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

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Monoband log-cell Yagi designs currently come in two varieties: a. Short-boom designs with 2 to 5 elements in the log cell, and b. Long-boom designs using 2 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.

In a series of articles for *The National Contest Journal*, I developed a number of emergent properties of short-boom log-cell Yagis. Among them were 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 ratios, again with the ability to provide relatively smooth front-to-back ratios across a considerable bandwidth.

3. Superior front-to-rear ratios, defined as the averaged value of power from -90 degrees off the main lobe maximum in one direction around the rear of the azimuth pattern to the corresponding azimuth point that is -90 degrees from the main lobe on the other side of the azimuth pattern, subtracted from the maximum forward power of the main lobe, and given in dB.

4. Superior flat VSWR curves for a considerable bandwidth.

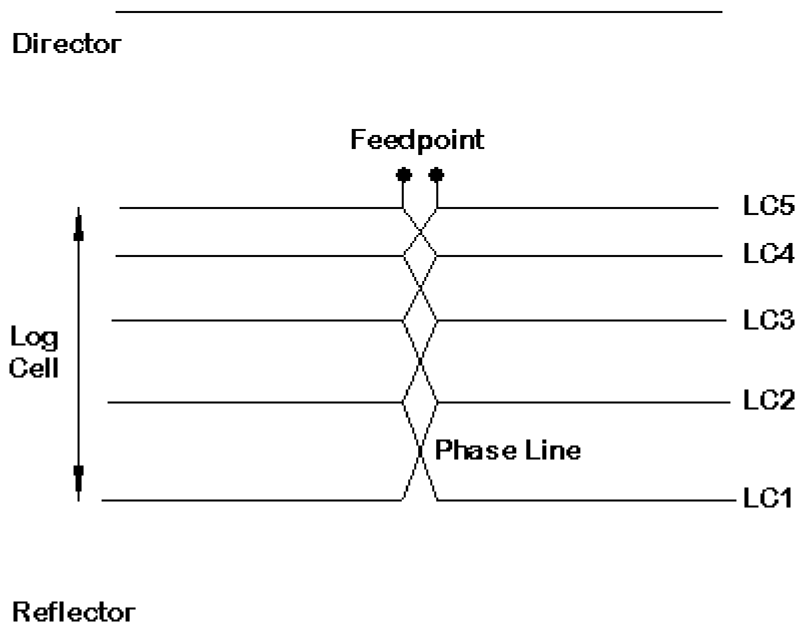
The unanswered question left by these studies is whether these properties can be developed in a long-boom, higher-gain log-cell Yagi. This basic question led to others, including perhaps the most fundamental of all: what is involved in the design of a long-boom log-cell Yagi.

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, I 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. 5-1** 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.

Fig. 5-1 Components of a Monoband Log-Cell Yagi



The log-cell historically has been either casually or rigorously designed. Small cells (usually 2 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 LPDA 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. 5-2 reviews the basic components of an LPDA, a explored in Volume 1. 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:

$$t = \frac{R_{n+1}}{R_n} = \frac{D_{n+1}}{D_n} = \frac{L_{n+1}}{L_n} \qquad \textbf{(1)}$$

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.

