The Monoband Log-Cell Yagi Revisited—Part 3: Some Practical Log-Cell Yagi Designs

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In this part of our visit to the log-cell Yagi, we shall look at some practical designs. The first two versions—using log cells of 2 and 3 elements, respectively—will involve casual designs, typical of those in some of the past literature. Then, we shall examine more complex designs using log cells with 4 and 5 elements, each carefully constructed on LPDA principles. In the process, we shall also look at a test we can perform to estimate the chances for a log-cell Yagi performing to its fullest potential.

Each of our design examples will use a reflector and a director in addition to the log-cell driver. Hence, the total element count will be two greater than the number of elements in the cell. As with all of the models in this series, the designs will be for 10 meters. Scaling to 20 meters in one direction and to 6 meters in the other direction are straightforward tasks.

All models will use uniform diameter elements. Actual element lengths will have to be lengthened if a builder chooses a tapered diameter schedule. Additionally, the builder will have to devise a plan for implementing the phase line associated with each log cell. High impedance lines can be fabricated from round wires. Low impedance lines may require the use of flat aluminum strap or of a double square boom to effect a satisfactory phase line.

Casual 4- and 5-Element Log-Cell Yagis

Our initial models employ either 2 or 3 elements in the log cell, as illustrated in **Figure 1**. Both models use 200-Ω phase lines, with driver elements spaced a standard 2 feet apart. This spacing accords with a number of articles from the past, although the magic in its selection eludes me. The resulting 4-element log-cell Yagi is 96 inches (8 feet) long, while the 5-element log-cell Yagi is 138 inches long (11.5 feet). Coincidentally, these two lengths coincide closely with the lengths of the medium-bandwidth Yagis introduced in Part 1 as comparators for log-cell Yagis. You should keep the graphs for those antennas handy as we examine the two new designs. Both of the antennas in Figure 1 use 1-inch diameter elements.

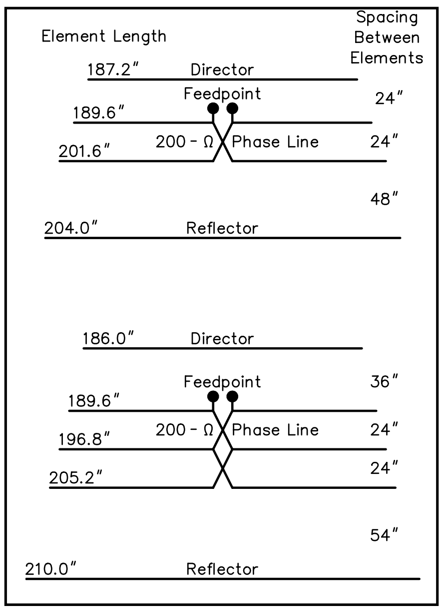

Figure 1—Outlines of 4- and 5-element 10-meter log-cell Yagis.

Both log-cell Yagis exhibit very smooth gain curves over the first MHz of 10 meters, as demonstrated in the frequency sweep graph shown in **Figure 2**. The 4-element antenna with only 2 elements in the cell has the lower gain level, as one might expect. It coincides roughly with the gain curve for the 8-foot 3-element Yagi of Part 1. The 5-element antenna provides only about a half dB of additional gain. In contrast, the 3-element Yagi of the same boom length in Part 1 provides an average free-space gain of about 8 dBi, another half dB greater than the log-cell Yagi with the same boom length.

Figure 3 shows that the two log-cell Yagi designs provide fairly mediocre front-to-back ratios. Nowhere in the specified bandwidth does the front-to-back ratio of either antenna reach 18 dB. (In contrast, both Yagi designs exceed 20 dB front-to-back ratio for most of the first MHz of 10 meters.) Where the log-cell Yagis have an advantage is in the feedpoint impedance. Both designs, as illustrated in **Figure 4**, provide less than 2:1 50-Ω SWR from 28 to 29 MHz. By way of contrast, the two Yagi designs require a beta match or comparable network to yield similar results.

