Some Aspects of Long-Boom, Monoband Log-Cell Yagi Design

It's neither a Yagi nor an LPDA, but a combination of the two. See how a driven log-periodic cell can function as the driven element of a Yagi.

By L. B. Cebik, W4RNL

Monoband log-cell Yagi designs currently come in two varieties: (1) Short-boom designs with two to five elements in the log cell, and (2) Long-boom designs using two elements in the cell and numerous parasitic elements. Since the advent of computer-aided antenna design, both log-cell Yagi types have shown shortcomings based on misunderstandings of what is possible with the log-cell Yagi. Short-boom log-cell Yagis employ up to twice as many elements as competing Yagi designs for comparable performance. Long-boom designs with small log cells tend to show no advantages at all over modern Yagi designs of similar boom length.

1434 High Mesa Dr
Knoxville, TN 37938-4443
cebik@cebik.com

In a series of articles for *The National Contest Journal* (see Reference 2), I developed a number of emergent properties of short-boom log-cell Yagis. Among them are the following:

1. Moderate gain for a given boom length, with the ability to provide relatively smooth gain over a considerable bandwidth.
2. Superior front-to-back (F/B) ratios, again with the ability to provide relatively smooth F/Bs across a considerable bandwidth.
3. Superior front-to-rear (F/R) ratios are based on rear gain considered to be the averaged value of power from +90° off the main lobe maximum in one direction, around the rear of the azimuth pattern to the corresponding azimuth point that is –90° from the main lobe on the other side of the azimuth pattern. That rear gain is then subtracted from the maximum forward power of the main lobe to give F/R in decibels.
4. Superior flat SWR curves for a considerable bandwidth.

The unanswered question left by the series is whether these properties can be developed in a long-boom, higher-gain log-cell Yagi. This basic question led to others, including perhaps the most fundamental of all: What is involved in the design of a long-boom log-cell Yagi?

In the following notes, I shall try to develop the major parameters of long-boom log-cell Yagi design. Following a brief review of basic log-cell principles, I shall try to sort out and track the significant design variables that influence log-cell Yagi performance.

The results will be a series of preliminary designs of various boom lengths. To assess the potential of long-boom log-cell Yagis, we shall close with a brief comparison between a selected design and a roughly comparable pure Yagi design of similar boom length and operating bandwidth.

Background

The log-cell Yagi is a hybrid array composed of a log-periodic dipole array (LPDA) used as the driver "cell" along with one or more parasitic elements. Fig 1 provides an outline of a typical log-cell Yagi, along with some designations that we shall use later in this study. Although the sketch shows one reflector and one director, other designs have omitted the reflector and some have added further directors.

The log-cell historically has been either casually or rigorously designed. Small cells (usually two elements) have employed phased-element techniques such as those found in the ZL Special. More complex cells have used standard LPDA design techniques, following the lead of P. D. Rhodes, K4EWG, in his article, "The Log-Periodic Dipole Array," (*QST*, Nov 1973, pp 16-22). The most fundamental aspects of LPDAs revolve around three interrelated design variables: α (alpha), τ (tau) and σ (sigma). Any one of the three variables may be defined by reference to the other two.

Fig 2 shows the basic components of an LPDA. The angle α defines the outline of an LPDA and permits every dimension to be treated as a radius or the consequence of a radius (R). The most basic structural dimensions are the element lengths (L), the distance of each element from the apex of angle α, (R) and the distance between elements (D). A single value, τ, defines all of these relationships in the following manner:

$$\tau = \frac{R_{n+1}}{R_n} = \frac{D_{n+1}}{D_n} = \frac{L_{n+1}}{L_n} \qquad \text{(Eq 1)}$$

where element n and n+1 are successive elements in the array working toward the apex of angle α.

For the log-cell of a hybrid design, one usually selects values of τ and of σ to create an LPDA for a relatively narrow frequency range. Rhodes recommended a τ of 0.95, which is close to the maximum recommend value for any LPDA design. He selected a σ of 0.05 to produce what he apparently considered to be a reasonably short cell length. Interestingly, I have encountered no questions in the literature concerning these values.

The original Rhodes and Painter log-cell Yagi array from 1976 is still featured in *The ARRL Antenna Book* (see Reference 1). It uses a four-element cell for 20 meters. Because 20 meters is a reasonably narrow band (about 2.47% of the band center frequency), it does not provide a test of log-cell Yagi bandwidth potential. Therefore, in the following notes, I shall adopt the entire 10-meter band from 28.0 to 29.7 MHz as a more appropriate test ground for log-cell Yagi design (about 5.89% of the band center frequency of 28.85 MHz).

Moreover, I shall also adopt a five-element log-cell design in preference to the four-element cell used by Rhodes. In preliminary design work that used a slight modification of the Rhodes design, scaled to 10 meters (model 412), and a corresponding five-element cell plus reflector and director (model 514), I developed the arrays whose dimensions appear in Table 1. In *NEC-4* models of these arrays, I encountered the following general property differences.

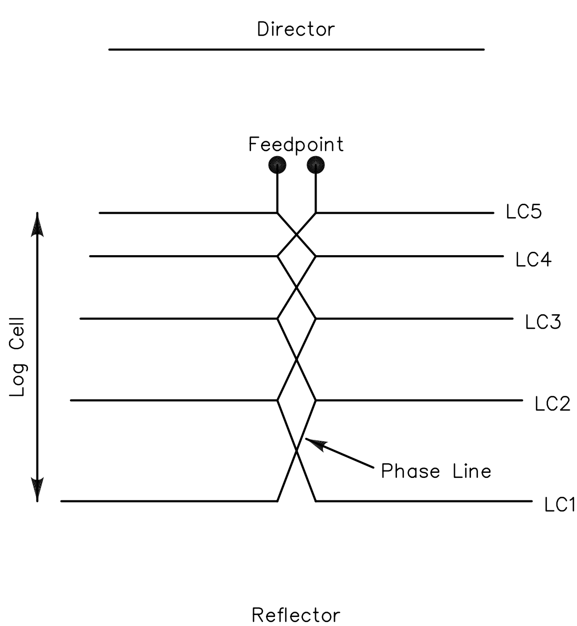


Fig 1—The components of a monoband log-cell Yagi.

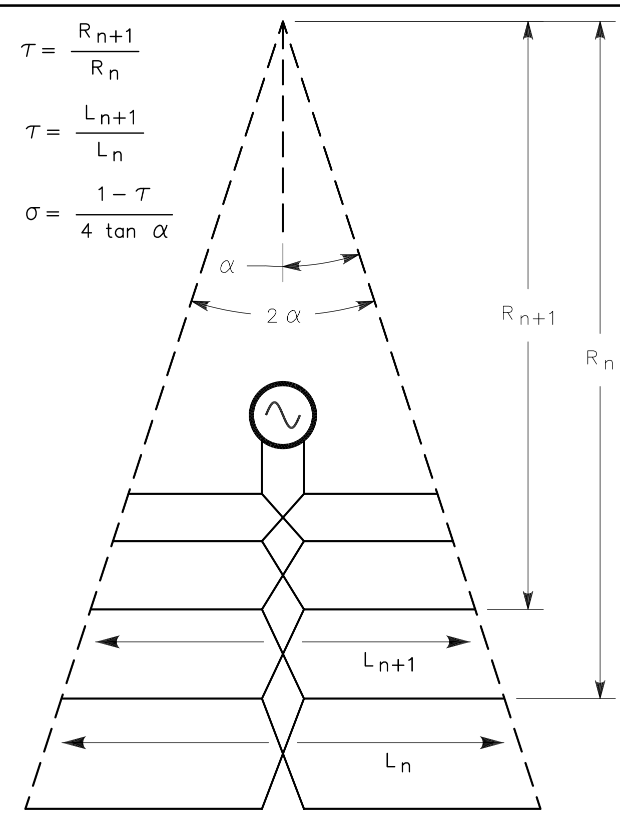


Fig 2—The basic relationships within a log-periodic dipole array (LPDA).

As shown in Fig 3, the gain curves for the two antennas differ in form—a factor that will become one of the design questions to be explored. The initial values of the five-element cell array are lower than for the four-element cell array, although the larger array shows a steadily increasing gain across 10 meters. Fig 4 clearly demonstrates an improvement in 180° F/B by adding one more element to the log cell. The flatter 50-Ω SWR curve is apparent in Fig 5. It is possible to refine the two models to level some of the differences between them. However, the five-element cell remains superior in its performance across a band as wide as 10 meters.