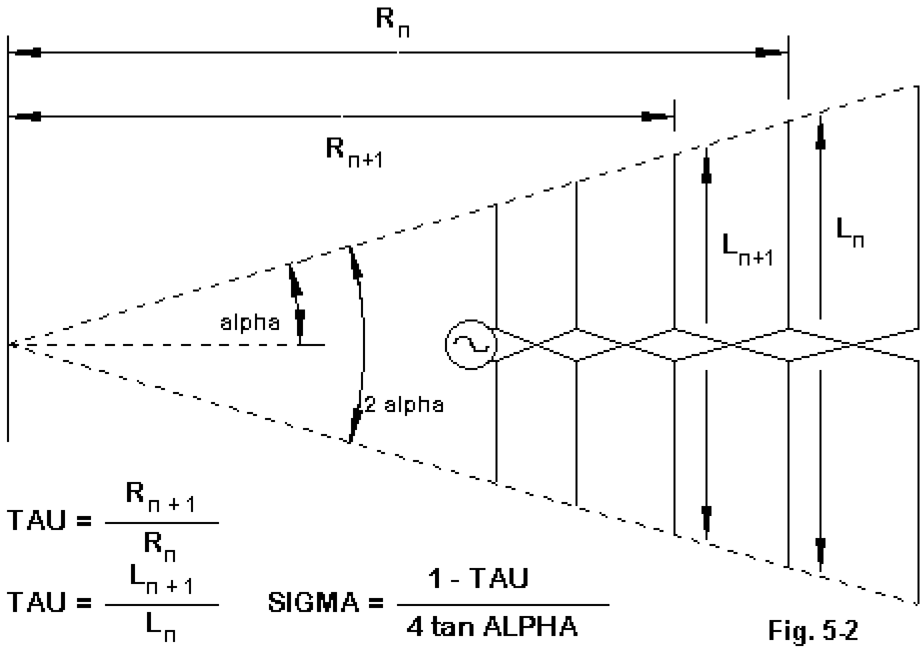


Fig. 5-2

The original Rhodes array is still featured in *The ARRL Antenna Book* (Chapter 10). It used a 4-element cell for 20 meters. Because 20 meters is a fairly 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 5-element log cell design in preference to the 4-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 5-element cell–plus reflector and director–(model 514), I developed the arrays whose dimensions appear in **Table 5-1**.

In NEC-4 models of these arrays, I encountered a collection of general property differences that make the 5-element log-cell superior to the smaller version. Complete details of the differences have been explored in the *NCJ* articles, but a graphical review of the differences may be a useful preliminary to our attempts to expand and improve the performance the log-cell Yagis.

Table 5-1. Dimensions of Preliminary 10-Meter Log-Cell Yagis

4-Element Log-Cell (6-Element Array): Model 412

Element	Half-Length Feet	Half-Length Wavelengths	Spacing from Reflector Feet	Spacing from Reflector Wavelengths
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

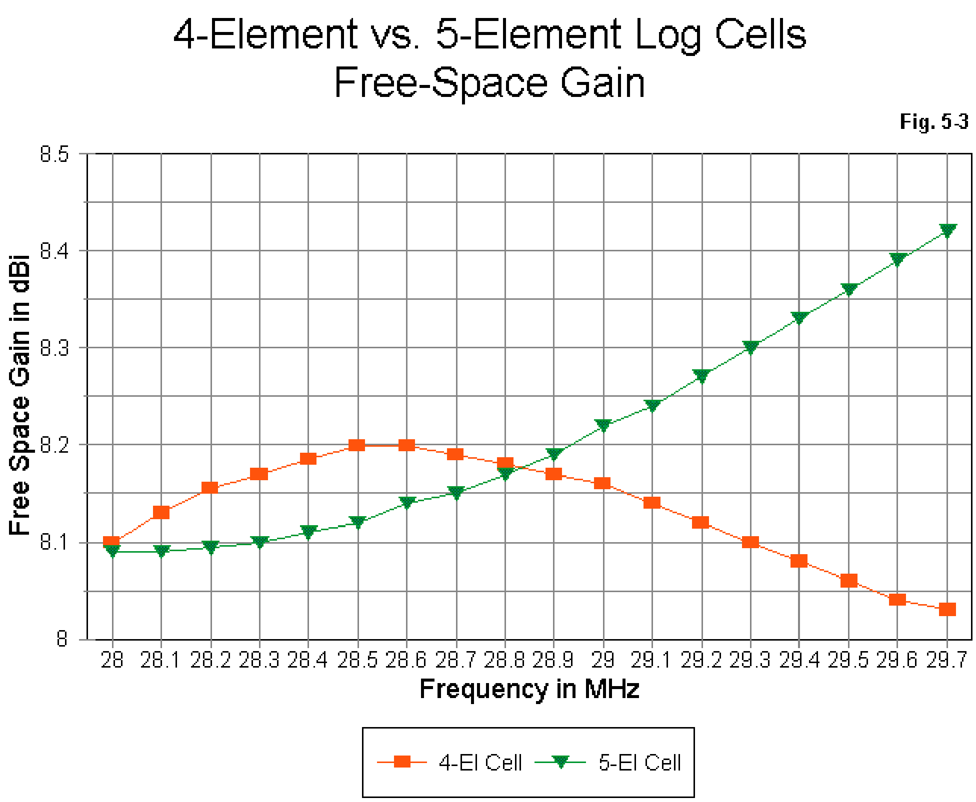
$\tau = 0.95$ $\sigma = 0.05$ Element Diameter = 1.0" Phase Line Zo = 75 Ohms