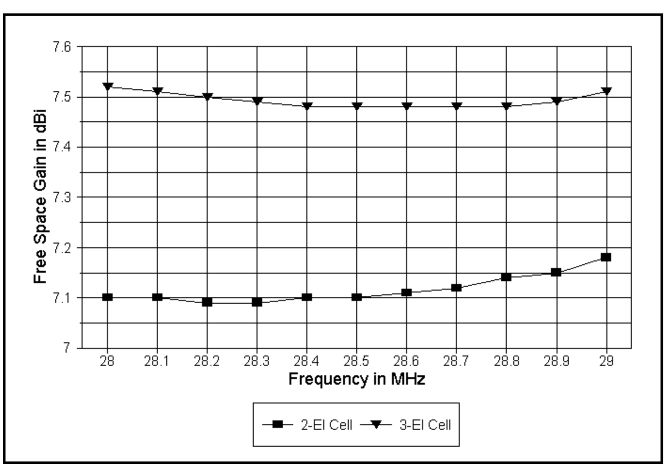

Figure 2—Frequency sweep of the free-space gain of "Short Cell" 4- and 5-element log-cell Yagis (with 2 or 3 elements in the log cell itself) from 28-29 MHz.

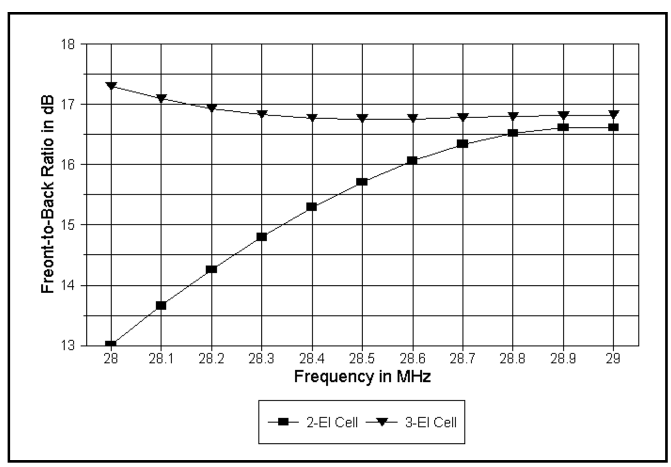

Figure 3—Frequency sweep of the front-to-back ratios of "Short Cell" 4- and 5-element log-cell Yagis (with 2 or 3 elements in the log cell itself) from 28-29 MHz.

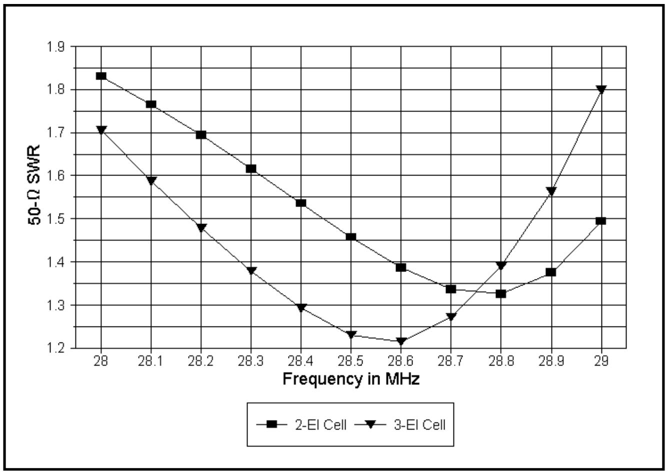

Figure 4—The 50-Ω SWR curves of 4- and 5-element log-cell Yagis (with 2 or 3 elements in the log cell itself) from 28-29 MHz.

Table 1
2- and 3-Element Log Cell Independent Performance

Frequency (MHz)	*28.0*	*28.5*	*29.0*
2-Element Log Cell:			
Free-Space Gain (dBi)	4.58	4.70	4.83
Front-to-Back Ratio (dB)	6.88	7.21	7.48
Feedpoint Impedance (R +/- *j*X Ω)	13 + *j*0	12 + *j*5	11 + *j*11
3-Element Log Cell:			
Free-Space Gain (dBi)	7.09	6.93	6.74
Front-to-Back Ratio (dB)	11.6	11.9	12.0
Feedpoint Impedance (R +/- *j*X Ω)	11 – *j*22	9 – *j*8	8 + *j*3