As is evident from the curves for the two preliminary log-cell Yagi designs, the studies of design elements will be undertaken using *NEC-4*. Elements will be of uniform diameter, although they may vary from one model to another. Thus, the modeling work may also be undertaken in *NEC-2* with equal ease and accuracy. Each element will have 21 segments, since this value assures convergence of results without excessive segmentation. Phasing lines are created by using the TL facility of *NEC*. The velocity factor is set at 1.0 for all models. Some models may use phase-line characteristic impedances that may be very difficult to fabricate. In general, values as low as 75 and 80 Ω require facing flat-face stock, since these characteristic impedance values are not feasible with air dielectric lines using round conductors. Methods of physically constructing the arrays modeled lie beyond the scope of this study, but may be found in recent editions of *The ARRL Antenna Book* and other sources.

Fundamentals of Long-Boom Design

Historically, log-cell Yagi design appears to be confined to relatively short boom lengths if the log-cell is complex. Long-boom designs have largely been confined to log cells with only two elements. It remains unclear why long-boom log-cell Yagis with complex cells have not appeared in the amateur literature. One might speculate that Rhodes' note setting σ at 0.05 may have been taken as a limiting value.

Any LPDA, though, may be extended in length at least up the its optimum value for σ, which is calculated as follows:

$$\sigma_{opt} = 0.243\tau - 0.05 \qquad \text{(Eq 2)}$$

Table 1—Dimensions of Preliminary 10-Meter Log-Cell Yagis

Four-Element Log-Cell (Six-Element Array): Model 412

Element	*Half Length* (Feet)	*Half Length* (λ)	*Spacing from Reflector* (Feet)	*Spacing from Reflector* (λ)
Reflector	8.65	0.255	—	—
LC1	8.58	0.252	2.96	0.087
LC2	8.10	0.238	4.70	0.138
LC3	7.66	0.225	6.34	0.186
LC4	7.25	0.213	7.87	0.231
Director	7.20	0.211	12.40	0.364

τ = 0.95; σ = 0.05; Element Diameter = 1.0"; Phase Line Z_0 = 75 Ω

Five-Element Log-Cell (Seven-Element Array): Model 514

Element	*Half Length* (Feet)	*Half Length* (λ)	*Spacing from Reflector* (Feet)	*Spacing from Reflector* (λ)
Reflector	8.76	0.260	—	—
LC1	8.50	0.249	2.93	0.086
LC2	8.05	0.236	4.65	0.136
LC3	7.59	0.223	6.28	0.184
LC4	7.20	0.211	7.82	0.230
LC5	6.85	0.201	9.29	0.272
Director	6.98	0.205	14.45	0.424

τ = 0.95; σ = 0.05; Element Diameter = 0.875"; Phase Line Z_0 = 80 Ω

Note: λ dimensions taken at 28.85 MHz.

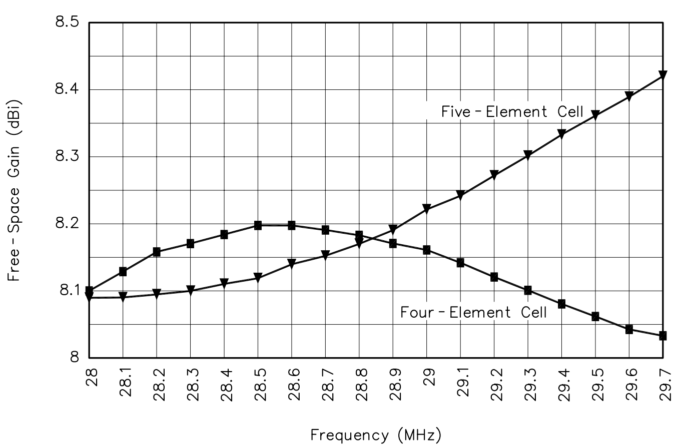


Fig 3—Log-cell Yagis with four-element and five-element cells: free-space gain.

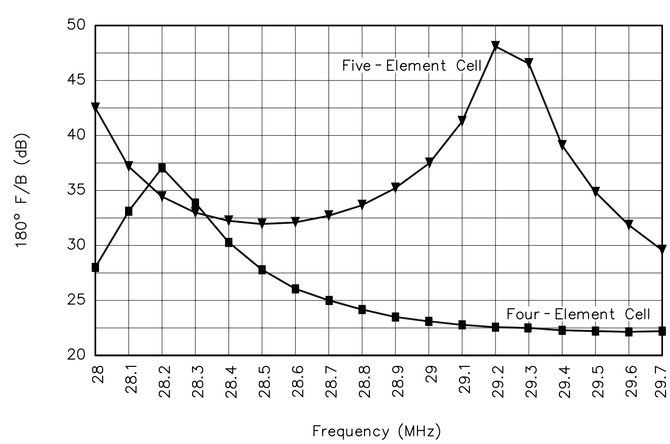


Fig 4—Log-cell Yagis with four-element and five-element cells: 180° F/B.

For a τ of 0.95, the optimum value of σ is about 0.18. There remains much room for experimentally lengthening the log cell by increasing the value of σ to achieve almost any reasonable boom length.

Some of the rhetoric surrounding LPDA design also leaves a wrong impression for those who have not calculated actual designs. Array gain is most closely associated with the value of τ such that higher values yield greater array gains for any value of σ. What may not be clearly realized is that for any value of τ, the array gain also increases with increasing values of σ. As an initial move, one may increase a log-cell Yagi's gain by simply increasing the value of σ and expanding the log-cell dimensions lengthwise.

One consequence of taking this design route is that the number of elements in the array does not increase with the boom length. Given the earlier decision to work with seven-element arrays only, the number of elements becomes more sensible with longer boom lengths. Although seven elements may seem to be excessive for a 14-foot beam, they become more natural with 26 and 28-foot booms. (Here, "natural" means simply more in line with common experience in pure Yagi designs.)

To initially test the potential for long-boom log-cell Yagis with longer log cells, I created a number of models to compare with Model 514. Table 2 provides the dimensions of models 520, 526 and 528. Although 526 and 528 reflect boom lengths of about 26 and 28-feet, respectively, the boom length of 520 varies from 19 to nearly 20 feet, depending upon some variations to be created later.

The technique for creating these designs was initially simple (and simplistic): Increase the value of σ, recalculate element spacing using $\tau = 0.95$, and then adjust the reflector and director length and spacing to develop a usable design. "Usable design" means that across 10 meters it has a reasonably stable gain, a stable F/B and a 50-Ω SWR below 1.5:1. To achieve these goals in the shortest possible time, I varied other factors, including the characteristic impedance of the phase line and the element diameter.

Most immediately apparent from Table 2 is that increasing σ required a resizing of the log-cell relative to its initial calculation. A simple increase in σ using the same initial rear-element length should theoretically have produced performance curves similar to those of model 514. With each increase of σ, however, the log cells required a downward adjustment in element length to achieve acceptable performance. Only models 526 and 528 use elements similar in length, but there are significant differences in the performance of these two arrays that go beyond gain differences. The table also shows the final values of σ for each design: 0.051, 0.087, 0.121 and 0.1412, respectively, for the designs in order of increasing length.

Fig 6 shows the free-space gain curves for models 514 through 528. On the wide-range gain scale, the upward progression of gain in 514 is put into somewhat better perspective to display the 0.33-dB total gain change across the band. Model 520 is about 4.5 feet longer overall and displays a similar gain curve; however, the upper end of the curve is reaching its peak value as the rate of increase approaches zero. Model 526 is about 6.5 feet longer than 520, and the amount of increase in gain over 520 is proportional to the boom-length increase; however, this curve peaks almost exactly at the mid-band point. The overall gain change across the band is only 0.23 dB. The longest model, 528, shows the expected further gain increase over 526. The 10.0 dBi gain figure extends from 28.8 to 29.0 MHz so that the band-edge gain values are only 0.02 dB apart, for a total gain change of only 0.26 dB across the band. We shall explore the reasons for the two distinctly different types of gain curves within the overall set shortly.

