The Monoband Log-Cell Yagi Revisited—Part 4: V-ing the Log-Cell Yagi Elements

One perennial design feature of log-cell Yagis has been the use of elements that form a forward **v**. Perhaps the chief proponent of this design feature has been Zimmer, K4JZB, in his 1983 *CQ* articles on log-cell Yagis, although the idea reappears from time to time in related contexts.[1] For one 5-element version of the antenna, the text claims a 16 dB gain, although the frame of reference for the gain figure is not given.

All of the designs that we have explored in the first three parts of this series have used linear elements. Given the widespread repute of **v**-ed elements to improve gain, directivity or other aspects of beam performance, it may be useful to explore the matter further. Since **v**-ed elements present no challenges to the limits of *NEC*, we may use this modeling software to develop some appropriate comparisons between various types of antennas using linear and **v**-ed elements.

The V-ed Dipole

In order to understand the performance of **v**-ed beams, we should begin with the **v**-ed dipole, that is, a dipole that is bent forward from linear by a certain number of degrees on each side of center. **Figure 1** shows the general outline of the models used in this exercise. A standard 200-inch dipole length is used throughout, with 1-inch aluminum tubing as the material. The model uses a short, 3-segment, linear wire at the center of the antenna in order to provide the feedpoint segment with equal length segments on either side.

[1]Robert F. Zimmer, K4JZB, "Development and Construction of 'V' Beam Antennas," *CQ*, Aug, 1983, pp 28-32; and "Three Experimental Antennas for 15 Meters," *CQ*, Jan, 1983, pp 44-45.

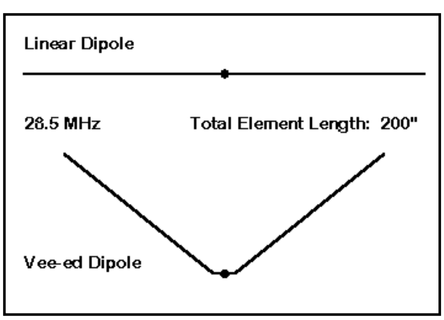

Figure 1—General outlines of linear and horizontally v-ed dipoles.

The degree of **v**-ing refers to the angle made on each side of the antenna relative to a line that would represent a linear element. Hence, 10 degrees of **v**-ing would bend each side of the dipole 10 degrees forward of the linear line. None of the angles used in this test presses any *NEC* limitation for accuracy of results.

Table 1 provides an indication of what occurs when a dipole element is **v**-ed forward. The free-space gain of the antenna decreases for each level of **v**-ing. As well, the feedpoint impedance decreases. Perhaps most significantly, the front-to-side ratio also decreases. **Figure 2** compares the free-space azimuth patterns of a linear and a 40-degree **v**-ed dipole and graphically illustrates the reduction in side rejection for the **v**-ed version.

When used as an inverted-**v** antenna with the legs angled downward, the reduced side rejection is sometimes listed as an advantage, despite the reduction in broadside gain. However, when the dipole is **v**-ed horizontally, nothing is gained by way of directivity or other effect that might be useful in a multi-element beam antenna. Since all of the designs that we shall consider use the $^1/_2$-λ dipole as their starting point, we should not have any expectations that **v**-ing the elements will yield added performance in any particular area.

Perhaps what lies behind the idea that **v**-ing elements may yield added performance is the concept of the **v**-beam, a

Table 1
Gain, front-to-side ratio and impedance of dipoles at various degrees of v-ing.

*Forward Angle (degrees)**	*Free-Space Gain (dBi)*	*Front-to-Side Ratio (dB)*	*Feedpoint Impedance (R +/- jX Ω)*
0 (linear)	2.15	>30	77 + *j*18
10	2.12	21	76 + *j*17
20	2.02	15	70 + *j*15
30	1.85	12	62 + *j*10
40	1.62	9	50 + *j*2
50	1.37	7	37 - *j*8

Note: The total length of the 1-inch diameter aluminum dipole element is 200 inches to yield a feedpoint impedance close to resonance at 28.5 MHz when each side is bent forward 40 degrees from linear. See **Figure 1** for the general outline of the test model.
* Relative to a linear dipole.