Table 2
4-Element Log Cell Independent Performance

Frequency (MHz)	*28.0*	*28.5*	*29.0*	*29.5*
Free-Space Gain (dBi)	7.24	7.47	7.47	7.29
Front-to-Back Ratio (dB)	17.7	14.0	12.8	13.1
Feedpoint Impedance (R +/– *j*X Ω)	95 – *j*2	39 – *j*11	39 + *j*12	75 + *j*4
50-Ω SWR	1.90	1.41	1.42	1.51

The two log-cell Yagis, then, require extra elements to provide performance that fails to equal the performance of well-designed 3-element Yagis. One only skirts the issue by saying that the failure results from casual design, since that statement gives no clue of how to distinguish casual from careful design. However, there is a fairly simple modeling test we can perform as a measure of a log-cell Yagi's performance.

If we extract the log-cell driver elements from the overall antenna, we may model them independently. In a well-designed log-cell driver, the array will show fairly high gain and a feedpoint impedance that does not depart radically from the values obtained when the driver is part of the total log-cell Yagi.

Table 1 provides values for the 2- and 3-element log cells extracted from the antennas we have been examining. The checkpoints at 28, 28.5 and 29 MHz for both cells show fairly low gain, with the 2-element cell especially low. (Although registered for reference, the low front-to-back ratios are of no concern in this test.) The feedpoint impedances of the cells are roughly one-fourth the values obtained for the complete antennas. We shall want to keep these figures in mind as we check more complex and more carefully designed log-cell drivers.

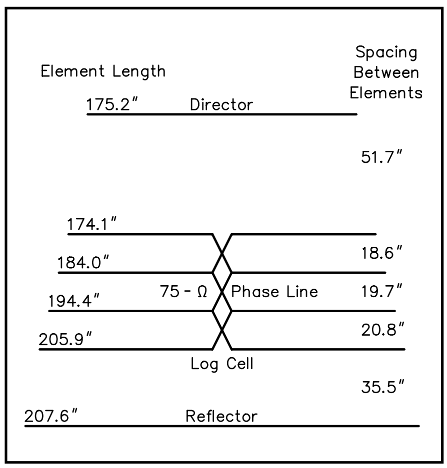

Figure 5—The outline of a 6-element 10-meter log-cell Yagi.

A 6-Element Log-Cell Yagi

The 6-element log-cell Yagi, with a 4-element log cell, shown in **Figure 5**, is adapted and scaled from the Rhodes and Painter log-cell Yagi for 20 meters that appears in *The ARRL Antenna*

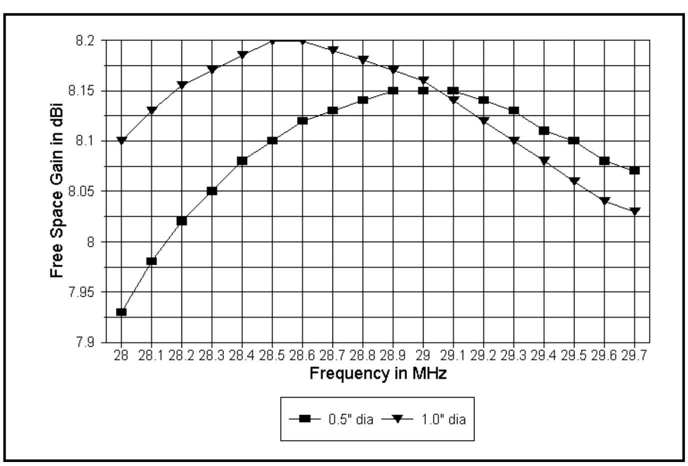

Figure 6—Frequency sweep of the free-space gain of 6-element log-cell Yagis (with 4 elements in the log cell itself) with element diameters of 0.5- and 1-inch from 28-29.7 MHz.