In Fig 7, we find an even greater diversity of curve types. The very high F/Bs of the shortest design, 514, also show the greatest variations in level, with nearly 19 dB separating the peaks from the "nulls" (if a minimum F/B value of 27.2 dB can be called a null). Models 520 and 528 show an overall change of just above 4 dB in the 180°F/B across the band. The shorter of the two models exhibits higher intrinsic values, and the peaks for the two antennas fall toward opposite ends of the band.

Model 526 shows the least variation in F/B: a mere 0.79 dB over the 1.7 MHz of 10 meters. The average F/B is 26.1 dB, though, which is considerably lower than the value for any other of the designs. Of importance to the design is the increased spacing for both the reflector and director, relative to the smaller models, as well as the lengths of these elements. Also significant is the lower characteristic impedance of the phase line.

Virtually all of the designs share one

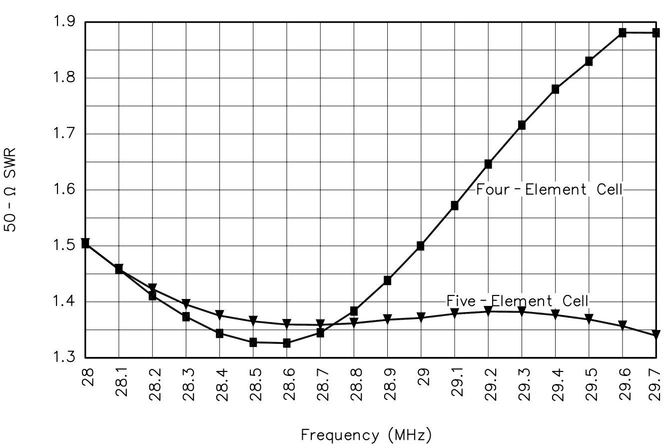


Fig 5—Log-cell Yagis with four-element and five-element cells: 50-Ω SWR.

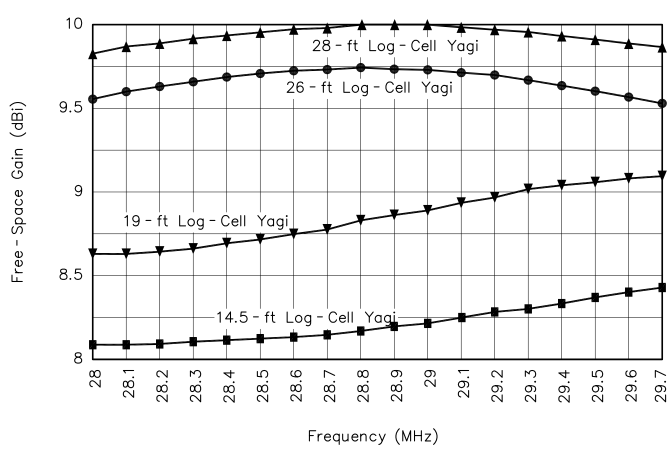


Fig 6—Seven-Element log-cell Yagis from 14.5 to 28 feet long: free-space gain.

trait: a well controlled rear-lobe structure. Fig 8 illustrates this point by displaying expanded azimuth patterns of the model-520 rear lobes at the band edges and at the mid-band point. The three rear patterns reflect 180° F/B patterns between 27 and 28 dB. In all three cases, an averaged F/R value for the array would exceed the 180° F/B value.

Fig 9 shows another aspect of model 526: Its 50-Ω SWR never climbs as high as 1.5:1. The other curves show much the same variety as the F/B curves, with only the curve for model 520 showing the anticipated mid-band minimum value.

We began the exercise with a question: Can we enlarge the seven-element log-cell Yagi by increasing the value of σ and making other small adjustments to obtain good wide-band gain, F/B, and 50-Ω SWR curves? The modeled performance curves we have just examined provide an affirmative answer; however, these same curves raise a larger number of questions still to be answered. Perhaps we can formulate a summary question to cover the unexamined territory: What are the variables in log-cell Yagi design and how does each affect the performance curves?

Performance Variables in Log-Cell Yagi Design

Thus far, we have isolated only one definitive variable in the design of log-cell Yagis. As we increase σ, we must decrease the initial log-cell element length (for element LC1) before applying the prescribed value of τ to obtain the lengths and spacings of the other log-cell elements. This design guideline is incomplete, though, since it does not indicate how much to shorten the element length or how to know when it is optimal.

Log-Cell Element Length

To examine the effects of log-cell element length on the performance curves of a given design, I took model 520 and ran it through some variations in element length. I varied only the log-cell element lengths and then adjusted only the position (but not the length) of the parasitic director to yield acceptable F/B and SWR curves. Table 3 lists the dimensions of three representative models.

Changing the element length obviously changes the value of σ. Since the revisions to the original model increased the element lengths in the log cell (without changing the value of τ), the value of σ decreases slightly with each maneuver. In addition, the length of the array increases overall, since the director must be displaced forward to return reasonable F/B and SWR curves. The reflector length and position, as well as the phase-line Z_0 and the element diameter were preserved, however.

Fig 10 shows the effects of the changes on the array gain. Lengthening the log-cell elements gradually centers the gain peak well within the passband of the beam. One consequence of this movement is that the gain at the lower end of the band increases; however, as the peak gain approaches the mid-band frequency, the magnitude of the peak gain decreases. For the designer, there is a choice. For the most even gain across the band, longer log-cell elements are desirable, but at the cost of peak gain. If peak gain is desired, then the gain at the low end of the band will suffer accordingly.

Higher peak gain also results in a somewhat lower F/B value across the band, as revealed in Fig 11. Changing the log-cell element length to smooth out the gain actually produces greater

Table 2—Dimensions of Four 7-Element Log-Cell Yagis

Five-Element Log-Cell (Seven-Element Array): Model 514
(See Table 1.)

Five-Element Log-Cell (Seven-Element Array): Model 520

Element	*Half Length*		*Spacing from Reflector*	
	(Feet)	*(λ)*	*(Feet)*	*(λ)*
Reflector	8.80	0.258	—	—
LC1	8.38	0.246	2.89	0.085
LC2	7.93	0.233	5.81	0.171
LC3	7.49	0.220	8.59	0.252
LC4	7.10	0.208	11.23	0.330
LC5	6.75	0.198	13.74	0.403
Director	6.65	0.195	19.00	0.557

τ = 0.95; σ = 0.0873;Element Diameter = 0.5”;Phase Line Z_0 = 80 Ω

Five-Element Log-Cell (Seven-Element Array): Model 526

Element	*Half Length*		*Spacing from Reflector*	
	(Feet)	*(λ)*	*(Feet)*	*(λ)*
Reflector	9.00	0.264	—	—
LC1	8.36	0.245	4.12	0.121
LC2	7.91	0.232	8.19	0.240
LC3	7.47	0.219	12.06	0.354
LC4	7.09	0.208	15.73	0.461
LC5	6.73	0.198	19.21	0.563
Director	6.30	0.185	25.80	0.757

τ = 0.95; σ = 0.121;Element Diameter = 0.75”;Phase Line Z_0 = 65 Ω

5-Element Log-Cell (7-Element Array): Model 528

Element	*Half Length*		*Spacing from Reflector*	
	(Feet)	*(λ)*	*(Feet)*	*(λ)*
Reflector	8.70	0.255	—	—
LC1	8.11	0.238	4.00	0.118
LC2	7.68	0.225	8.55	0.251
LC3	7.25	0.213	12.88	0.378
LC4	6.88	0.202	17.01	0.499
LC5	6.53	0.192	21.10	0.619
Director	6.00	0.176	28.10	0.824

τ = 0.95; σ = 0.141;Element Diameter = 0. 75”;Phase Line Z_0 = 70 Ω

Note: Wavelength dimensions taken at 28.85 MHz.

variations in the F/B across the band. One conclusion we may reach from these curves is that the smooth F/B curve in model 526 does not result alone from centering the gain curve by lengthening log-cell elements.

Lengthening the log-cell elements, relative to the original version of model 520 also changes the SWR curve when the phase-line Z_0 remains constant. The shallow dip at the band center for the original model becomes a sharp dip at 28.1 MHz for the first revision. For the second revision, the dip moves below the end of the band. Had we lengthened the elements further, the curve would have flattened further.