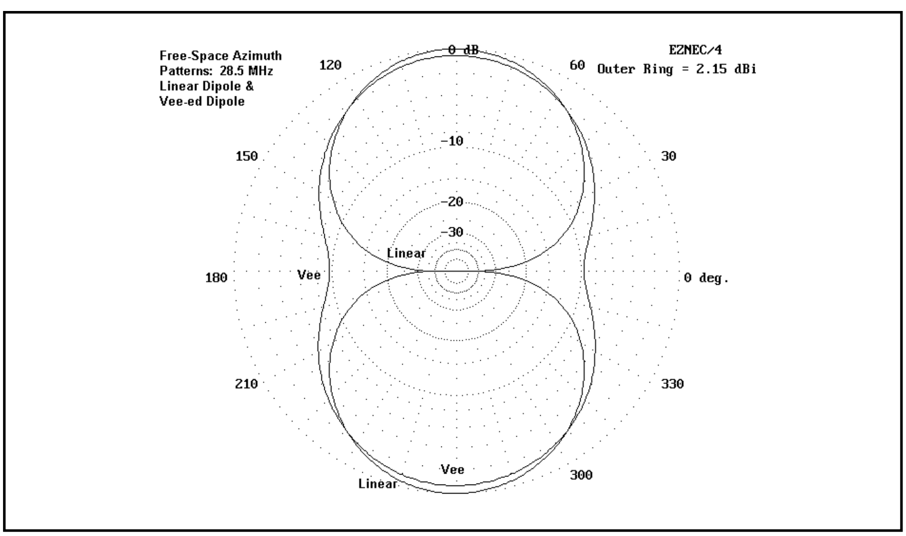

Figure 2—Free-space azimuth patterns for linear and v-ed dipoles at 28.5 MHz.

very old and simple antenna design. However, the **v**-beam is always many wavelengths long and produces many lobes and nulls. When the designer chooses the proper angle between the elements, the main lobes combine to form a single very strong bi-directional lobe set along the line bisecting the angle between wires. There will almost always be lesser lobes and nulls to the sides, that is, roughly broadside to the wires. If one terminates each of the far ends of the **v** with resistors to ground, then the **v**-beam develops a unidirectional pattern.

However, the $^1/_2$-λ dipole develops only a single lobe at right angles to the wire, resulting in a bi-directional pattern. There are no lobes at angles away from broadside that may combine into a single stronger lobe. The dipole lobes can only be distorted from their shape when produced by a linear wire.

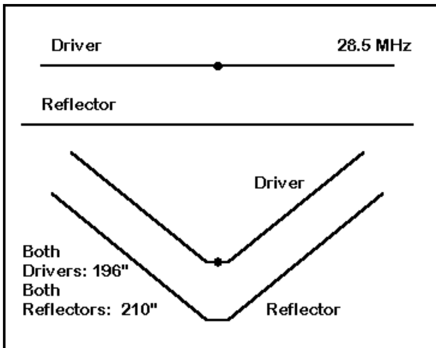

Figure 3—General outlines of linear and horizontally-v-ed 2-element Yagis.

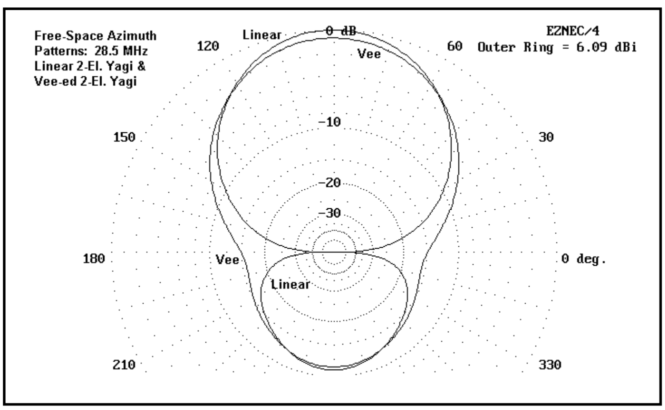

Figure 4—Free-space azimuth patterns for linear and v-ed 2-element Yagis at 28.5 MHz.

2-Element V-ed Beams

Rather than leave the subject with only the dipole as an indicator of the performance of **v**-ed antenna arrays, let's look at a few beam designs, beginning with 2 elements. Throughout, we shall bend the elements forward 40 degrees as a standard level of **v**-ing. **Figure 3** shows the general outline of linear and **v** Yagis using a driver and reflector in each case. The driver length is 196 inches for both antennas, and the reflector is 210 inches long. Element spacing is 48 inches. The **v**-ed version of the antenna shows a feedpoint impedance of 23 + *j*4 Ω at 28.5 MHz, close to resonance. When stretched to linear shape, the impedance rises to 36 + *j*30 Ω.

Figure 4 provides comparative free-space azimuth patterns for the two versions of the Yagi. The **v**-ed version has a free-space gain of only 5.45 dBi compared to the linear version gain of 6.09 dBi. Both antennas have front-to-back ratios of about 10.8 dB, but the **v** shows far less side rejection than the linear antenna. This result is, of course, consistent with the results of our dipole test.