5-Element Log-Cell (7-Element Array): Model 514

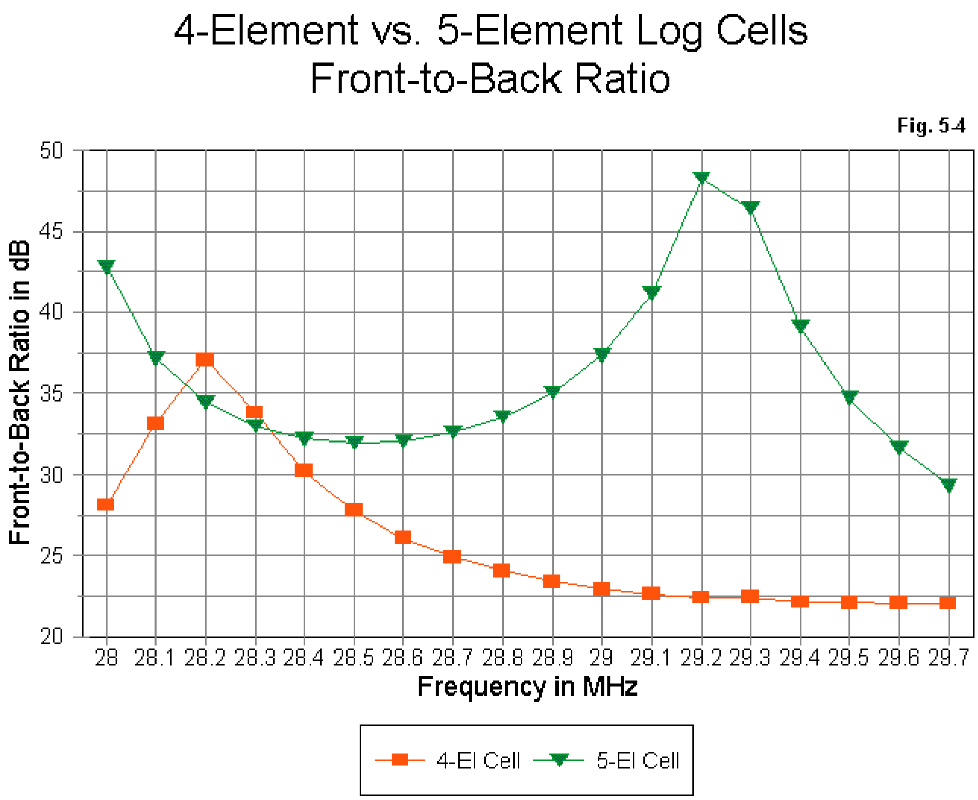
	Element	Half-Length	Spacing from Reflector	
	Feet	Wavelengths	Feet	Wavelengths
Reflector	8.76	0.260	---	–-
LC1	8.50	0.249	2.93	0.086
LC2	8.05	0.236	4.65	0.136
LC3	7.59	0.223	6.28	0.184
LC4	7.20	0.211	7.82	0.230
LC5	6.85	0.201	9.29	0.272
Director	6.98	0.205	14.45	0.424

$\tau = 0.95$ $\sigma = 0.05$ Element Diameter = 0.875" Phase Line Zo = 80 Ohms

Note: Wavelength dimensions taken at 28.85 MHz.



As shown in **Fig. 5-3**, 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 5-element cell array are lower than those of the 4-element cell array, although the larger array shows a steady increase in gain across 10 meters.


