Another 40M Directional Antenna, with comparison testing

Jeff VE1ZAC November 2020 r1

My plan on 40M antenna enhancements was to assemble a couple of popular directional antennas to compare with an OCF dipole for 40M. Being located in the NE of the continent means the SW-NE line with a reversible antenna array is excellent for use in contests and for a large amount of interesting DX.

I have an 80M OCF dipole (Carolina Windom in Radio Works parlay), the dual loop array for 20M and 40M from my last piece "A New QTH, and a New Loop Array at VE1ZAC/ VE1ZU" and a receive only SAL20 shared apex loop array from Array Systems.

Now it's time for a vertical array. I have the property space to play with one of these and much time was spent evaluating the many possible configurations.

Some self imposed requirements:

- Being a single band antenna, I want it matched to 50 ohm coax at the antenna at 1.5 SWR or better. (Not something I normally insist on)
- I have some random aluminum tubing of various diameters and will make use of it for the elements.
- I prefer in ground radials because of the desire to use the field for other activities and to facilitate mowing.
- Switching to be accomplished by DC over coax.
- Must be rated for a KW of power
- NE-SW primary directions but omni mode also needed.
- If a 4 direction array is not chosen, this antenna should allow expansion if desired in the future. (unlikely at this time, but you never know !)
- Compromised radial field. Fit the antenna system in a reasonably compact foot print. (Don't obsess over the last .25 dB of gain.)

What to build ?

For ease of implementation, a 2 element array could fill most of my requirements, so long as it can also work broadside. This also would use up my stash of aluminum tubing. Modeling shows good forward gain potential and quite good front to back ratios over a compromised radial field and good ground all around the antenna and out to several wavelengths.

These will be ¼ wave elements and the optimum radial field is suggested by several studies at 60 elements of near ¼ wavelength long or 32 feet. That's a lot of radials. Modelling and extensive study of published data suggests that 20 radials of 1/8 wavelength will not give up much in forward gain. In the worst case maybe 1 dB. To help the directivity out a little I added 4 x ¼ wavelength radials to each element. A ground rod at each element and a copper radial connector halo with soldered radial connections allowed the radials to be fabricated in a work shop and then dropped in place around the element bases. Each element was secured to the soil with a galvanized spike. The ground rod was connected to each radial halo copper ring.

The elements are not the same diameter due to the odd sizes of tubing I had on hand. I elected to make them the same length and gambling on the

base impedance being at least close. The odds on them being identical are slim anyway since we are relying on radials on the ground. There are too many variables to predict a perfect match.

The space I set the antenna on was chosen for good elevation and in a section of my property that needs some grass attention. This field has not been maintained in many years and it is due for a turn over and fresh seeding with pasture mix grasses. I tilled up and seeded the antenna area in advance so I won't have to pull up radials while working the ground around the antenna next year. The space laid out is approx. 30 feet by 60 feet.

I will skip my usual EZNEC model explanations as the subject of arrays have been covered extensively by many others. The only interesting part of my modelling refinements was to see how well my modelled base complex impedances matched the actual measured numbers. If they are close, it indicates my model grounds and radials are realistic and can be used to qualify the model.

<u>A look at the impedance isuses</u>

The EZNEC proposed base impedance of a single element based on a MININEC ground is 34 –j41 , or 53 ohms as a scalar quantity.

After building the antenna and measuring the elements with a VNA at the base, we have 37.3 -j20.3 (42.5 ohms) for one element and 40.2 –j16.7 (43.5 ohms) for the other.

Not bad, when compared to the EZNEC model. This indicates to me that we have captured reasonable ground-radial interactions for a single element.

I want to use the Christman delay line calculations for this antenna, as I did for the previous loop array. Normally one would attempt to make two identical elements for a two element array. But this is pretty hard and in my case could only reasonably be accomplished by adding some L and C to one of the elements at the base to make it match. Since they are so close in value, I ignored any differences and used the EZNEC predicted values in the worksheet, since they were so close.