Since our ultimate goal is to evaluate **v**-ed element use in log-cell Yagis, we may revise the outline in **Figure 3** to provide each element with a separate feed point. In this manner, we may directly control the relative current magnitude and phasing on each element. Let's try this experiment to see if **v**-elements promise any improved performance when independently phased.

When independently phased for a maximum rear null, the **v**-ed version shows a free-space forward gain just below 5.9 dBi when the rear element is set at a relative current magnitude of 0.94 and a phase of 141 degrees (with the forward element set to a magnitude of 1.0 at a phase angle of zero degrees). For a maximum null to the rear, the comparable linear rear element must be set at a current magnitude of 0.98 with a phase angle of 139 degrees. Under these conditions, the linear phased array shows a forward gain of nearly 6.4 dBi. **Figure 5** shows free-space azimuth patterns that illustrate the pattern differences. Besides the $^1/_2$-dB gain differential, the low side rejection of the **v** version is clearly evident.

There are no simple means of obtaining the optimal phasing conditions for the **v**-ed phased array. The closest that I have come is the use of a 35-Ω phasing line from one element to the next. Higher values of phase-line characteristic impedance yield lower performance figures. However, unlike available lines, the modeled line required a velocity factor of 1.0, with lesser values producing poorer results. **Figure 6** shows the resulting free-space azimuth pattern, which has a forward gain of just over 5.6 dBi and a front-to-back ratio of just under 17 dB.

All-in-all, we must account the results of our attempt to **v** 2-

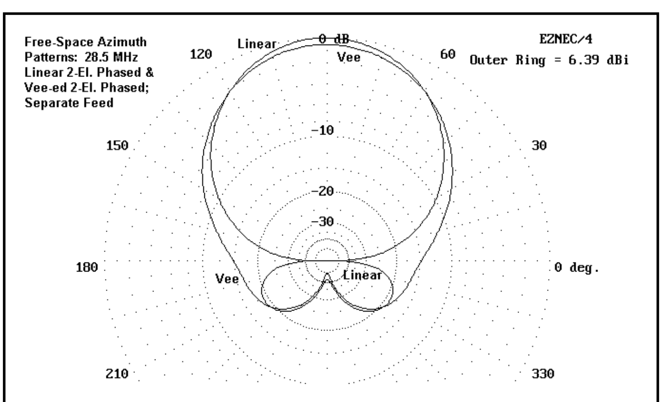

Figure 5—Free-space azimuth patterns for linear and v-ed 2-element phased arrays at 28.5 MHz, using separate feeds for each element.

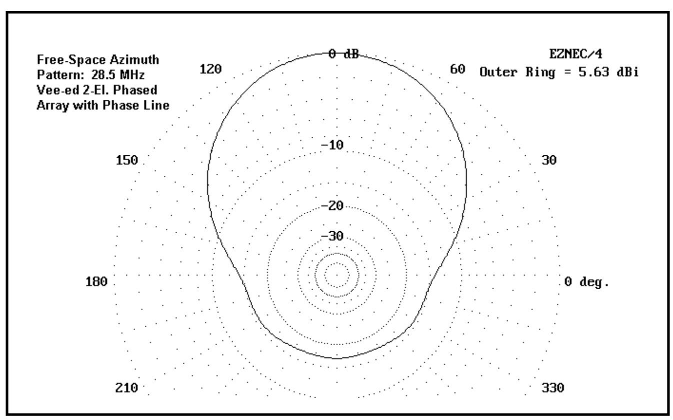

Figure 6—Free-space azimuth patterns for a v-ed 2-element phased array at 28.5 MHz, using a phasing line between elements.

element arrays a disappointment. However, the results should not be surprising, since such arrays depend for their performance directly upon the dipoles that compose them.

The V-ed Log-Cell Yagi

The results of our experiments with 2-element parasitic and phased arrays unfortunately do not bode well for the performance of **v**-ed log-cell Yagis. However, with a multi-element cell and additional parasitic elements, we cannot dismiss the possibility of superior **v** performance without suitable testing. Therefore, I have taken one of Zimmer's designs—a 5-element log-cell Yagi—and developed both linear and **v**-ed models. The general outline of the **v**-ed version appears in **Figure 7**.

The reflector for each model is 211.5 inches long and placed 48 inches behind the 3-element log-cell. Working from the rear forward, the cell elements are 201 inches, 198.8 inches and 196.6 inches, each spaced 24 inches from the next. The director is placed 48 inches forward of the cell and is 187.6 inches long. The phase-line characteristic impedance producing the most usable results was 200 Ω.