The gain-centering effect of modifying the lengths of the log-cell elements can be examined by modeling the log cell alone, without the parasitic elements. Because the director and reflector are dimensioned to smooth log-cell Yagi performance across the operating bandwidth, the log cell alone will show more variation in gain across the band. The frequencies at which we find gain peaks will, however, closely coincide with peak-gain frequency of the entire beam. The gain of the log-cell alone may only be down by about 0.6 dB relative to the peak gain of the final array. At band edges, however, the gain difference may well exceed 1 dB. As the length of a log-cell Yagi increases (by lengthening the log cell itself), the role of the parasitic elements changes from increasing gain to smoothing performance across the pass band.

Element Diameter

As one would expect, increasing the diameter of the elements in a log-cell Yagi lowers the center frequency of the curves in all of the categories we have been using to express array performance: gain, F/B, and 50-Ω SWR. As a demonstration of the phenomenon, I used the original model 520, the dimensions of which appear at the top of Table 3, as the basis for a number of variations. I increased the initial 0.5-inch-diameter elements first to 0.75 inch and then to 1.0 inch without changing any other physical or electrical property of the beam.

Fig 13 shows the effects of the increases on the free-space gain of the array. Although the peak gain of the 0.5-inch design occurs above the 10-meter band, the larger-diameter

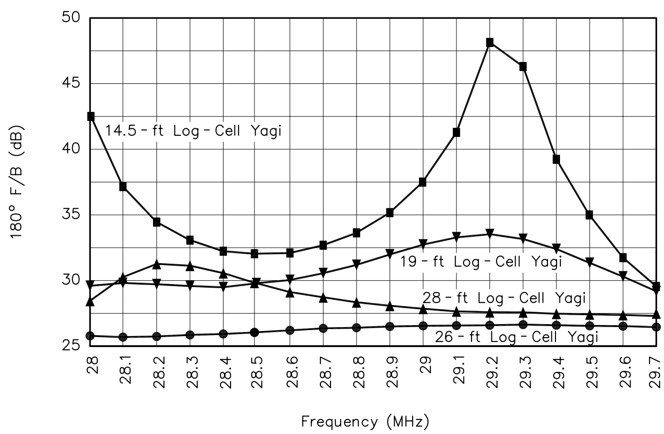
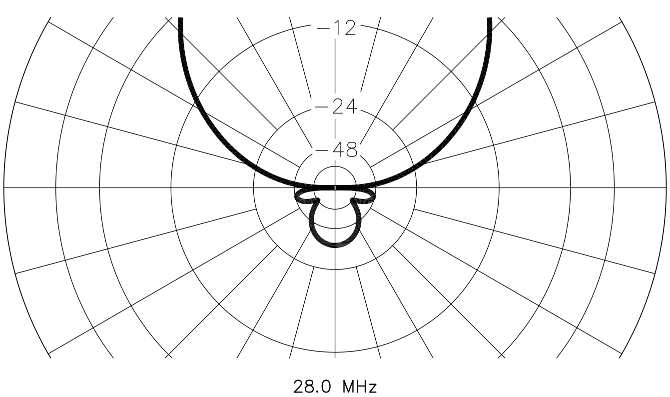
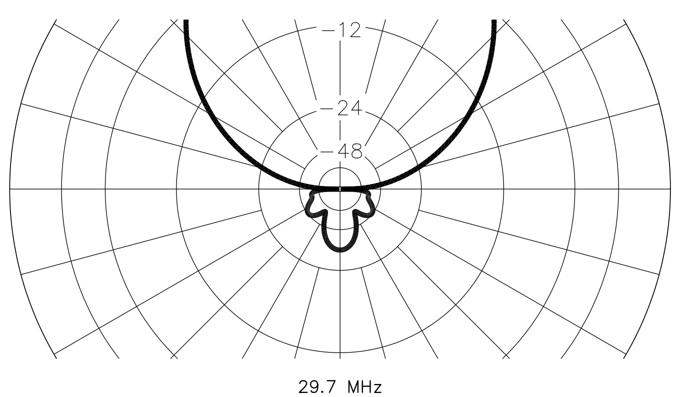


Fig 7—Seven-Element log-cell Yagis from 14.5 to 28 feet long: 180° F/B.





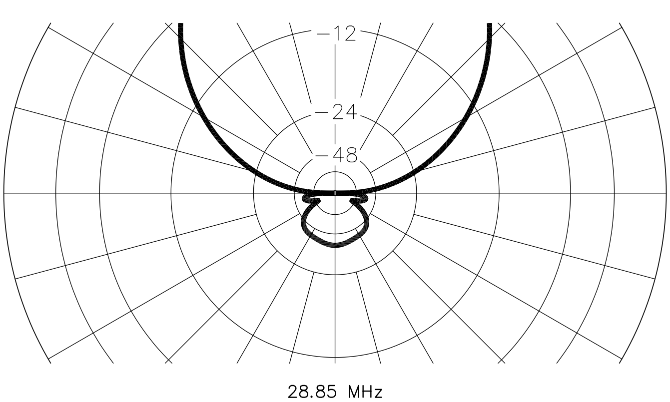


Fig 8—Expanded views of the rearward azimuth patterns of a 19-foot seven-element log-cell Yagi at 28.0, 28.85, and 29.7 MHz. The outer ring is 9.08 dBi.

models reveal peak-gain values within the band, with an approximate 0.25-MHz decrease in frequency per 0.25-inch diameter increase. Moreover, increasing the element diameter increases the intrinsic peak-gain value by an amount that is slightly more than one expects with a single driver, such as in a pure Yagi. The effect is a function of the driver cell and is consistent with results for pure LPDA arrays using low-impedance phasing lines.

More dramatic are the curve shifts in the 180° F/B as we increase element diameter alone. In Fig 14, we note a larger shift down the band as we move from 0.5-inch to 1.0-inch elements. As well, the maximum F/B peak for the 1.0-inch-element model is much higher than that for the one with smaller elements; however, the range of F/B values also increases. To smooth the curve for the F/B element with the larger-diameter elements would require other modifications to the design, including readjustments to the parasitic elements.

As shown in Fig 15, the 50-Ω SWR curves are nearly congruent, with the larger elements achieving the lowest SWR minimum. As the element diameter increases, the resistive component of the impedance decreases, but only marginally. In general, for the design given, the resistive component increases steadily from near 40 Ω at 28.0 MHz to about 65 Ω at 29.7 MHz. The reactance curve, however, shifts more radically. In model 520 for all element diameters, the reactance never reaches a positive (inductive) value of 1 Ω anywhere in the passband. Instead it remains capacitive, with the zero or near zero-point moving lower in the band as the element diameter increases. Since the zero-reactance point coincides with a lower resistive component when the diameter is largest, the net SWR minimum is lower.

In every respect, the effects of increasing the element diameter in a log-cell Yagi can be classified as normal to the LPDA behavior of the log cell.

Phase-Line Characteristic Impedance

Whereas changing the element diameter has rather large consequences for the gain curve of a log-cell Yagi, changing the characteristic impedance of the log-cell phase line as minimal effect. Using the same design—the original model 520 at the top of Table 3—I changed the characteristic impedance of the phase line, using a low value of 70 Ω and a high value of 100 Ω. The small pull on the gain curve toward a lower frequency and very slightly higher peak value shows up on Fig 16.

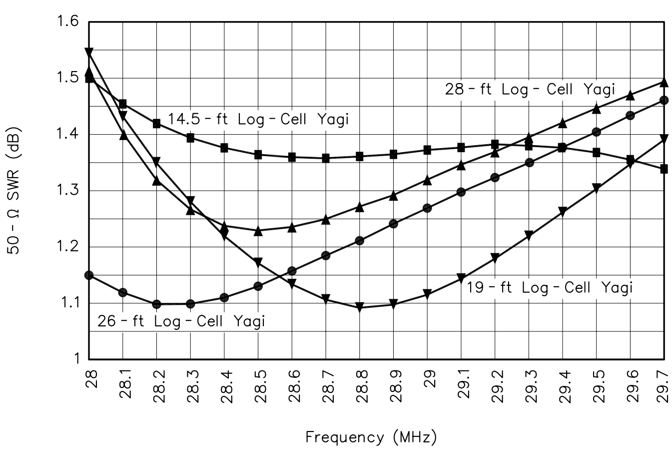


Fig 9—Seven-Element log-cell Yagis from 14.5 to 28 feet long: 50-Ω SWR.