This is a bit of a shortcut to getting results but since the elements are close and we have plenty of ground vagaries anyway, I chose this method. As you will see, I don't seem to be suffering by using this shortcut.

My EZNEC array projections based on this established ground version and a 100 deg phase shift (model optimized for my desired gain and elevation angle) are:

Phase shift	-100 degrees
Element 1:	16 –j56.3
Eelment 2:	45 –j15.3

<u>Christman calculation results</u>

Armed with these EZNEC element impedances, the W6RMK spreadsheet was used to calculate the two feed line lengths. Mine came out to 18.8 feet and 51.6 feet. Since my elements are 32 feet apart, and my switching network and feed point is midway between them, the actual delay line is added to one feedline and switched between the two for forward – reverse direction. I used 18.8 foot feedlines and 32.8 feet.

The usual relay system is in the box shown. I desired 3 direction modes: SW, NE and omni/broadside. DC over the coax transmission line controls the relays.

There are 3 relays in my usual surplus plastic toolbox housing. Two are associated with switching the feeds and one is used to ground/unground the end of an L C match used in broadside mode. Each feedline has a ferrite sleeve choke and the transmission line has a large toroid choke.

The spreadsheet predicted my feed point impedance would be 36 –j24.2.

The measured feed point impedance after building was 37 –j20.3 in one direction, and 40.2 –j16.7 in the other. Not bad. To lower the reactance slightly would only require a capacitor, in addition to the feedline capacitor to isolate the DC control signal from the RF.

After feeding with 225 feet of RG213, I have the following impedance at the shack end:

NE: 1.35 SWR and 38 –j5.6
SW: 1.55 SWR and 32.6 -j4.1
Both: 1.65 SWR and 30.36 j4.2

I am happy with this result. The antenna handles a kilowatt of power and shows an excellent receive F/B ratio.

To determine if the forward power gain is there requires anecdotal performance observation. I have not figured out a reasonable way to do range measurements ….yet. (Working on it)

Comparison results

This comparison is for 40M only and compares the OCF 80M dipole, the 2 element vertical and the dual loop array. The Brewster take-off angle is likely more important to consider when comparing antennas at 4 or 5 wavelengths out. The EZNEC calculated elevation angles are fine but assume a very linear and level ground out to about 4 wavelengths or farther. I don't have that here. I am on the side of a gentle slope with a lake at the bottom and more rise behind me up to another 100 feet at 3 or 4 KM. *(Sorry about mixing metric and imperial units. Canada , eh ?)*