Figure 8 shows free-space azimuth patterns for the linear and the **v**-ed versions of this antenna. The linear version is virtually identical to the 5-element log-cell Yagi examined in Part 3 of this series. Once more, the **v**-ed version of the antenna shows lower gain with a reduced front-to-side ratio.

For the **v**-ed log-cell Yagi, the relative current magnitude and phasing on the three driven elements at 28.5 MHz with the 200-Ω phasing line—from front to rear—was 0.87 at 15.9 degrees, 0.52 at 147.2 degrees and 0.32 at 171.4 degrees. These values offer us one more experimental possibility.

Suppose we separately feed each element of the log cell and optimize the current magnitude and phasing on each element. For example, if we set the forward element at a magnitude of 0.7 and a phase angle of 20 degrees, the middle element at 0.67 at 145 degrees, and the rear element at 0.4 at 169 degrees, we can increase both the gain and the front-to-back ratio of the array. The resulting free-space azimuth pattern appears in **Figure 9**.

For a further comparison across the first MHz of 10 meters, we can plot the free-space gain values of the linear and 200-Ω phase-line **v** array against the **v** array with separately fed driver elements. **Figure 10** shows the results. The linear array exceeds the gain of the phase-line-fed **v** array by an average of $^1/_2$-dB. The hypothetical separately-fed array has slightly more gain than the linear array.

In **Figure 11**, we can see the potential front-to-back values for each antenna, with the linear and phase-line-fed **v**-ed array having quite similar values. The hypothetical array using separately fed driver elements is potentially capable of considerably better front-to-back performance.

The difficulty with both the phase-line-fed **v** array and the alternative with separately fed drivers is feeding the system. The **v**-ed array with a phase line shows a tendency toward rapid feedpoint impedance changes, ranging from 50 Ω at 28 MHz down to about 10 Ω at 29 MHz. Indeed, experiments that varied the spacing of the reflector and the director failed to come up with a relatively constant feedpoint impedance

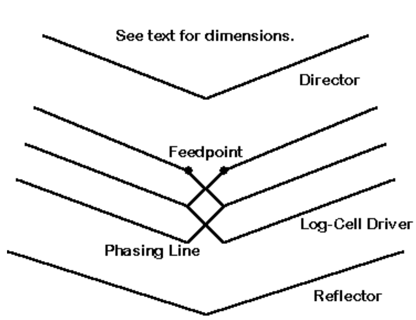

Figure 7—General outline of a 5-element v-ed log-cell Yagi.

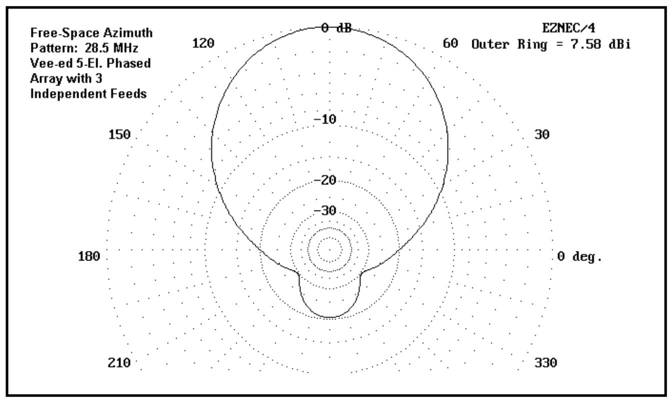

Figure 9—Free-space azimuth patterns for a v-ed 5-element log-cell Yagi at 28.5 MHz, using separate feeds for each element.

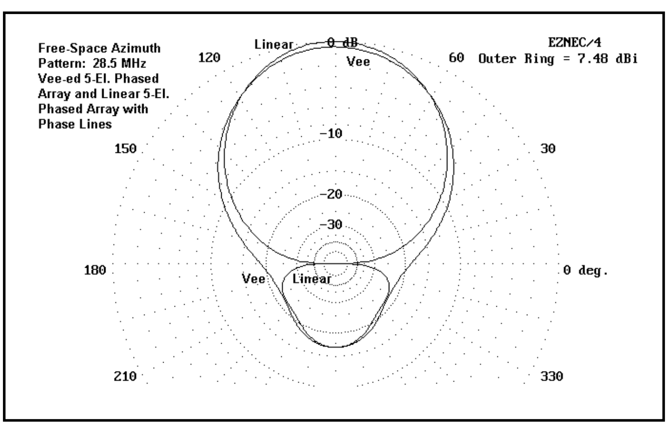

Figure 8—Free-space azimuth patterns for linear and v-ed 5-element log-cell Yagis at 28.5 MHz, using 200-Ω phase lines between driver cell elements.