4-Element vs. 5-Element Log Cells
Front-to-Back Ratio
Fig. 5-4
Front-to-Back Ratio in dB
50
45
40
35
30
25
20
28 28.1 28.2 28.3 28.4 28.5 28.6 28.7 28.8 28.9 29 29.1 29.2 29.3 29.4 29.5 29.6 29.7
Frequency in MHz
4-El Cell
5-El Cell

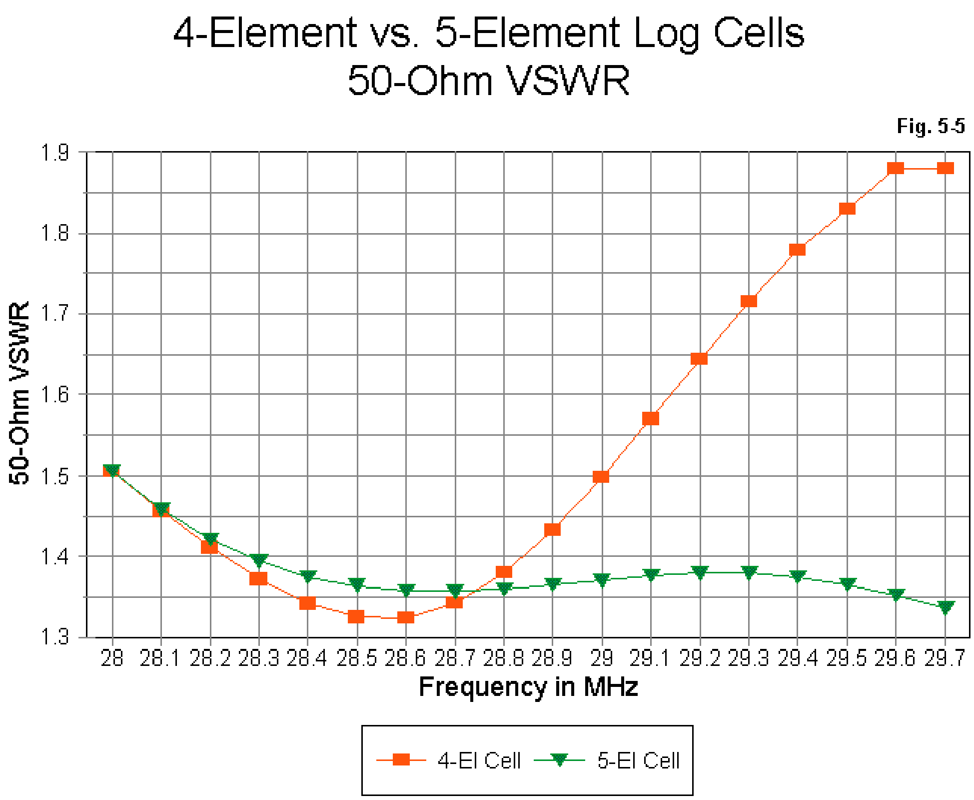

4-Element vs. 5-Element Log Cells
50-Ohm VSWR
Fig. 5-5
50-Ohm VSWR
1.9
1.8
1.7
1.6
1.5
1.4
1.3
28 28.1 28.2 28.3 28.4 28.5 28.6 28.7 28.8 28.9 29 29.1 29.2 29.3 29.4 29.5 29.6 29.7
Frequency in MHz
4-El Cell
5-El Cell

Fig. 5-4 clearly demonstrates an improvement in 180-degree front-to-back ratio by adding one more element to the log cell.

The flatter 50-Ohm VSWR curve is apparent in **Fig. 5-5**. It is possible to refine the two models to level some of the differences between them. However, the 5-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 Ohms require facing flat 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.

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

$$s_{opt} = 0.243\, t - 0.051 \qquad \textbf{(2)}$$

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 misimpression for those who have not calculated actual designs. Array gain is most closely associated with the value of τ such that the higher the value, the greater the array gain 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 length-wise.

