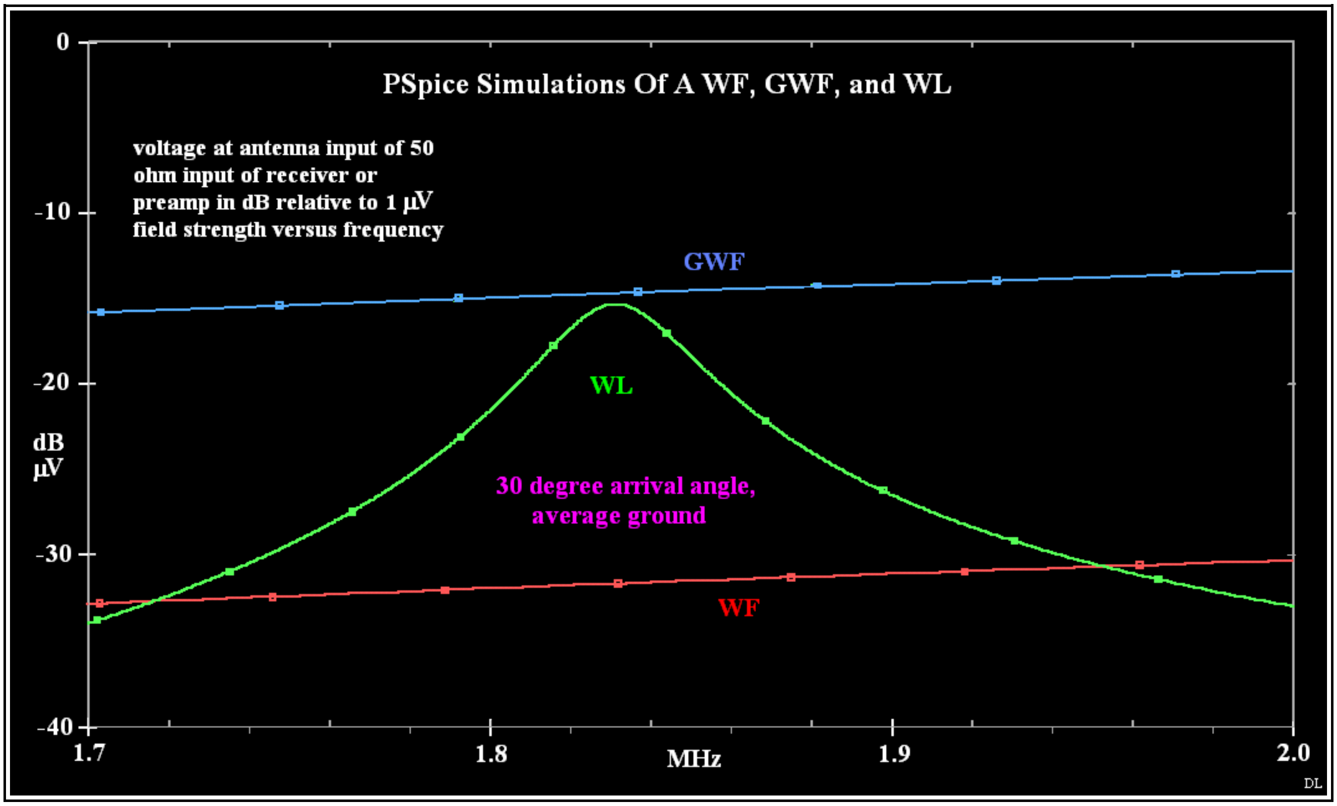
Dallas Lankford, 12/24/2010, rev. 12/28/2010

For the past several months I have been developing capacitor terminated mismatched broadband MW loop arrays with improved low band sensitivity compared to the dual delta flag and quad delta flag MW arrays which I developed in 2008 and 2009. The mismatch was necessary to make the capacitor terminated MW loop arrays broadband. The DDLA and QDLA loop arrays were tuned to the lower part of the MW band, which in such a way that the gain was more or less flat throughout the MW band instead of rolling of 20 dB or more from high to low for the DDFA and QDFA flag arrays. The DDLA has as much as 12 dB more measured gain than the DDFA at the low end, and about 4 dB less gain at the high end, with the break even point at about 1100 kHz. A QDLA has not yet been tested.