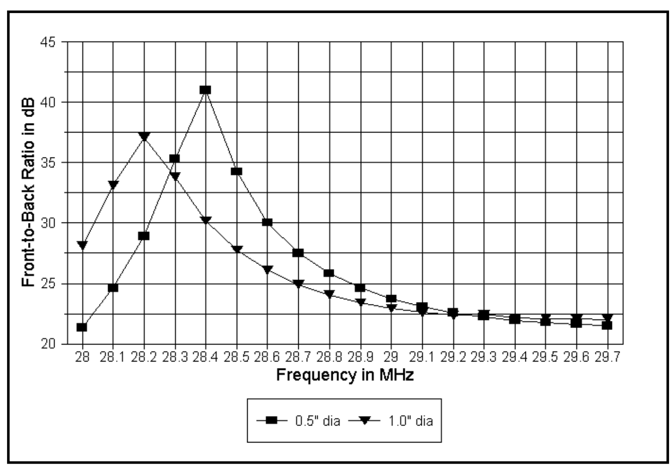

Figure 7—Frequency sweep of the front-to-back ratios of 6-element log-cell Yagis (with 4 elements in the log cell itself) with element diameters of 0.5- and 1-inch from 28-29.7 MHz.

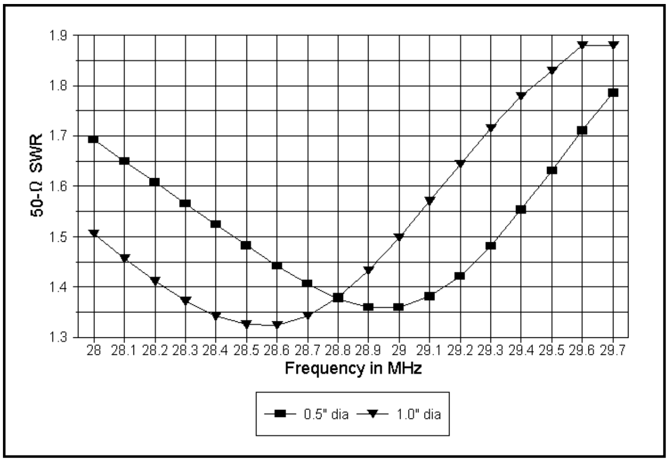

Figure 8—The 50-Ω SWR curves of 6-element log-cell Yagis (with 4 elements in the log cell itself) with element diameters of 0.5- and 1-inch from 28-29.7 MHz.

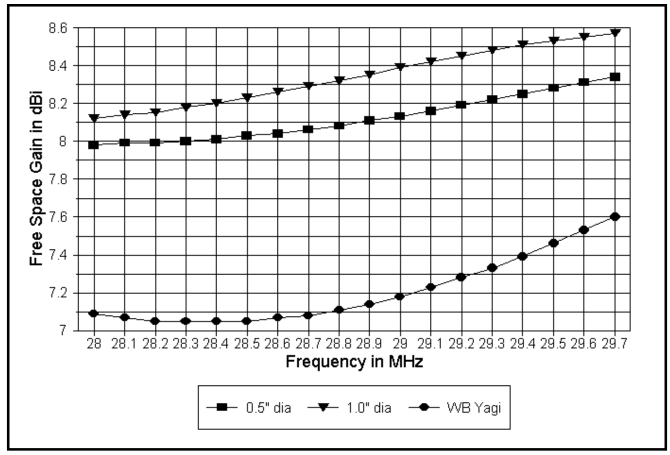

Figure 10—Frequency sweep of the free-space gain of 7-element log-cell Yagis with element diameters of 0.5- and 1-inch from 28-29.7 MHz. For comparison, values are also given for a 4-element wide-band Yagi.

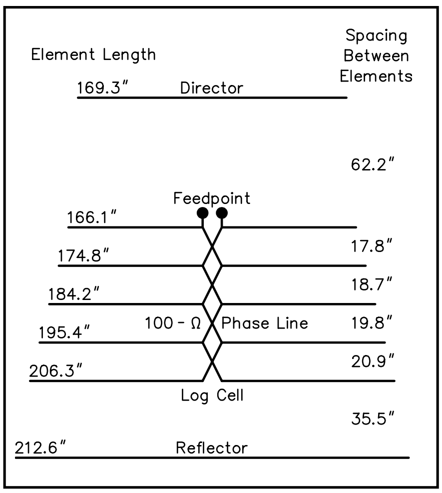

Figure 9—The outline of a 7-element 10-meter log-cell Yagi.

