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A 3-Element 160 Meter Vertical Array

In May/June 2008 *NCJ*[1] Al Christman, K3LC, suggested adding a fifth element at the center of a standard 4-square array to improve the pattern. In his scheme the 4-square was transformed into two reversible 3-element arrays at right angles to each other. In the 3-element array, one element was parasitic and two were driven. The remaining two elements were inactive.

After reading the article I realized I had already used a very similar 3-element array on 160 meters, and I can say that it works as advertised. The pattern is very good indeed. My array had one important difference, however. Only the center element was driven; all other elements were parasitic. With this configuration pattern nulls were not quite as deep as the K3LC version, but they were very close. In exchange I had an antenna that eliminated *all* of the transmission lines and phasing networks associated with a driven array. These components were replaced with a small tapped inductor and a SPDT relay at the base of each parasitic element and a simple tapped inductor at the base of the driven element.

Incorporating this idea into a 4-square and eliminating the transmission lines and phasing networks should reduce losses substantially and save a lot of time, not to mention the expense of phasing networks and transmission lines. The new arrangement is also much easier to adjust for peak performance than a standard 4-square or even K3LC's version. There is, of course, the disadvantage of an additional element in the case of a modified 4-square, but if you already have four elements in place, the center element does not have to be self-supporting. It could be a wire suspended from the other four elements. A number of similar arrays use a tower as the driven element, with the parasitic elements suspended from the tower.[3, 4]

What follows describes my 160 meter array "as built." The approach used is very flexible, and there are many different ways it could be implemented to suit a particular situation. You could use the 3-element array just as I did or modify a 4-square.

The N6LF 160 Meter Array

Figure 1 is a sketch of the 160 meter 3-element array. Each element is 80 feet of 4-inch aluminum irrigation pipe, top loaded with two 40-foot lengths of #12 wire sloping downward at about 45°. The length of each loading wire was adjusted so the elements — *without* base loading — were individually self-resonant at about 2.0 MHz. This made it possible to adjust the final resonant frequencies by adding a small tapped inductor (about 5 µH) in series with the base of each element.

For director operation a tap point was selected that made the element resonant at 1.95 MHz; for reflector operation a tap was selected for resonance at 1.8 MHz. The self-resonant frequencies of the parasitic elements were adjusted with the other two elements *open circuited*. After both parasitic elements were tuned, one was set to be a reflector and the other a director. At this point the driven element was tuned to resonance (1.83 MHz in my case) and matched to the feed line by varying the tap on the base coil.

The change from director to reflector was done using a SPST relay and two taps on the base inductors for the parasitic elements (see Figure 2). The inductors were made a bit larger than the minimum required size so the two values of inductance required could be reached simply by moving the taps. The bottom end of the coil is not connected to anything. This was just a matter of convenience during adjustment.

To match the feed line to the driven element I also used a small inductor with two taps, but no relay was needed. One tap was connected directly to ground and used to resonate. The other tap was adjusted for minimum SWR on the input feed line — very close to 1:1 at 1.830 MHz. Figure 3 shows an example of a base inductor and relay; I used a vacuum there only because it was handy. A simple open contact relay would be fine for this application, as long as the contacts can carry the current. One small trick was to invert the NO and NC contacts between the two parasitic elements so that with no power to the relay, the antenna would fire east. With power applied it would fire west. In my case I powered the relay via the coaxial feed line, using RF chokes and capacitors to isolate the RF from the dc voltage for the relay.

Radiation Patterns

Figures 4 and 5 depict the radiation patterns derived from *NEC*. The predicted parasitic element currents assume 1 A at

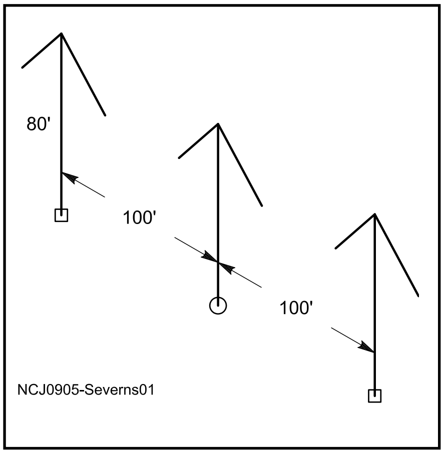

Figure 1 — A *NEC* view of the N6LF 3-element 160 meter array

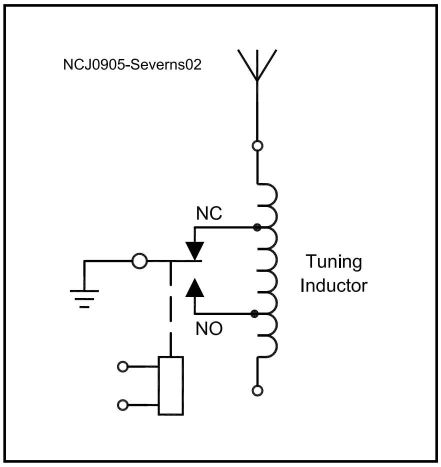

Figure 2 — Tapped base inductor with a relay to change from reflector to director operation

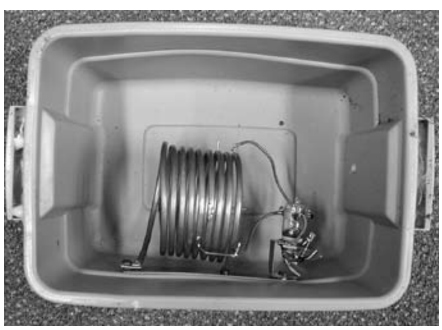

Figure 3 — Relay and base inductor example

[1]Notes appear on page 15.