A few weeks ago I read a 2009 Dayton presentation by K3NA about his 160 meter band binomial resonant loop array. I am not a ham, and only casually listen to top band for MW propagation indicators, but I enjoy reading about lower frequency antennas even if I may never use them. Also, I wanted to use EZNEC and PSpice methods to learn more about resonant arrays in and near the MW band, but I do not have any practical experience with 3 element binomial arrays, and I do not have 300 feet of linear space in my yard which would be needed to implement the K3NA array. I do have practical experience with dual broadband MW flag arrays which were inspired by the marvelous top band rotatable WF dual array developed by NX4D and further developed by N4IS ; see also here . And they do not require much space, only 30 feet for the original WF dual array. So I decided to study resonant WF dual arrays because it it would be easy to put up a fixed (non-rotatable) WF/WL and test it/them at the high end of the MW band using a 1680 kHz Monroe station 30 miles away as a stable source signal around midday when the signal was mainly ground wave.



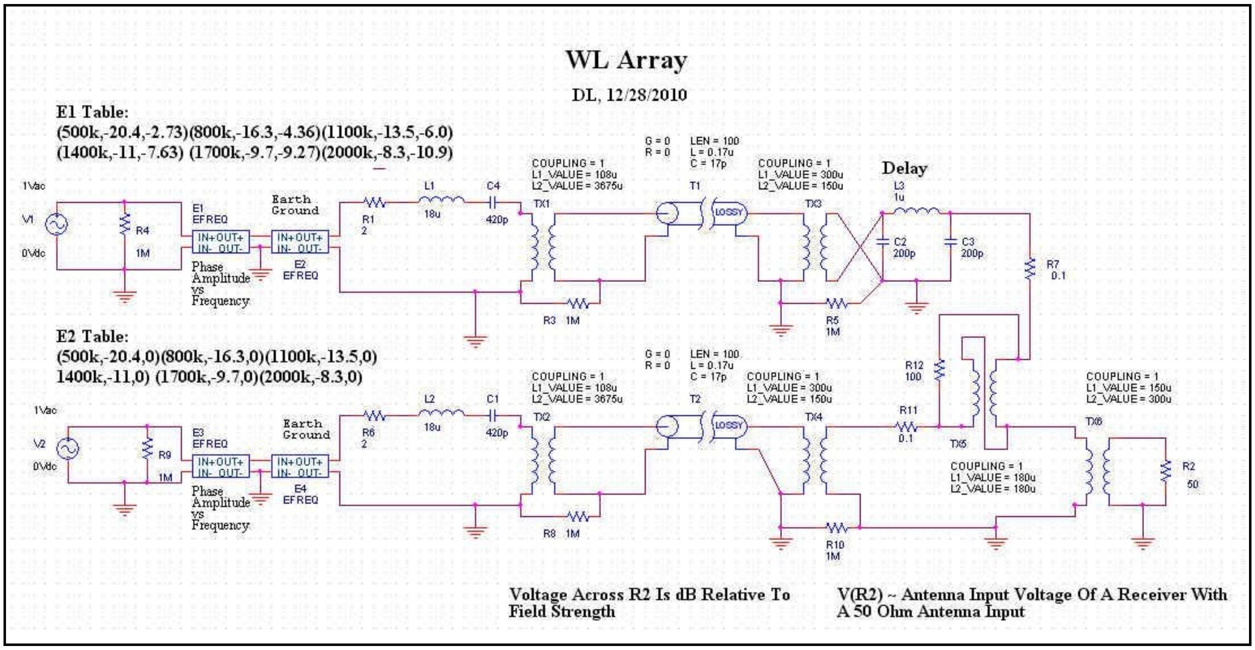
Above is a diagram of the narrow bandwidth Waller Loop array, abbreviated WL, which I implemented. The loop wires were #18 stranded tinned insulated, and the masts were 10 feet long 2x2's nailed about 6 feet up two pine trees about 35 feet apart. At the tops of the 2x2's were nylon cable ties looped through the ends of the 2x2's through which were passed two 0.24" inch nylon ropes for hoisting the WL about 17 feet into the air, just enough to clear the ground. The 2x2's were nailed to the opposite sides of the trees from the loop array between the trees for mast strain relief, and the two ropes were tied to short metal stakes about 220 degrees around the trees also for mast strain relief. The two loops were spaced 16 feet apart with a 0.25" nylon rope, and short nylon ropes attached to bricks were used to affix the bottoms of the loops. I had all parts on hand except the 2x2' which I bought at a local Lowe's. The entire WL was implemented in less than a day. My total cost, not counting the parts I had on hand, was about $20.