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 7-element arrays only, the number of elements becomes more sensible with longer boom lengths. Although 7 elements may seem to be excessive for a 14' beam, they become more natural with 26' and 28' booms. (Here, "natural" means simply more in line with common experience with 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 5-2** provides the dimensions of Models 520, 526, and 528. Although 526 and 528 reflect boom lengths of about 26' and 28', respectively, the boom length of Model 520 varies from 19 to nearly 20 feet, depending upon some variations to be created later.

Table 5-2. Dimensions of 4 7-Element Log-Cell Yagis

5-Element Log-Cell (7-Element Array): Model 514 (See **Table 5-1**.)

5-Element Log-Cell (7-Element Array): Model 520

	Element Feet	Half-Length Wavelengths	Spacing from Reflector Feet	Wavelengths
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 Zo = 80 Ohms	

5-Element Log-Cell (7-Element Array): Model 526

	Element Feet	Half-Length Wavelengths	Spacing from Reflector Feet	Wavelengths
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 Zo = 65 Ohms	

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

	Element Feet	Half-Length Wavelengths	Spacing from Reflector Feet	Wavelengths
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 Zo = 70 Ohms	

Note: Wavelength dimensions taken at 28.85 MHz.

The technique for creating these designs was initially simple (and simplistic): increase the value of σ, recalculate element spacing using a τ of 0.95, and then adjust the reflector and director length and spacing to develop a usable design. "Usable design" meant one that across 10 meters had a reasonably stable gain, a stable front-to-back ratio, and a 50-Ohm 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 5-2** is that fact 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. However, with each increase of σ, 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.