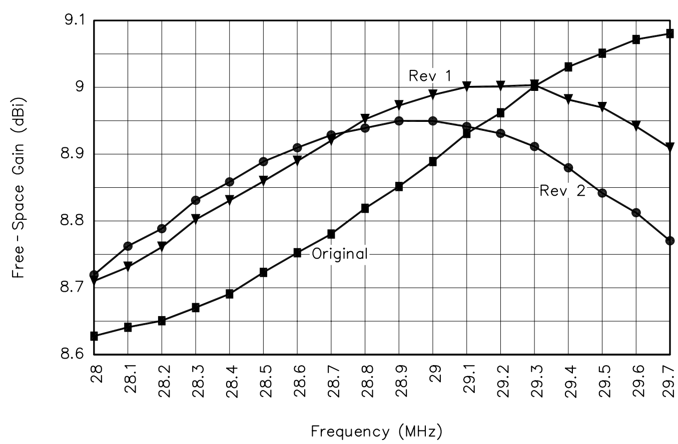


Fig 10—Model 520 with log-cell element lengthening: free-space gain.

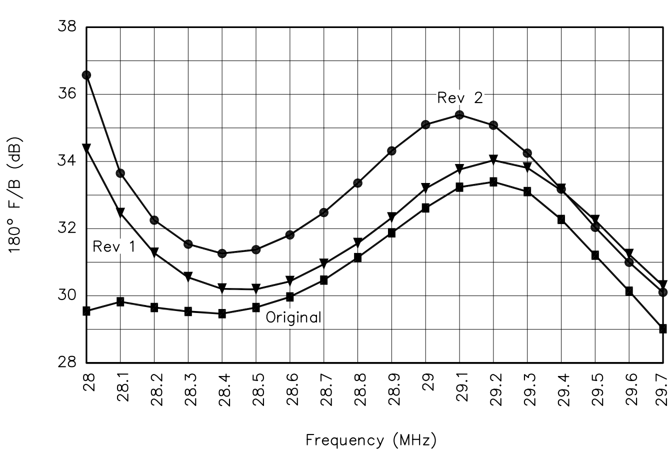


Fig 11—Model 520 with log-cell element lengthening: 180° F/B.

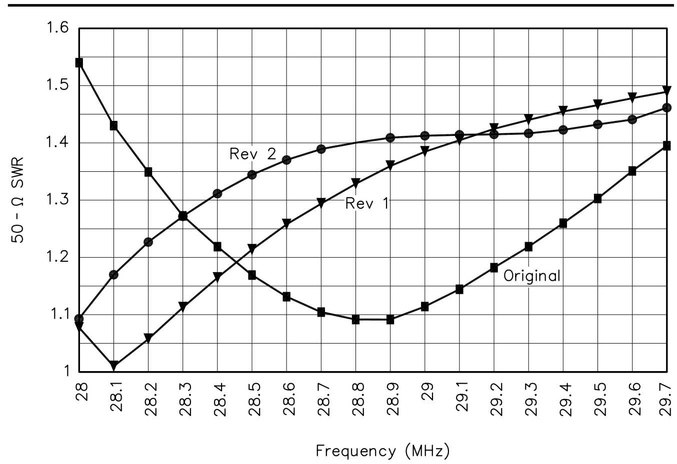


Fig 12—Model 520 with log-cell element lengthening: 50-Ω SWR.

The effect of the phase-line impedance on the 180° F/B curve is much more profound. As the phase-line impedance increases, so too does the peak F/B and the rate of change in value from one frequency to the next. In general, the smoothest F/B curves for long-boom log-cell Yagis occur with the lowest obtainable phase-line characteristic impedance.

The characteristic impedance of the phase line is directly related to the resistive component of the cell feed-point impedance. Higher line Z_0 increases the resistive part of the impedance. At the mid-band frequency (28.85 MHz), the feed-point impedance is $50 - j4\ \Omega$ for the 70-Ω design, $53 - j3\ \Omega$ for the 80-Ω model and $63 + j1\ \Omega$ for the 100-Ω version of model 520. Moreover, the lowest feasible characteristic impedance for the log-cell also tends to yield the smoothest SWR curve.

Although element diameter and phase-line Z_0 produce relatively small changes in the performance curves compared to changing the length of the log-cell elements, these facets of log-cell Yagi design provide a measure of array design control. In effect, by varying one or both of these parameters, the designer can tailor the performance curves more closely to a desired profile.

The Parasitic Elements

From the analyses so far given, we can begin to redesign some of the original log-cell Yagis that we initially sampled. Models 514 and 520 would both benefit from lengthening the log-cell elements to center the gain curve within the 10-meter passband. As well, reducing the phase-line Z_0 to about 70 Ω would reduce the F/B excursions in 514. Obviously, adjustments to the director may be needed to bring all three performance curves into a maximally centered position, if one or more of the curves was not smooth enough to suit standards applied to the design.

Two of the designs appear to achieve the smoothest performance across the band. Model 528 achieves the smoothest gain curve and an acceptably high

Table 3—Dimensions of Three Versions of Model 520

Original Model 520

Element	*Half Length (Feet)*	*Half Length (λ)*	*Spacing from Reflector (Feet)*	*Spacing from Reflector (λ)*
Reflector	8.80	0.258	—	—
LC1	8.38	0.246	2.89	0.085
LC2	7.93	0.233	5.81	0.171
LC3	7.49	0.220	8.59	0.252
LC4	7.10	0.208	11.23	0.330
LC5	6.75	0.198	13.74	0.403
Director	6.65	0.195	19.00	0.557

τ = 0.95; σ = 0.0873;Element Diameter = 0.5”;Phase Line Z_0 = 80 Ω

Revision 1 to Model 520

Element	*Half Length (Feet)*	*Half Length (λ)*	*Spacing from Reflector (Feet)*	*Spacing from Reflector (λ)*
Reflector	8.80	0.258	—	—
LC1	8.50	0.249	2.89	0.085
LC2	8.08	0.237	5.81	0.171
LC3	7.67	0.225	8.59	0.252
LC4	7.29	0.214	11.23	0.330
LC5	6.92	0.203	13.74	0.403
Director	6.65	0.195	19.40	0.569

τ = 0.95; σ = 0.0860;Element Diameter = 0.5”;Phase Line Z_0 = 80 Ω

Revision 2 to Model 520

Element	*Half Length (Feet)*	*Half Length (λ)*	*Spacing from Reflector (Feet)*	*Spacing from Reflector (λ)*
Reflector	8.80	0.258	—	—
LC1	8.58	0.252	2.89	0.085
LC2	8.15	0.239	5.81	0.171
LC3	7.75	0.227	8.59	0.252
LC4	7.36	0.216	11.23	0.330
LC5	6.99	0.205	13.74	0.403
Director	6.65	0.195	19.70	0.578

τ = 0.95; σ = 0.0852;Element Diameter = 0.5”;Phase Line Z_0 = 80 Ω

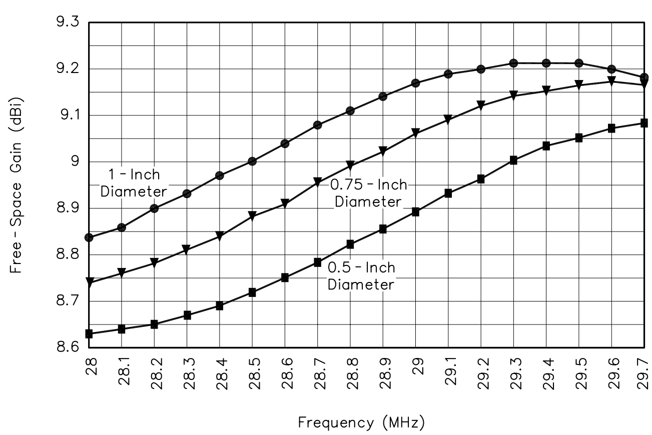


Fig 13—Model 520 with element-diameter enlargement: free-space gain.

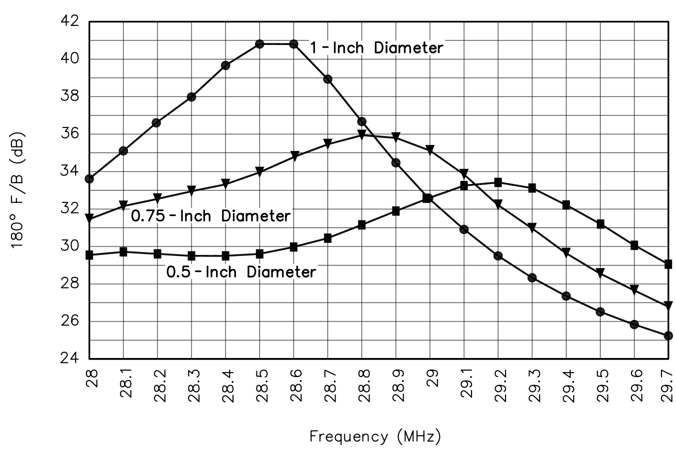


Fig 14—Model 520 with element-diameter enlargement: 180° F/B.