Above are PSpice simulations of the Waller Flag array, Giant Waller Flag array, and Waller Loop array. The WF and WL traces agree with measured results. The GWF was not implemented; the GWF trace is a simulation only, but should agree well with measurements. Below is the PSpice schematic of the WL array which was used to generate the trace above.

Tune up was done on Monroe, LA 1680 kHz because the midday ground wave is strong and stable. I presume the procedure described here can be done on a nearby 1.83 kHz signal. I used two 600 pF air variables in place of the fices capacitors, and tuned the loop for max signal indication with the WL max pointed at Monroe. The receiver used for the tune up was an SDR-IQ attached to a battery powered laptop via USB cable. Insulated shafts had been fitted to the air variables, but I think that was not necessary. Adjustment for max signal was made by alternate adjustments of the air variable caps. The air variables were carefully carried inside and measured with an AADE L/C meter. Fixed terminating caps were made with paralleled micas, and put onto the loops in place of the air variables. Max signal was observed to have been unchanged. The loop array was lowered, detached from the hoisting ropes, rotated 180 degrees, and hoisted back up into the air again. The phaser of my WL array is designed to have a deep null; with the standard 180 degree phase shift of a Waller Flag, EZNEC predicts virtually no null. I wanted a deep null to be sure the implemented WL was performing as expected. To my great surprise, there was virtually no null.

More EZNEC and PSpice simulations of the WL revealed that tuning up on the maximum actually moved the resonant frequencies of the two loops away from each other, which lowered the RDF (from almost 10 to about 6) and ruined



the null. It turned out that the correct way to tune up the WL array was to tune up on the null. By that I mean adjust the caps with the null end of the array pointed at the tune up signal, and adjust the caps for deepest null. After this was done, and a new pair of fixed terminating capacitors assembled and placed on the loops, the null was there, but not nearly as deep. One new air variable, 5-40 pF, with 8:1 reduction drive, was assembled and clipped across each fixed cap in turn, and adjusted to study the null depth issue. It was found that an additional 5 pF of capacitance was needed for one of the fixed capacitors. After this was done, the null was deep again. The loop was lowered, rotated 180 degrees again, and the max end pointed at Monroe. Measured WL gain was 16 dB more than measured WF gain at 1680kHz (the loops were set up with banana jacks and plugs so that conversion for WL to WF could be done in a few minutes). Similar performance is to be expected at 1.83 MHz.

The 2 ohm resistors were included in the design of the WF (see the diagram above) to lower the Q of the loops and make tune up easier. When the 2 ohm resistors were removed, the WL gain advantage over the WF was 18 dB. Inclusion or omission of the 2 ohm resistors was found to have no effect on the null.