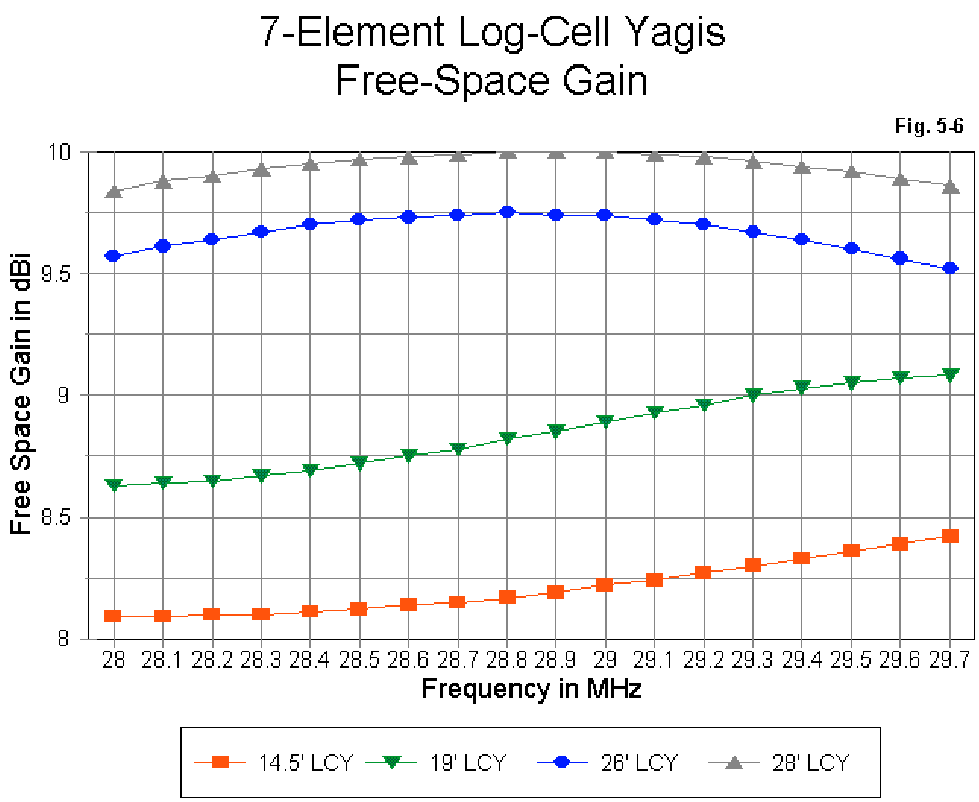
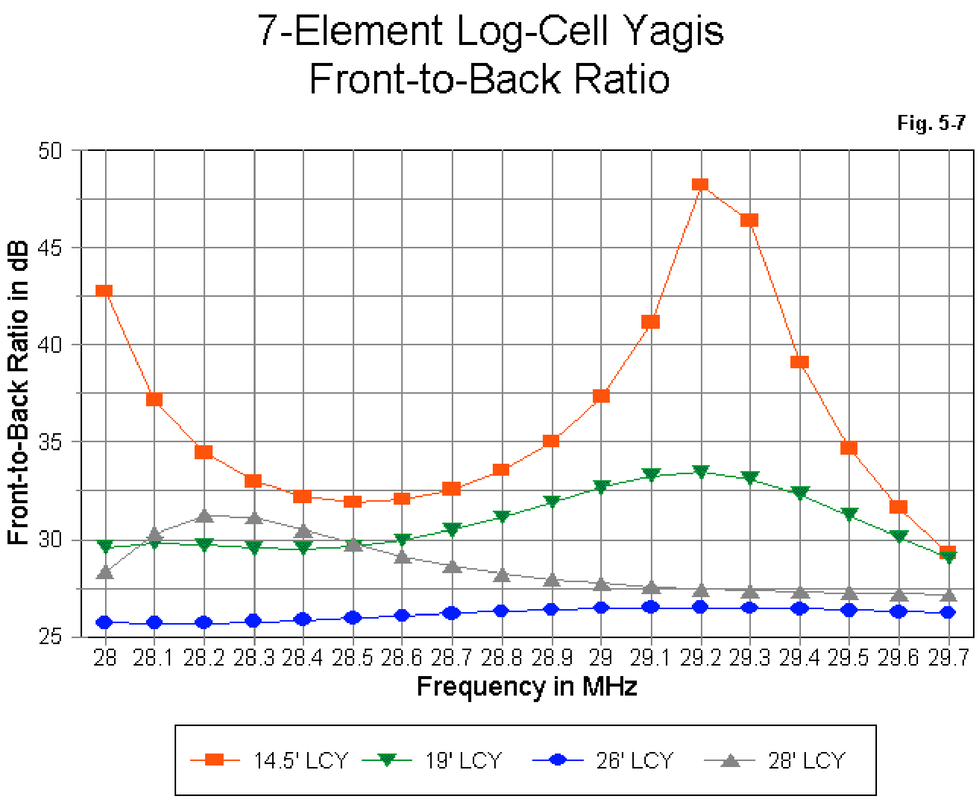


Fig. 5-6 shows the free-space gain curves for models 514 through 528. On the wide-range gain scale, the upward progression of gain in 514 is put into somewhat better perspective to display the 0.33 dB total gain change across the band. Model 520 is about 4.5' longer overall and displays a similar gain 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' 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 change in gain across the band is only 0.23 dB. The longest model, 528, shows the expected further increase in gain 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. 5-7**, we find an even greater diversity of curve types. The very high front-to-back ratios of the shortest design, 514, also show the greatest variation in level, with nearly 19 dB separating the peaks from the "nulls" (if a minimum front-to-back 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-degree front-to-back ratio across the band. The shorter of the two models exhibits the higher intrinsic values, and the peaks for the two antennas fall toward opposite ends of the band.

Model 526 shows the least variation in front-to-back ratio: a mere 0.79 dB over the 1.7 MHz of 10 meters. However, the average front-to-back ratio is 26.1 dB, 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 trait in common: a well-controlled rear bbe structure. **Fig. 5-8** illustrates this point by displaying expanded azimuth patterns of the rear lobes of model 520 at the band edges and at the mid-band point. The three rear patterns reflect 180-degree front-to-back patterns between 27 and 28 dB. In all three cases, an averaged front-to-rear value for the array would exceed the 180-degree front-to-back value.