Table 3

5-Element Log Cell Independent Performance

Frequency (MHz)	28.0	28.5	29.0	29.5
Free-Space Gain (dBi)	7.31	7.38	7.42	7.43
Front-to-Back Ratio (dB)	12.0	12.4	13.4	15.2
Feedpoint Impedance (R +/– *j*X Ω)	34 – *j*6	46 + *j*14	80 – *j*1	46 – *j*27
50-Ω SWR	1.51	1.37	1.60	1.77

Book.[1] The log cell has been designed according to LPDA principles, using an element length and spacing ratio of approximately 0.95. This ratio, when applied to a pure LPDA, tends to produce more gain but a lesser front-to-back ratio than lower numbers—for example, the value of 0.90 used in the LPDA design we examined in Part 2. The higher ratio value also produces a shorter cell for the same number of elements. The entire antenna, including the reflector and director, requires a 12.2-foot boom, nearly as long as the 4-element medium-bandwidth Yagi presented in Part 1 as a potential comparator.

If we extract the log cell from the antenna, we obtain the checkpoint values recorded in **Table 2**. Note the relatively uniform gain across the entirety of 10 meters, as well as the 50-Ω SWR values. According to our test, this log cell promises to form the basis of a good antenna that may be useful across all of 10 meters.

Before we look at the modeled performance figures, we should note an additional dimension of this antenna. The phase line impedance is low (75 Ω). In addition, if we use different element diameters, we obtain results that change to a degree that is greater than the changes we might expect in a Yagi using the same two element diameters. The effects of element diameter on the log cell driver (or on LPDAs) are significant. Therefore, the performance graphs for this antenna will record values for both ½-inch and 1-inch diameter elements.

Free-space gain figures appear in **Figure 6**. The fatter element model not only shows a gain peak that is lower in frequency than the thinner version, but as well its peak gain values are higher. Moreover, the curve is flatter. The gain values rival those of the 3-element medium-bandwidth Yagi on a 12-foot boom, but do not match the values for the 4-element medium bandwidth Yagi on the 13-foot boom. Both of the Yagis, of course, only covered the first MHz of 10 meters.

The front-to-back values are less radically different, as illustrated in **Figure 7**. Essentially, the thinner version is capable of a higher peak front-to-back ratio. However, both versions of the antenna exhibit better than 20 dB front-to-back ratio across the 28 to 29.7 MHz span.

Both versions of the antenna exhibit acceptable SWR curves across all of 10-meters, as shown in **Figure 8**.

A 7-Element Log-Cell Yagi

The bandwidth of 10 meters presses the 4-element log cell to its limits, although the 6-element log-cell Yagi does manage to cover the band with good gain, good front-to-back values, and a direct 50-Ω feed system. We can improve upon the design by adding one more element to the log-cell to obtain the design shown in **Figure 9**. The 5-element log cell for this antenna uses the same tapering ratio for elements in the log cell. However, using an additional element allows the longest element to be a bit longer and the shortest element to be a bit shorter. The cost is a longer boom, about 14.6 feet long in this case. The phase line is 100 Ω.

Table 3 provides a look at the performance of the log cell independently of the entire antenna. Gain is even more uniform across the band than for the 4-

[1]Notes appear on page 18.

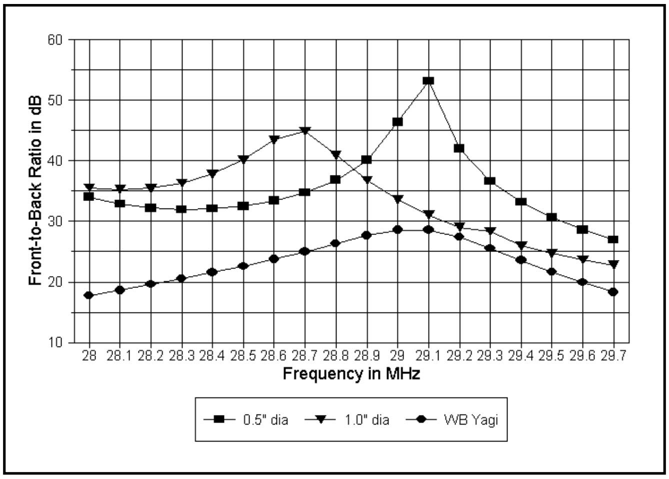

Figure 11—Frequency sweep of the front-to-back ratios of a 7-element log-cell Yagis with element diameters of 0.5- and 1-inch from 28-29.7 MHz. For comparison, values are also given for a 4-element wide-band Yagi.