F/B, despite a small "bump" in the curve near 28.2 MHz. The model's impedance ranges from about 38 to 65 Ω resistance and from –13 to + 20 Ω reactance. Hence, its SWR curve will not match that of model 526.

Model 526 manages the smoothest composite set of performance curves of the initial models. The gain varies by under 0.25 dB across the band, while the F/B varies by under 0.8 dB. The 50-Ω SWR is under 1.5:1 across the band. In exchange for the smooth performance, the F/B never exceeds 26.5 dB, a somewhat low figure for log-cell Yagi designs in general.

For the moment, our question is simple: How can we obtain this performance other than by simply replicating the design in hand? The answer emerges from the way in which we size and place the parasitic elements. The initial guidelines provided by Rhodes for placing the director and reflector call for spacings from the nearest log-cell element of 0.15 and 0.085 λ, respectively. In general, these spacing values will produce a working log-cell Yagi, with two provisos:

1. The lengths of these elements will change as σ increases, and

2. The spacing—especially of the director—will increase with increases in σ.

Close spacing of the director and reflector tends to yield the highest values of F/B. The F/B will be somewhat erratic with close spacing of the parasitic elements, and gain will not be maximum. Smoothing the F/B across a wide passband requires increased spacing between the log cell and the two parasitic elements. Model 526 shows the degree of increase necessary. The reflector is spaced about 0.12 λ from the rear element of the log cell, while the reflector is about 0.19 λ ahead of the cell.

To test and illustrate the principles of parasitic-element placement, I returned once more to model 520. The first revision of this model, in Table 3, has a log cell that is almost perfectly proportional to the one used in the longer model 526. I then used reflector and director spacings similar to those in the longer model to smooth the performance of the shorter version of the array. To further match the models, I decreased the phase-line Z_0 to 65 Ω and increased the element diameter to 0.75 inch.

Of course, in the process of increasing the parasitic-element spacing, the total model length for 520 grew to about 21.1 feet. Table 4 summarizes

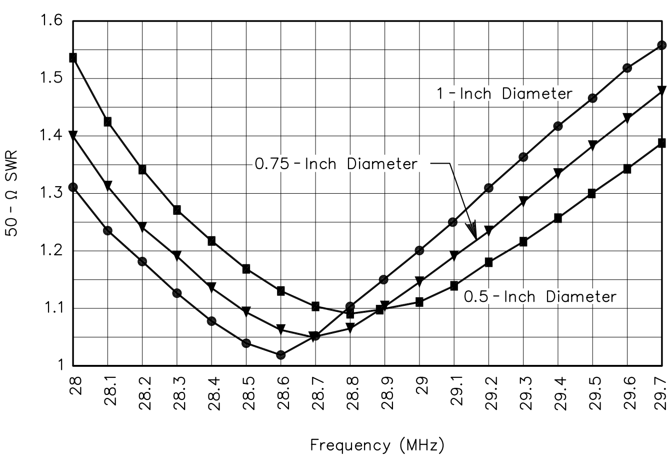


Fig 15—Model 520 with element-diameter enlargement: 50-Ω SWR.

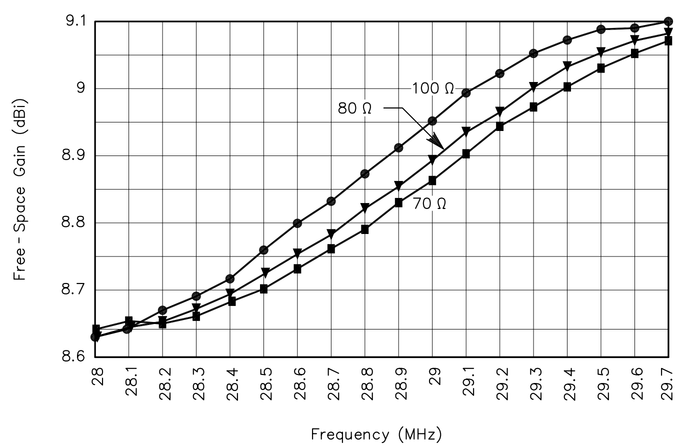


Fig 16—Model 520 with various phase-line characteristic impedances: free-space gain.

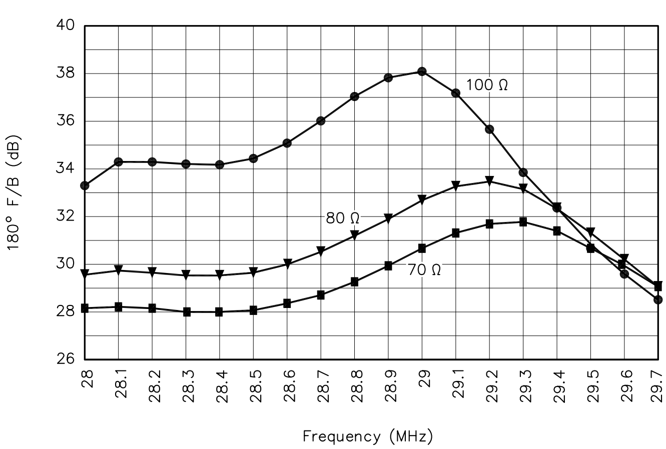


Fig 17—Model 520 with various phase-line characteristic impedances: 180° F/B.

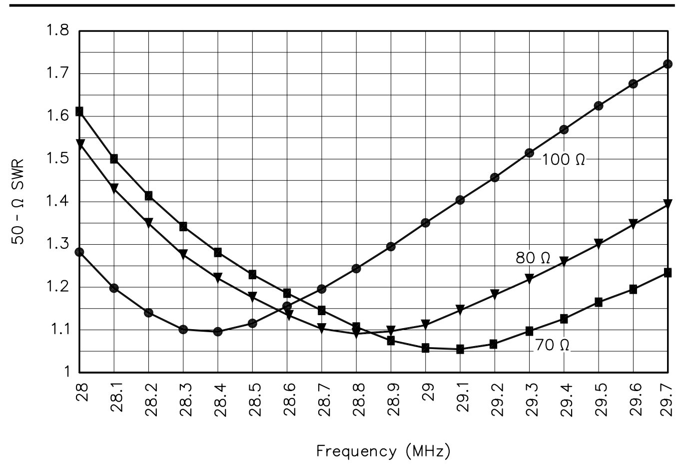


Fig 18—Model 520 with various phase-line characteristic impedances: 50-Ω SWR.

the results by giving the dimensions for 526, for the first revision of 520 and for the wide-band version of 520. The long reflector of the wide-band version of 520 is identical to that used in 526 and is about 0.12 λ behind the log cell.

Table 4—Dimensions of Wide-Band Log-Cell Yagis

Five-Element Log-Cell (Seven-Element Array): Model 526

Element	*Half Length* (Feet)	(λ)	*Spacing from Reflector* (Feet)	(λ)
Reflector	9.00	0.264	—	—
LC1	8.36	0.245	4.12	0.121
LC2	7.91	0.232	8.19	0.240
LC3	7.47	0.219	12.06	0.354
LC4	7.09	0.208	15.73	0.461
LC5	6.73	0.198	19.21	0.563
Director	6.30	0.185	25.80	0.757

τ = 0.95; σ = 0.121;Element Diameter = 0.75”;Phase Line Z_0 = 65 Ω

Revision 1 to Model 520

Element	*Half Length* (Feet)	(λ)	*Spacing from Reflector* (Feet)	(λ)
Reflector	8.80	0.258	—	—
LC1	8.50	0.249	2.89	0.085
LC2	8.08	0.237	5.81	0.171
LC3	7.67	0.225	8.59	0.252
LC4	7.29	0.214	11.23	0.330
LC5	6.92	0.203	13.74	0.403
Director	6.65	0.195	19.40	0.569

τ = 0.95; σ = 0.0860;Element Diameter = 0.5”;Phase Line Z_0 = 80 Ω

Wide-Band Version of Model 520

Element	*Half Length* (Feet)	(λ)	*Spacing from Reflector* (Feet)	(λ)
Reflector	9.00	0.264	—	—
LC1	8.50	0.249	4.10	0.120
LC2	8.08	0.237	7.02	0.206
LC3	7.67	0.225	9.80	0.287
LC4	7.29	0.214	12.44	0.365
LC5	6.92	0.203	14.95	0.438
Director	6.80	0.200	21.21	0.622

τ = 0.95; σ = 0.0860;Element Diameter = 0.75”;Phase Line Z_0 = 65 Ω

The required director for 520 is longer but less widely spaced than the one used in 526: Shorter spacing calls for longer director elements in most parasitic designs.