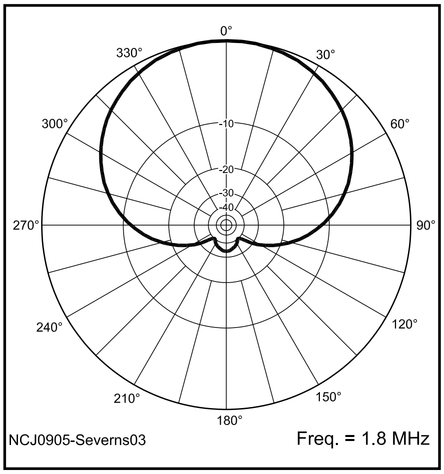

Figure 4 — N6LF array azimuth pattern at 20° elevation

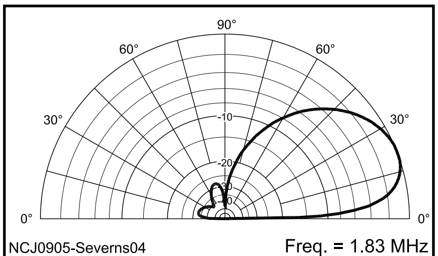

Figure 5 — N6LF array elevation pattern at 0° azimuth

0° degrees in the driven element. Table 1 offers a comparison to those for the K3LC array. Both the patterns and the currents in the N6LF array are close to those specified by K3LC.

Joe Johnson, K3RR, has suggested another way to tune the elements.[4] Instead of reducing the top loading so the elements are self-resonant above the desired frequency and using an inductor to resonate, he suggests using a little extra top loading so that the elements are self-resonant below the desired frequency. He then resonates the elements again using series capacitors. This might prove more efficient and, if part of the capacitance is variable, make adjustment very easy. A relay then would be used to short out a portion of the capacitance to switch from director to reflector.

Building Your Own Version

If you're not replicating the antenna as I've described it, then you'll have to determine in advance the proper element height and top loading using modeling software such as *EZNEC*.[2] When you do this you will find that the achievable current amplitudes and phases and the resulting pattern will depend on the height and loading of the verticals, as well as on element spacing.

Table 1
Element current amplitude and phasing in the N6LF and K3LC arrays

	N6LF	**K3LC**
Director	0.43 A @ –128°	0.5 A @ –130°
Reflector	0.59 A @ +127°	0.5 A @ +130°

When all the elements in an array are driven you can have any combination of phase and amplitude for the element currents — at least in principle. When some of the elements are parasitic, however, there are built-in limitations to the achievable element current phases and amplitudes. For example, I found I could much more closely approximate the K3LC element currents with 80-foot top-loaded elements than I could with full quarter-wave (130-foot) elements. This is not to say that the taller elements wouldn't work, but operating as parasitics I could not get as good a pattern because I could not achieve the desired current phases and amplitudes as closely. This was fine from my point of view, since I would much rather put up 80-foot elements than 130-foot elements. The final efficiency was still quite high even with the shorter elements, although I had to be very aggressive with my ground system.

It's been suggested that element length doesn't matter, and all you need to do is tune a parasitic element to resonate at the desired frequency.[5] That is not the case, however. Obtaining a better pattern in a parasitic array by using shorter loaded elements is nothing new. For example, a 2-element Moxon style Yagi — where the ends of the elements are bent toward each other — can have a substantially better front-to-back (F/B) than the same antenna with full-sized elements. In a recent talk, Tom Schiller, N6BT — who has a great deal of experience with parasitic arrays — discussed the utility of using shorter, loaded elements in a parasitic array.[6]

Conclusions

Overall, Al's idea to improve the pattern of a 4-square by converting it into two 3-element arrays at right angles works just fine. There are many variations on this theme to fit different situations.

Notes

[1]A. Christman, K3LC, "Modifying the 4-Square Array for Improved Front-to-Back Ratio," *NCJ*, May/June 2008, pp 5-6
[2]R. Lewallen, **www.eznec.com**
[3]J. Devoldere, ON4UN, *Low-Band DXing*, (4^{th} ed), ARRL, pp 13-30 through 13-35
[4]J. Johnson, K3RR, private communication
[5]J. Devoldere, ON4UN, *Low-Band DXing*, (4^{th} ed), ARRL, p 13-28
[6]T. Shiller, N6BT, Pacificon 08, Antenna Forum, Oct 17-19, 2008, **www.pacificon.org**

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