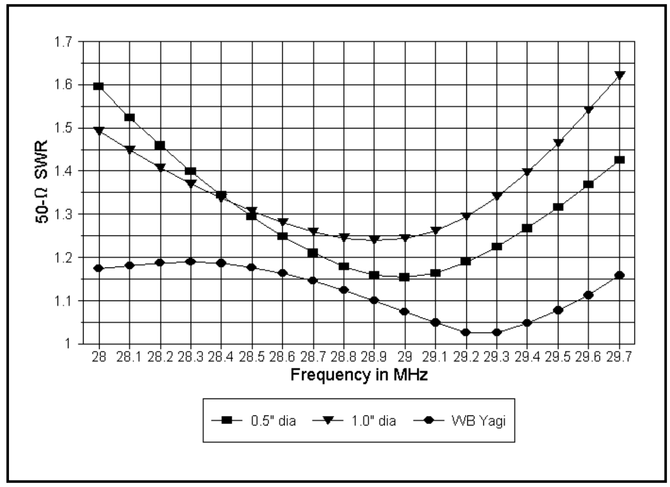

Figure 12—The 50-Ω SWR curves of 7-element log-cell Yagis with element diameters of 0.5- and 1-inch from 28-29.7 MHz. For comparison, values are also given for a 4-element wide-band Yagi.

element log cell, with acceptable 50-Ω SWR figures. Once more, the front-to-back figures are unimportant in this context, since the parasitic elements will establish those values in the final antenna. In fact, the log cells used in these antennas are designed for gain rather than for a balance of operating characteristics (just as was the case for the 2-element cell in the 3-element array examined in Part 2). We should expect the overall antenna to reflect the potentials of the log cell.

Figure 10 shows the free-space gain of two versions of the resulting log-cell Yagi, one using 1/2-inch diameter elements, the other using 1-inch diameter elements. For contrast, values are also shown for the 4-element wide-band Yagi, introduced in Part 1. We should expect lesser performance from this 8-foot boom Yagi. If you desire, you may substitute the values for the 8-foot-boom LPDA.

The differences between the half-inch and one-inch versions of the log-cell Yagi are even more dramatic than for the preceding model, with nearly 0.25 dB differential in gain in places across the band. Values for the half-inch model are similar to those for the 3-element 12-foot boom medium-bandwidth Yagi, but the log-cell Yagi covers the entire 10-meter band. The one-inch model shows only slightly less gain than the 4-element medium-bandwidth Yagi. For either model, the gain curve is very smooth, illustrating the benefit of the extra element in the log cell.

One reason for adding the wide-band 4-element Yagi to the graphs is that it demonstrates the incremental improvement in front-to-back ratio provided by the 7-element log-cell Yagi all across the band, as shown in **Figure 11**. Because no element length adjustments were made when changing element diameters, the half-inch model exhibits the superior curve, with a front-to-back ratio better than 30 dB up to 29.5 MHz. The one-inch model, with a few added adjustments, can replicate the half-inch model curve, but with a slightly lower peak value. If you refer to the azimuth "snapshot" in Part 1 of this series, you will also learn that the rear quadrants show a very well-behaved rear lobe with no major quartering side lobes to falsify the impression left by the 180-degree front-to-back values.

The 50-Ω SWR curves, shown in **Figure 12**, demonstrate that the 7-element log-cell Yagi has a smoother curve than its 6-element counterpart. The curve for the version using 1-inch diameter elements is flatter, but does not dip quite so low as the curve for the half-inch version. However, adjustments to the exact phase-line characteristic impedance would likely permit either curve to bottom at close to 1:1 SWR. The phase-line characteristic impedance selected for the models represent a standard number, but actual construction would permit refinements.