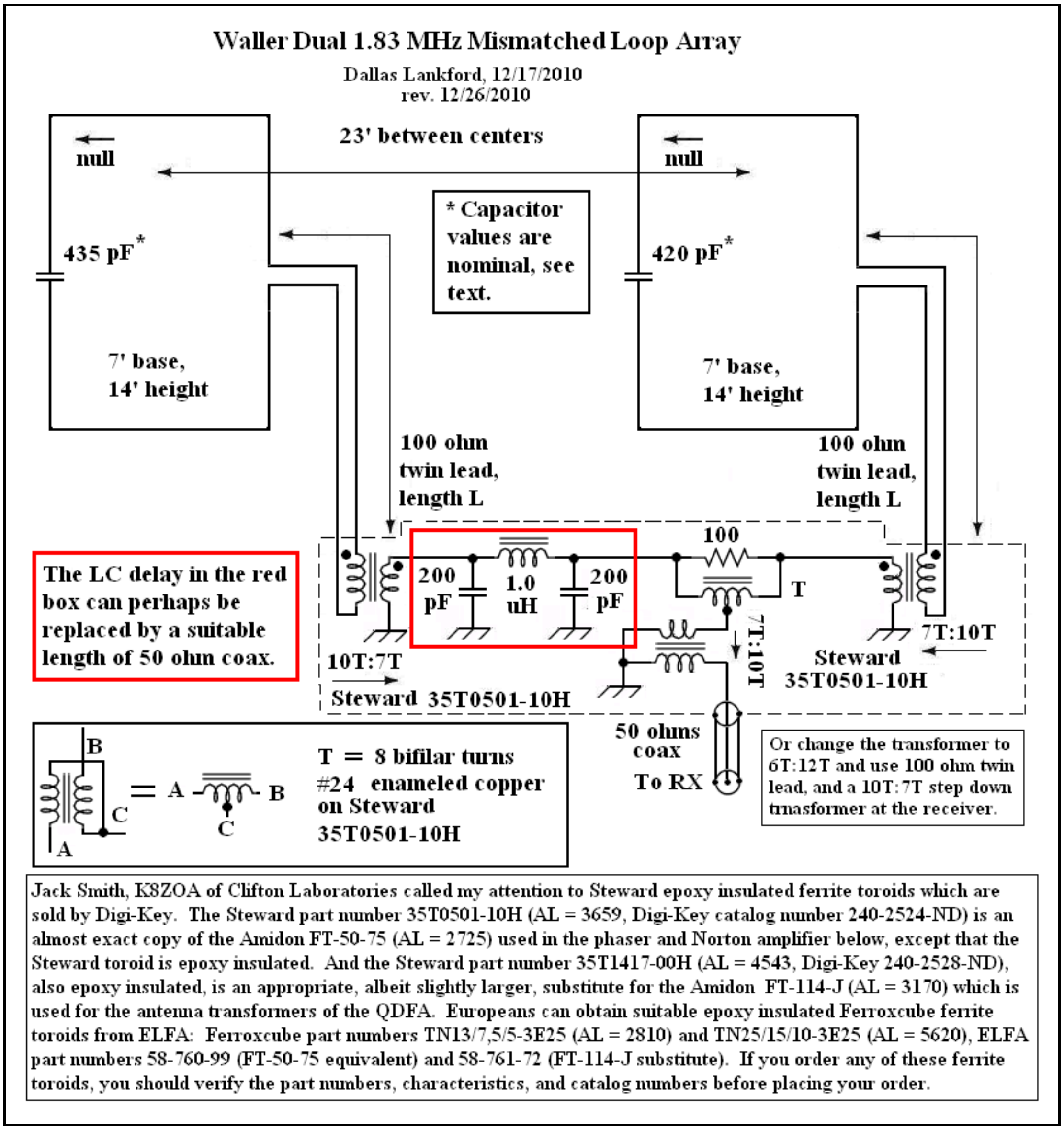
These have been interesting learning experiences, and I hope to find some application for them for MW arrays.

A second article about Waller Capacitor Terminated Mismatched Loop Arrays follows below. The two articles have been kept separate to avoid confusion between WL and WML arrays.