Log notes for 40M antennas at VE1ZAC Sept 2020 R3												
				Relative Rcv S meter:	Lobes	F/B 4 S	F/B 2 S					
	UTC				+	++	+			*W6EL*	*W6EL*	
Date	**time**	**SFI /K**	**Station / call**	**QTH**	**OCF**	**Verts**	**Loops**	**Dir**	**Dist KM**	**Angle**	**Hops**	**Notes**
Sep-07	20:25	70-1	BC "TheVault"	Ireland	S4	S6-7	S8-9	NE	4147	19	F-F-F	6985 AM
	20:50	70-1	LY2PX	Lithuania	S0	S1	S3	NE	6093	17	F-F-F-F	SSB
	21:00	70-1	J69DS	St Lucia	S3	S5	S5	S	3305	14	F-F	SSB
	21:12	70-1	CHU	Ottawa	S4	S5	S6	W	1300	6	E	7850 AM, 4 S F/B loop
	21:30	70-1	W1AW	Harford, CT	S7	S7	S7	S	655	38	F	CW
Sep-08	11:37	70-0	W9JK	MidWest	S0	S3-4 *	S2	SW	1970	27	F-F	*Noisy
	23:00	70-0	D2EB	Angola		S3-4 *		E	9900	7	F-F-F-F	* Worked on low power CW
Sep-09	18:00	70-0	VA3KB	South Ont.	S2	S1	S0	W	1300	6	E	
	21:00	70-0	HF1920PS	Poland	S0	S1	S3*	NE	5892	8	E-F-F	* Worked on low power CW
	21:30	70-0	TZ4AM	Mali	S4	S5*	S4	NE	6280	10	F-F-F	* Worked on low power CW..didn't get through on loop
	22:00	70-0	DK1K	German Border	S6	S7	S8	NE	5381	13	F-F-F	
	22:05	70-0	TF8KY	Iceland	S7	S6	S7	NE	3473	14	F-F	
Sep-10	2:45	70-0	K7KG	Western US	S0	S3	S2	SW	3920	11	F-F	
	2:50	70-0	W6LVP	West Coast US	S2	S6	S4	SW	4720	8	F-F	
	11:58	70-0	W8MQ	Illinois	S4	S7	S4	SW	1510	16	F	
	12:00	70-0	N3RTD	Maryland	S0	S4	S0	SW	1000	9	E	
Sep-14	11:20	70-0	VK6KI	Australia	S4	S5-6	S4	NW	17,622	8	E-F-F-F-F-F-F-F	Polar path
Sep-19	10:40	70-1	JH1H	Japan	S0	S1-2 *	S0-1	NW	10674	9	F-F-F-F-F	* 500 W ,Could also hear VK talking to JH1H
Notes:												
W6EL:	Propagation program											
Radio:	IC7700, no atten., no gain											
S:	S unit, approx 6 dB											
* :	Comment											
+ :	35 deg Brewster elevation											
++ :	15 deg Brewter elevation											
F/B:	Receive front to back ratio											

What does it all mean ?

Close in, single hop contacts: Hard to tell the difference in the antennas. The OCF has a complex cloverleaf look to its gain pattern. It also has some gain over a 40M dipole if you are in one of the lobes. If your target station is in one of the nulls, you would see a drastic difference. Same thing goes for being null of the arrays. However, if you are "Downwind" of the array gain, you can see how they are similar for close in single hop contacts.

Two to four hops: You can clearly see the arrays outperforming the OCF.

Real DX: the arrays are the winner, and the vertical array outperforms the dual delta loop array by a margin.

On transmit, the vertical array clearly outperforms the 80M OCF dipole and the loop array by an obvious margin. Angola, Mali, Japan and the US mid West are 2 way QSO's to compare.

Utility

The OCF Dipole and the dual loop array are convenient and easy to use on 2 or more bands. The dual loop array especially, has attractive F/B figures on 20M and 40M..two of the most popular contest and dx bands. With fixed directivity in the NE-SW direction and my QTH, this is a very useful antenna. It also provides a backup for my tower Steppir on 20M. For all band use, it's hard to argue with the utility of the 80M OCF dipole.

For 40M use only, the vertical array is a clear winner. I have used it in three contests now, and many QSO's and it has produced stellar results. I am a fan.

As far as mechanical issues , I would rank the vertical array the easiest to deal with and pretty much wind insensitive *(I have one set of guys on each element for this reason)*, and the OCF dipole and dual loop array slightly more complex, and wind sensitive.