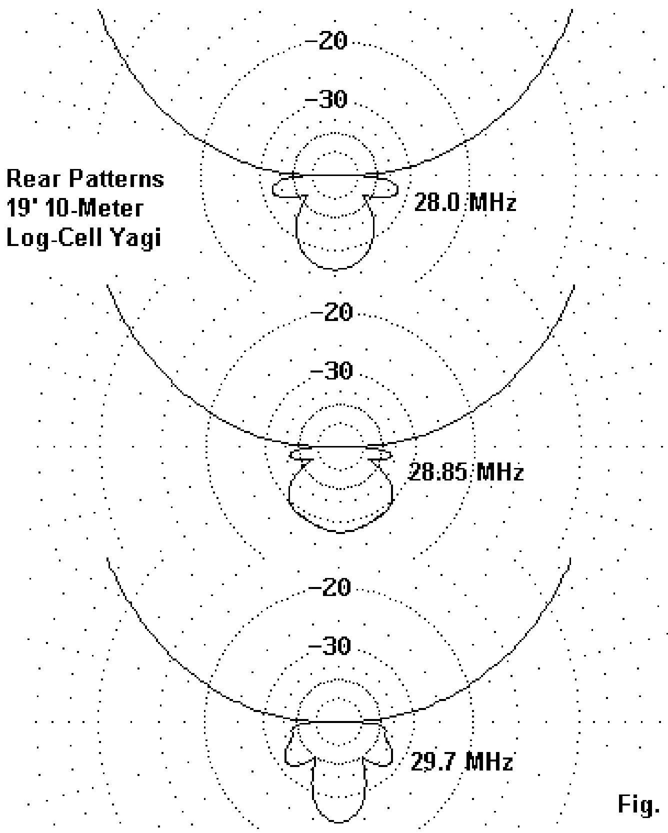


Fig. 5-8

Fig. 5-9 shows another aspect of model 526: its 50-Ohm SWR never climbs as high as 1.5:1. The other curves show much the same variety as the front-to-back curves, with only the curve for model 520 showing the anticipated mid-band minimum value.

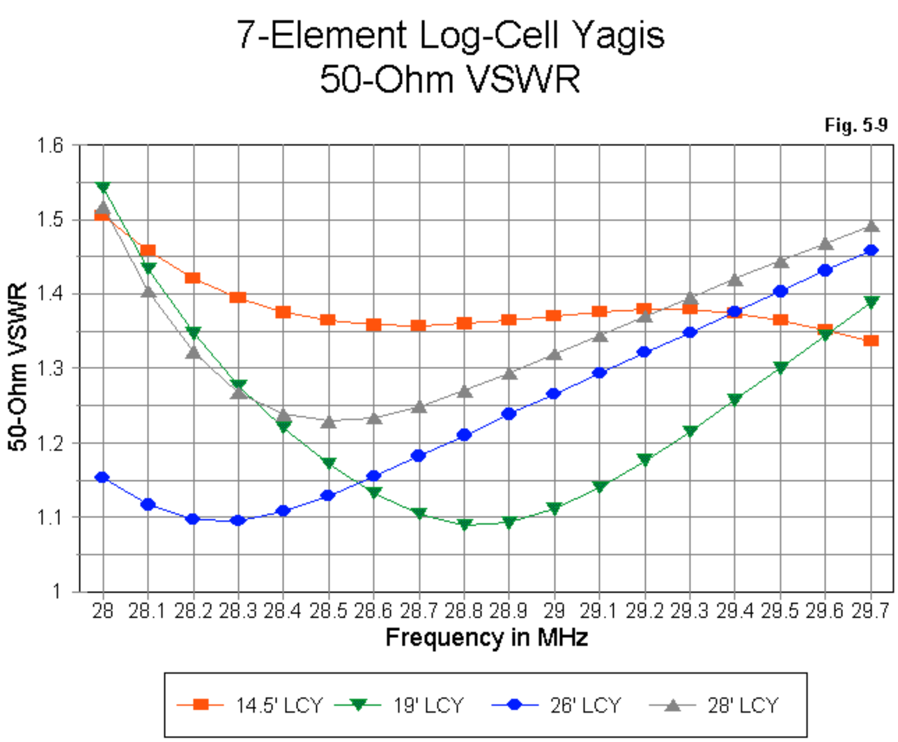


Fig. 5-9

We began the exercise with a question: can we enlarge the 7-element log-cell Yagi by increasing the value of σ and making other small adjustments to obtain good wide-band gain, front-to-back ratio, and 50-Ohm 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. However, this design guideline is incomplete, since it does not give us an indication of how much to shorten the element length or how to know when we have it where we want it.