Waller Capacitor Terminated Mismatched Loop Arrays

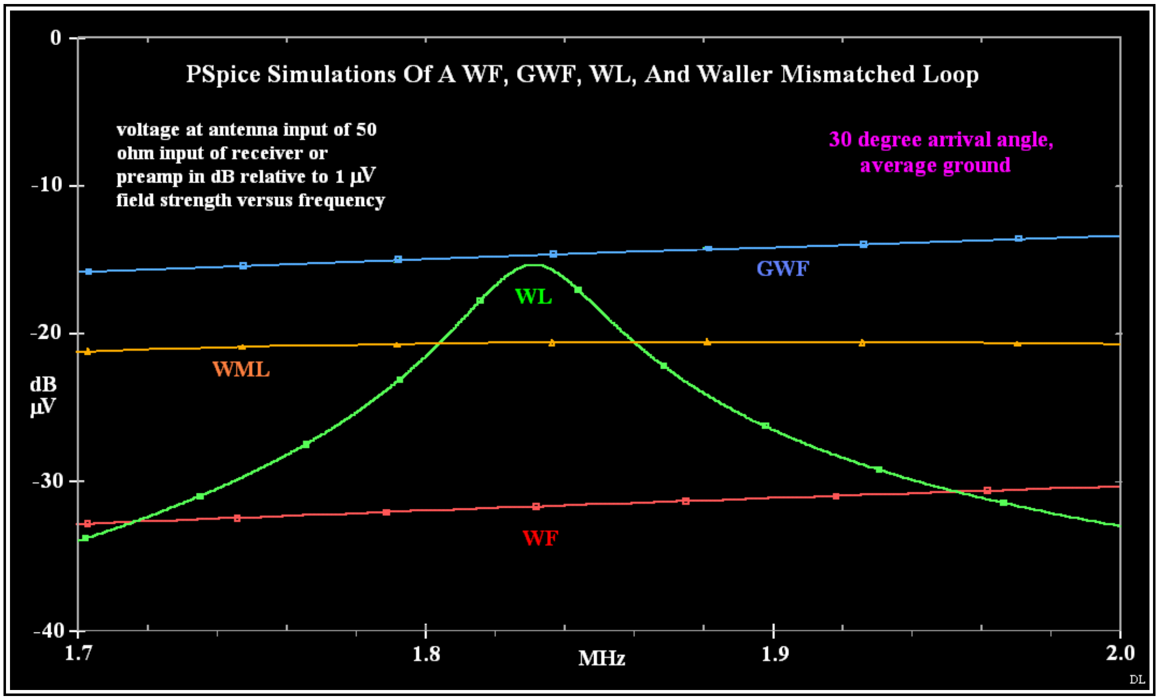
Dallas Lankford, 12/28/2010

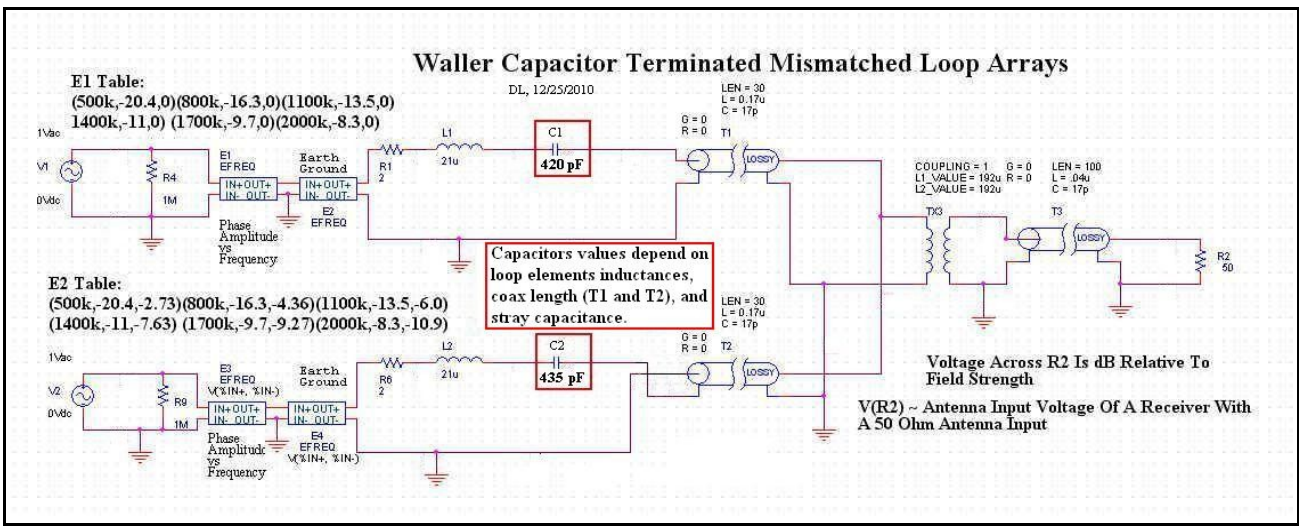
These arrays are similar to the capacitor terminated matched arrays which were discussed previously in a separate article. They are compact topband versions of the capacitor terminated mismatched dual MW loop arrays which I developed and tested in October 2010.