Fig 19 compares the gain of the three models on which we are focused. Model 526 has the highest and best-centered gain curve; however, the wide-band version of 520 shows increased gain and better curve centering relative to the design version on which it is based. Part of the centering derives from the decrease in phase-line Z_0, while part of the gain increase stems from the use of larger-diameter elements. Some of the increase can also be ascribed to the lengthening of the array overall. The gain differential across the 10-meter band for 520 has fallen to 0.23 dB.

The F/B of the wide-band version of 520 exhibits a similar levelness, as shown in Fig 20. The differential is less than 0.85 dB across the band, which is far smoother than provided by the base-line model, whose F/B curve is also traced in the graphic. The cost of such even performance is, of course, a lowering of the intrinsic F/B values by an average of 7 dB down to the 25-dB level. Note also that the F/B of the wide-band version of 520 is about 0.5 dB lower than for model 526.

Because model 520 was not optimized to center its gain curve prior to working with the parasitic elements, the 50-Ω SWR curve in Fig 21 has a slightly different shape than the corresponding curve for model 526. The SWR never rises above 1.45:1 across 10 meters though, and the curves reach their minimum values at the same frequency.

The exercise establishes that achieving flatter performance curves, espe-

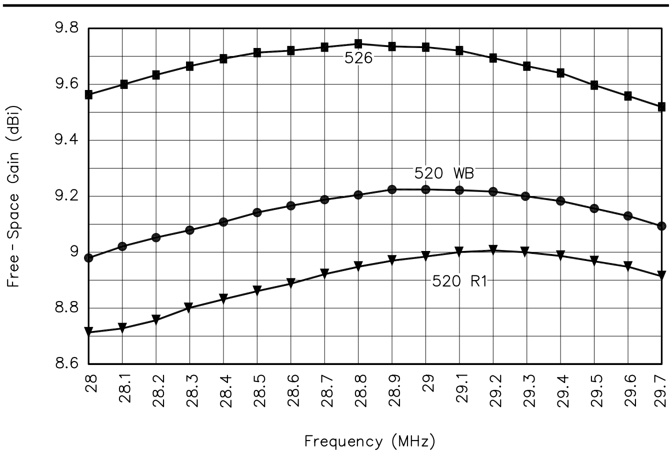


Fig 19—Two wide-band log-cell Yagis with revision 1 to model 520 as a reference: free-space gain.

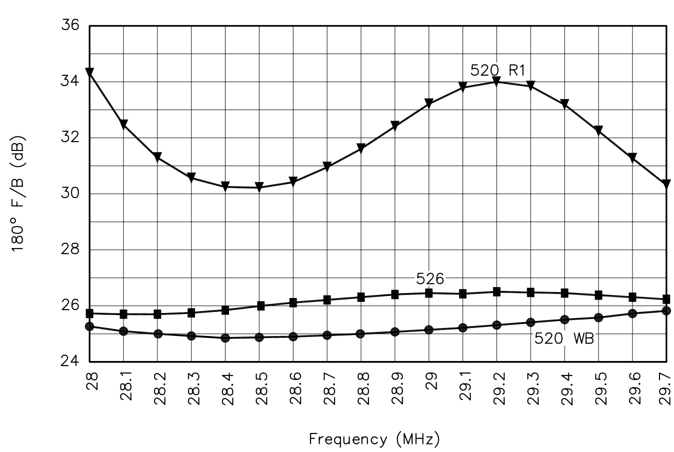


Fig 20—Two wide-band log-cell Yagis with revision 1 to model 520 as a reference: 180° F/B.

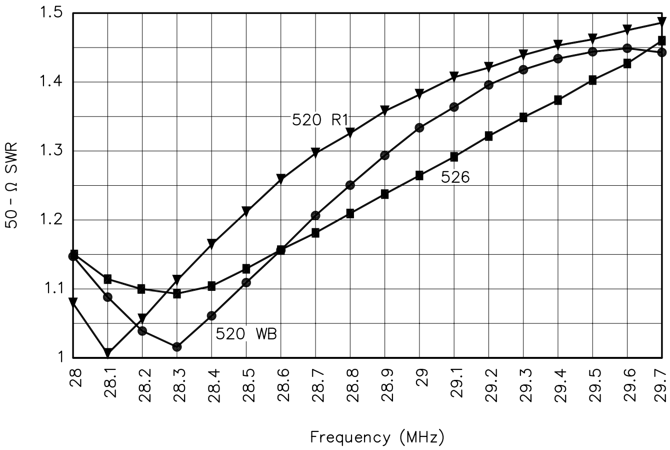


Fig 21—Two wide-band log-cell Yagis with revision 1 to model 520 as a reference: 50-Ω SWR.

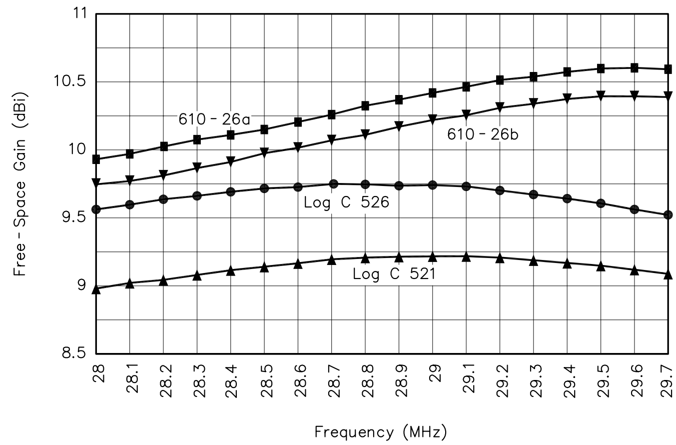


Fig 22—Comparative performance between four 26-foot arrays: two pure Yagis and two log-cell Yagis: free-space gain.

Table 5—Dimension of an Experimental Wide-Band 6-Element 10-Meter Yagi

Design 1: 610-26a

Element	*Half-Length (Feet)*	*Spacing from Reflector (Feet)*
Reflector	8.75	—
Driver	8.21	3.95
Dir. 1	7.75	6.19
Dir. 2	7.59	11.35
Dir. 3	7.67	17.95
Dir. 4	7.32	26.00

Design 2: 610-26b

Element	*Half-Length (Feet)*	*Spacing from Reflector (Feet)*
Reflector	8.79	—
Driver	8.29	4.24
Dir. 1	7.77	6.07
Dir. 2	7.60	11.35
Dir. 3	7.66	18.07
Dir. 4	7.28	26.00

Note: These N6BV designs are provisional and subject to further optimizing by their author.

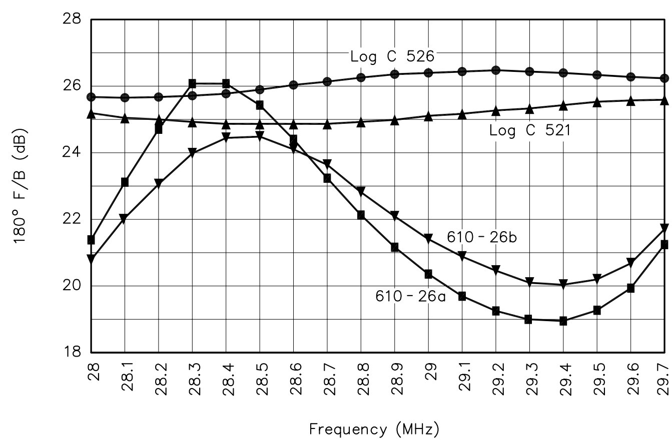


Fig 23—Comparative performance between four 26-foot arrays: two pure Yagis and two log-cell Yagis: 180° F/B.

cially for gain and F/B, is possible for virtually any boom length that is feasible with a five-element log cell. Spreading the reflector and director elements provides added gain but decreased F/B in the process of smoothing the performance curves. In contrast, closer spacing of the reflector and director yield higher but more erratic F/B values, as well as a bit less gain.