Summing Up So Far

The development of a log-cell Yagi requires careful attention to the design of the log-cell driver to obtain optimal results. Well designed log-cell Yagis are capable of good gain, but their chief operating characteristics that fall into the range of excellence (when compared to other available designs) are the front-to-back ratio and the operating bandwidth. As the 6- and 7-element log-cell Yagis demonstrate, the antenna type is capable of well over 6% frequency coverage in a monoband design.

Designing a log-cell Yagi for gain as we cross into Y2K appears to be an exercise in futility. Although Yagi design in the late 1970s and early 1980s had yet to reap the benefits of computerized optimization, current Yagi design can provide as much or more gain for a given boom length than log-cell designs. The Yagis have the additional advantage of mechanical simplicity, since they do not require the precision construction of a phase line to interconnect the elements in the log cell driver.

An interesting example of this point can be found by modeling the 5-element log-cell driven Yagi in Orr and Cowan.[2] The antenna uses a 2-element log-cell with a reflector and 2 more directors. This design on a 21-foot boom is capable of a peak free-space gain of about 9.5 dBi, with a very sharp peak in both the operating characteristics and the SWR curve. The rear lobes were acceptable but the front-to-back ratio exceeded 20 dB for only a narrow bandwidth.

I had occasion to study 5- and 6-element 20-meter Yagis of existing design.[3] The boom lengths range from 45 to 55 feet, corresponding to 22- to 27-foot booms on 10 meters. All of the designs were capable of a free space gain of 10 dBi across all of 20 meters, with better than a 20 dB front-to-back ratio. Some, such as the NW3Z/WA3FET OWA 6-element design, were capable of exceptionally low 50-Ω SWR values all across the band. In fact, the OWA design can be scaled readily for 10 meters and provide 1 MHz coverage on a 24-foot boom.[4]

As a gain enhancement, the log-cell driver technique has very limited utility amid current Yagi technology. Its chief merits involve operating bandwidth and front-to-back ratio. However, even here, its utility may be limited when the complexity and weight of the array are factored into antenna design and construction decisions. The medium-bandwidth Yagis described in Part 1 as comparators are fully adequate to provide full coverage of all of the upper HF bands except 10 meters. Only if weight is no concern and if extra front-to-back performance is a necessity on 20 or 15 meters would a log-cell Yagi such as the 6- and 7-element designs seem justified.

The natural home of the log-cell Yagi in Y2K is at 10 meters and above, where the bandwidths are more than 3% or so of their center frequencies. However, as we increase frequency, the materials we use for antenna elements increase in diameter relative to a wavelength. So even at VHF, the fat elements of Yagis can provide a wider operating bandwidth that often precludes the need for log-cell technology.

These notes are far from exhaustive, and my summary is based only on a few hundred models, the best of which have appeared in this series. Since antenna enthusiasts have an endless appetite for experimentation, it would not surprise me to see these analyses supplanted in the future by better and more ingenious log-cell Yagi designs.

One perennial direction of experimentation that we have not examined is the effect of setting the antenna elements into a forward swept Vee. Perhaps we can overstay our welcome for one more part in this series, devoted to this one topic, in order to discover whether "V" means "victory" or only half of a "virtual reality."

Notes

[1] P. D. Rhodes, K4EWG, and J. R. Painter, W4BBP, "The Log-Yagi Array," *QST*, Dec 1976. The main elements of this article are reprinted in *The ARRL Antenna Book*, 18th Edition, pp 10-25 to 10-27.

[2] W. I. Orr, W6SAI, and S. D. Cowan, W2LX, *Beam Antenna Handbook*, pp 251-253. For a 6-meter adaptation, see John J. Meyer, N5JM, "A Simple Log-Yagi Array for 50 MHz," *Antenna Compendium*, Volume 1, pp 62-63.

[3] See "Modeling 6 Long-Boom Yagis" at my Web site, http://www.cebik.com.

[4] A model of a 10-meter version of the NW3Z/WA3FET OWA is reported in Cebik, "The OWA for 10, 6 and 2 Meters," *AntenneX*, Aug 1999. ■