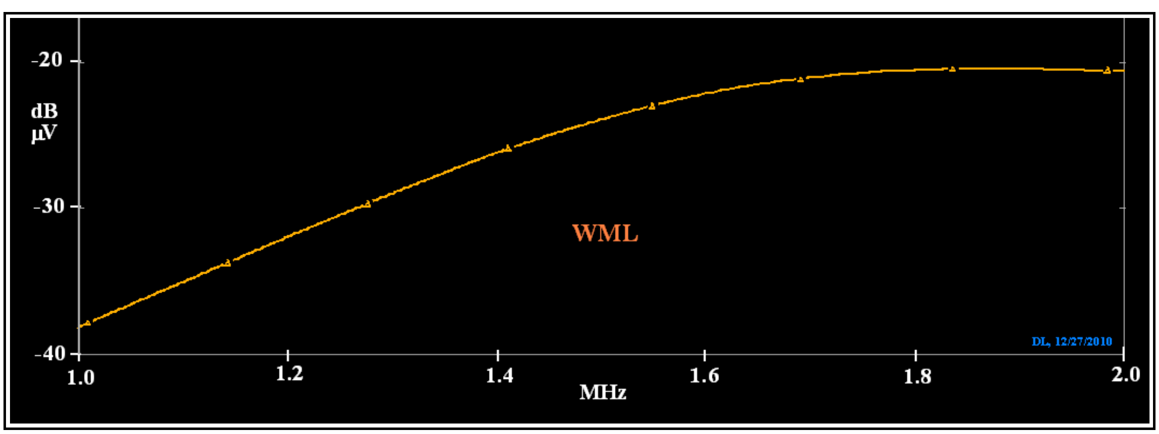


The diagram is identical to the matched array diagram, except that there are no 2 ohm resistors, and no matching transformers at the loop outputs of the loop elements. Tune up is much simpler than for the matched arrays. Air variables are used to tune the loop for maximum output when pointed at a stable source, and then the air variables are replaced with fixed micas paralleled to give the desired capacitances. Tune up can be done on a high end MW signal around midday because the WML array is broadband above resonance.

Below is a PSpice simulation of the mismatched loop array together with comparisons to the matched array, the giant Waller Flag, and the original Waller Flag, followed by a WL PSpice schematic.


PSpice Simulations Of A WF, GWF, WL, And Waller Mismatched Loop
voltage at antenna input of 50 ohm input of receiver or preamp in dB relative to 1 µV field strength versus frequency
30 degree arrival angle, average ground
GWF
WL
WML
WF
dB µV
0
-10
-20
-30
-40
1.7
1.8
1.9
2.0
MHz
DL


Waller Capacitor Terminated Mismatched Loop Arrays
DL, 12/25/2010
E1 Table:
(500k,-20.4,0)(800k,-16.3,0)(1100k,-13.5,0)
1400k,-11,0) (1700k,-9.7,0)(2000k,-8.3,0)
E2 Table:
(500k,-20.4,-2.73)(800k,-16.3,-4.36)(1100k,-13.5,-6.0)
(1400k,-11,-7.63) (1700k,-9.7,-9.27)(2000k,-8.3,-10.9)
C1
420 pF
C2
435 pF
Capacitors values depend on loop elements inductances, coax length (T1 and T2), and stray capacitance.
COUPLING = 1
L1_VALUE = 192u
L2_VALUE = 192u
LEN = 100
L = .04u
C = 17p
LEN = 30
L = 0.17u
C = 17p
Phase Amplitude vs Frequency
Earth Ground
Voltage Across R2 Is dB Relative To Field Strength
V(R2) ~ Antenna Input Voltage Of A Receiver With A 50 Ohm Antenna Input


WML
dB µV
-20
-30
-40
1.0
1.2
1.4
1.6
1.8
2.0
MHz
DL, 12/27/2010

The Waller mismatched Loop array was compared twice about midday to the original WF; on the first occasion the WML had 12 dB more measured gain than the WF, while on the second occasion the WML had 10 dB more measured gain than the WF. Because of its simplicity and ease of tune up, a WML might be a better choice for some than a WL. Above is a wider simulation of the WML; it rolls off as frequency decreases, just like the dual MW capacitor terminated mismatched loop from which it is derived; see here. This is why tuning up the WML at the top end of the MSW band is about has good as tuning it up at 1.83 Mhz.

According to EZNEC simulation the RDF of the WML is about 9.5, while the RDF of the original WF is 10.8+ depending on how it is implemented.