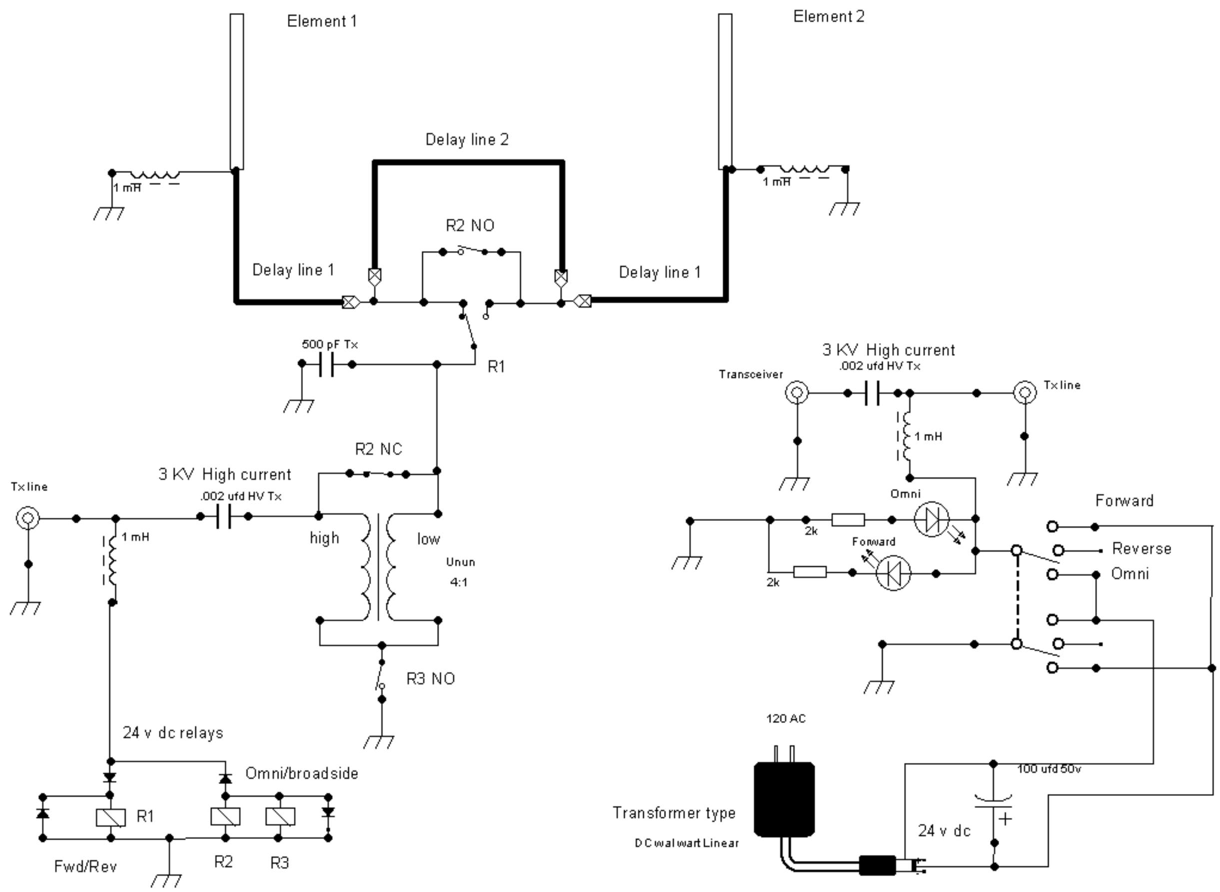
Retention: the bottom line

Am I willing to give up one of these antennas ? Nope. I love them all. Weather might have something to say in the future. But for now, they are all keepers and a joy to use in my rag chew, dx and contest activities.

In this picture you can just see parts of the dual delta loop array located down the slope from this vertical array. Down by the lake shore is a SAL20 receive array. The small plastic tube on the back of the mounting post holds a golf umbrella to provide shelter on sunny or wet days while working in the control box.

Schematic

Not well drawn, but here is what my control system looks like. The relays are 24V DC motor control open frame relays. The 4:1 unun is used to improve the match between the lower impedance of two elements hooked together to 50 ohms. The 500 pfD shunt C helps reduce the reactance of the system. Note, these matching components may not work for all builds. There is a static bleeder choke at each element to a ground rod.



The as built picture. Started out neat but morphed into this mess as changes were made on site. Works fine though. 7 MHz allows for this kind of poor wiring. The white foam material at bottom is to discourage the local chipmunks that decided this was a good spot to stash acorns. (Discovered while showing off the build to a visiting ham.)

References:

- Christman method Excel worksheet: *Jim Lux, W6RMK, w6rmk@earthlink.net*
- *Low Band DXing. 5th Edition. ON4UN John Develdore ARRL Publications*
- *EZNEC + V 6.0 W7EL https://www.eznec.com/*