A Comparison with Wide-Band Yagis

The analyses of the parameters affecting the performance of log-cell Yagis has aimed at producing a better understanding of how each design variable contributes to the final design. In the process of developing the analysis, we have encountered some models that have interesting properties, not the least of which are the wide-band models with relatively constant performance over the spread of the 10-meter band. Although the main purpose of these notes is not to either promote or denigrate the log-cell Yagi, some comparisons may be inevitable.

So far, we have developed performance numbers, but placing those numbers into some sort of usable perspective remains undone.

The log-cell Yagis we have examined use a total of seven elements. At the 26-foot boom length, it is possible to develop a wide-band, six-element Yagi. Two preliminary designs of promise have emerged from the work of Dean Straw, N6BV. I appreciate his sharing them with me for the purposes of this comparison. The Yagi dimensions appear in Table 5. The designs should be considered provisional and subject to further optimization by their originator.

In the following comparisons, I shall show curves for both Yagi designs (610-26a and 610-26b), along with curves for optimized the 26-foot and 21-foot log-cell Yagis (logc526 and logc521). I have included the shorter-boom log-cell Yagi

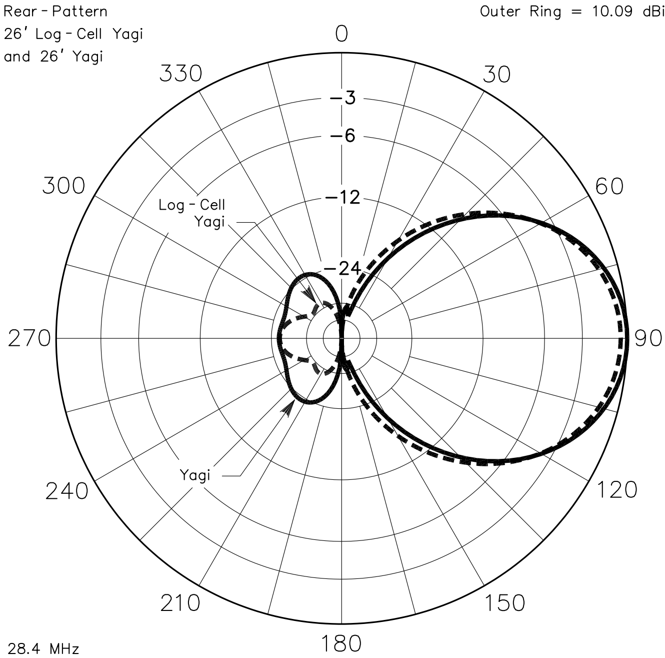


Fig 24—Rearward-lobe comparison between a 26-foot Yagi and a 26-foot log-cell Yagi.

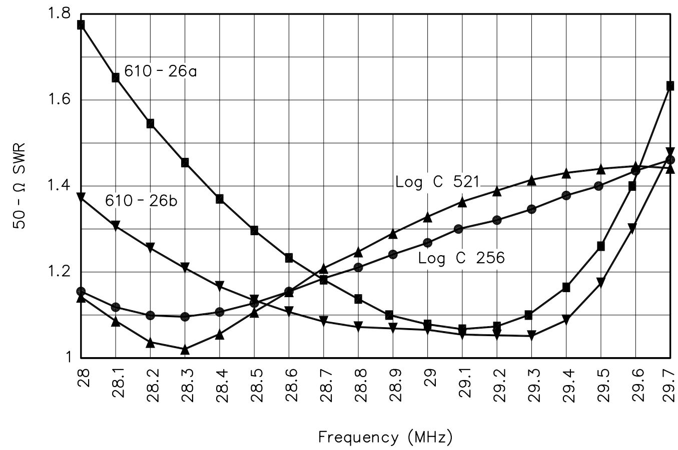


Fig 25—Comparative performance between four 26-foot arrays: two pure Yagis and two log-cell Yagis: 50-Ω SWR.

for two reasons. First, it demonstrates the consistency of log-cell Yagi design in all of the major operating categories. Second, its slightly lower performance curves—especially the gain—prevent the graphs from taking on an overly dramatic air by virtue of unrealistically spreading the Y-axis values.

As shown in Fig 22, the Yagis both show superior gain to the log-cell Yagi, despite the equivalency of boom length. The average gain of the Yagis is about 10.3 and 10.1 dBi, respectively. We shall see in subsequent graphs that the lower gain of 610-26b results in advantages in other categories of operation. The Yagis have a gain advantage over the log-cell Yagi of about 0.6 to 0.7 dB for the 26-foot model and even more for the 21-foot model. As is typical of Yagis with directors, the gain increases with frequency and does not peak until 29.6 MHz. The total gain variation across the band is about 0.65 dB. In contrast, gains of the 26-foot and 21-foot log-cell Yagis varies by less than 0.25 dB across the band.

The F/B of both log-cell Yagis is equally even across 10 meters, varying by less than 0.8 dB. As is evident in Fig 23, the Yagi F/B varies more widely: by more than 7 dB for model 610-26a. The design revisions that went into 610-26b, however, produce a shallower F/B curve that remains above 20 dB across the band. Yagi F/B reaches the level of the log-cell Yagi for only a small portion of the passband, near the lower end of the band.

An additional advantage accrues to the log-cell Yagi with respect to its rear lobes. Fig 24 overlays azimuth patterns at 28.4 MHz for two 26-foot-boom antennas—near the Yagi peak F/B peak value. As we noted with respect to Fig 8, the rear lobes of the log-cell Yagi tend to have a 180° F/B that is also the worst case F/B. Hence, an average F/R for the log-cell design would show a higher value than the 180° values used in the graphs; however, the Yagi rear pattern shows stronger radiation in quartering directions. Hence, the averaged F/R would show a lower value than the 180° F/B. The patterns in the figure are not only typical of those at every frequency across the band for these designs, they are also typical of the general class of long-boom, wideband Yagi and log-cell Yagi designs. The significance of these differences is, of course, a user judgment.

In Fig 25, we find the 50-Ω SWR curves for the four arrays. The Yagi SWR graphic can be refined into double humped curves typical of similar designs for 20 meters and other bands. Model 610-26b achieves a remarkably smooth curve that never exceeds 1.5:1, which is an improvement over the earlier design that peaked near 1.8:1. However, the log-cell Yagi curves, with lower average values and peak values just above 1.45:1, might be considered marginally superior. Operationally, the SWR differences between the better design in each antenna category are too small to be significant.

The comparison of the long-boom Yagi to the long-boom log-cell Yagi is designed solely to place a few specifications in perspective. Consistent with the results for short-boom log-cell Yagis, long-boom log-cell Yagis do not yield as much forward gain as comparably long pure Yagi designs. The log-cell Yagi, though, can be tailored either to yield very high F/B values or to have roughly equal gain and F/B values across a band as wide as 10 meters.

In the end, the type of array that a builder chooses will be a function of the specifications brought to the selection process. I hope these notes contribute to an understanding of what log-cell Yagis can produce by way of long-boom performance and the ways in which the many design variables contribute to the achievement of that performance.

References

1. *The ARRL Antenna Book*, 18th edition (Newington, Connecticut: ARRL 1997), Chapter 10, pp 10-25 to 10-27.
2. L. B. Cebik, "The Monoband Log-Cell Yagi Revisited," (four-part series) *National Contest Journal*, January through July, 2000.
3. W. I. Orr, and S. D. Cowan, *Beam Antenna Handbook*, pp 251-253.
4. P. D. Rhodes and J. R. Painter, "The Log-Yag Array," *QST*, Dec 1976, pp 18-21.
5. P. D. Rhodes, K4EWG, "The Log-Periodic Dipole Array," *QST*, Nov 1973, pp 16-22.
6. R. F. Zimmer, "Three Experimental Antennas for 15 Meters," *CQ*, Jan 1983, pp 44-45.
7. R. F. Zimmer, "Development and Construction of 'V' Beam Antennas," *CQ*, Aug 1983, pp 28-32.