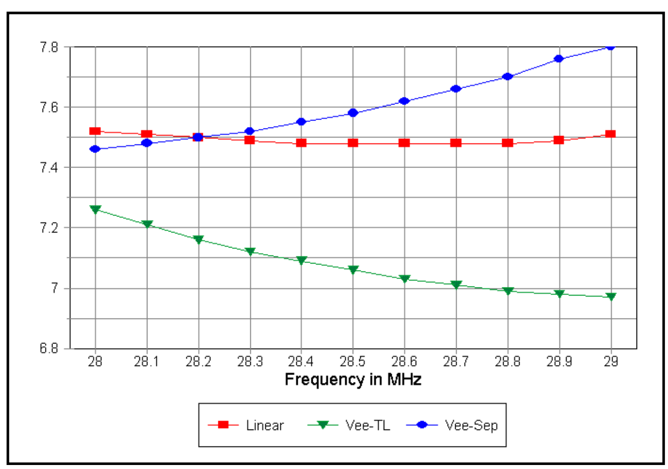

Figure 10—Free-space gain from 28-29 MHz of log-cell Yagis: linear, v-ed with a phase line, and v-ed with separate feeds.

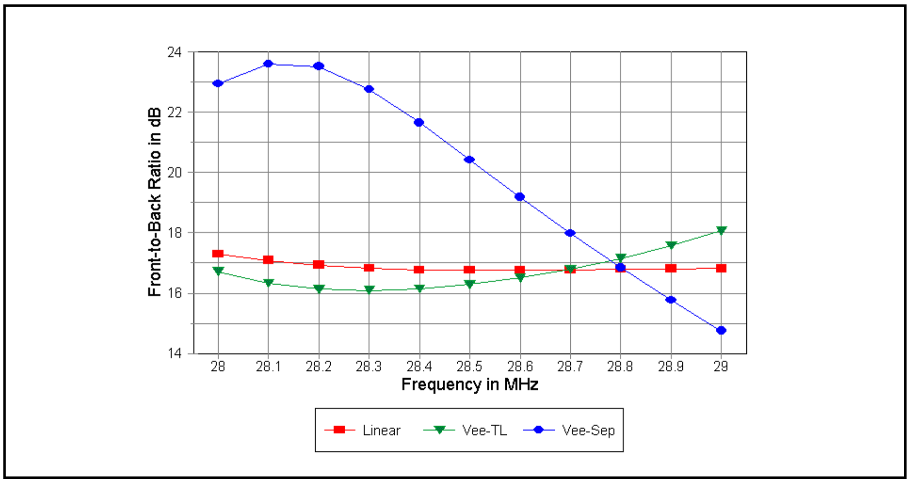

Figure 11—Front-to-back ratio from 28-29 MHz of log-cell Yagis: linear, v-ed with a phase line and v-ed with separate feeds.

for the first MHz of 10 meters. The smooth 50-Ω direct feed obtained by the linear model (which was far from the best of the log-cell Yagis examined in Part 3) is wholly absent from the **v**-ed model. Hence, the **v**-ed model with a phasing line would be useful for only a narrow operating bandwidth.

With separate feed for each driver element, the problem becomes insurmountable for the average amateur construction project. I know of no practical way to effect separate feeds for each element short of phasing networks for each element. The builder would also need the ability to measure currents and phase angles to a degree of precision beyond most ham shops.

The Bottom Line

In the entire set of experiments reported here—plus a considerable number of other models—**v**-ing elements of ½-λ-based arrays has proven to be an exercise in futility. Throughout, the **v**-ed versions always exhibited lower gain and reduced side rejection relative to comparable arrays using linear elements. The comparative azimuth patterns shown in this final part of the series are truly representative of the total collection of **v**-ed models run.

Since each **v**-ed model shows its heritage in the **v**-ed dipole, we may take the performance of that basic antenna in comparison to a linear dipole as correctly indicative of the performance reduction likely to occur in any **v**-ed array when set over and against a comparable array of linear elements. This note, of course, applies only to arrays based upon the ½-λ dipole. As we noted at the very beginning, multi-wavelength **v**-beams are another matter entirely.

The myth of the **v**-ed element array of ½-λ elements has perhaps persisted too long in amateur circles. I hope these notes help dispel it to some degree. More to the point, if a monoband log-cell Yagi is the design of choice to meet a given set of operating needs, then the best of the linear element log-cell Yagis examined in Part 3 will likely always be a better selection than a **v**-ed counterpart. ■