The following notes contribute to, but in no way complete, an enumeration of the performance variables involved in long-boom log-cell Yagi design.

1. 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 front-to-back and SWR curves. **Table 6-1** lists the dimensions of three representative models.

Table 6-1. Dimensions of 3 Versions of Model 520

Original Model 520

	Element	Half-Length	Spacing from Reflector	
	Feet	Wavelengths	Feet	Wavelengths
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 Zo = 80 Ohms	

Revision 1 to Model 520

	Element	Half-Length	Spacing from Reflector	
	Feet	Wavelengths	Feet	Wavelengths
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 Zo = 80 Ohms	

Revision 2 to Model 520

	Element	Half-Length	Spacing from Reflector	
	Feet	Wavelengths	Feet	Wavelengths
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 Zo = 80 Ohms

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 overall length of the array increases, since the director must be displaced forward to return reasonable front-to-back ratio and SWR curves. However, the reflector length and position, as well as the phase line Zo and the element diameter were preserved.

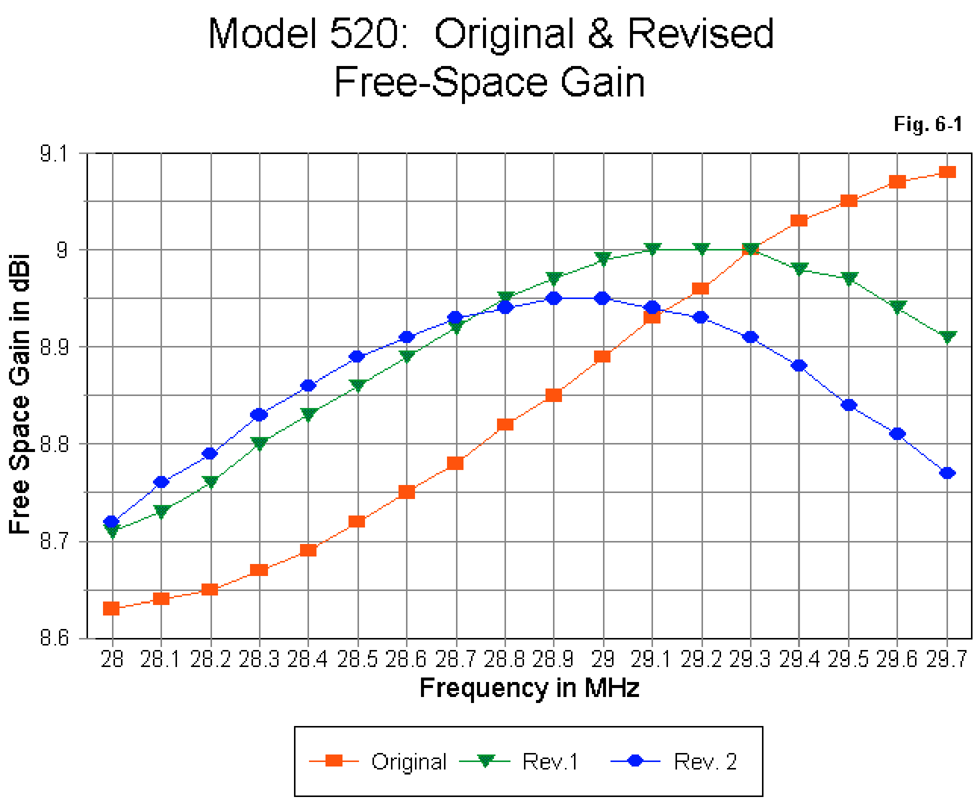
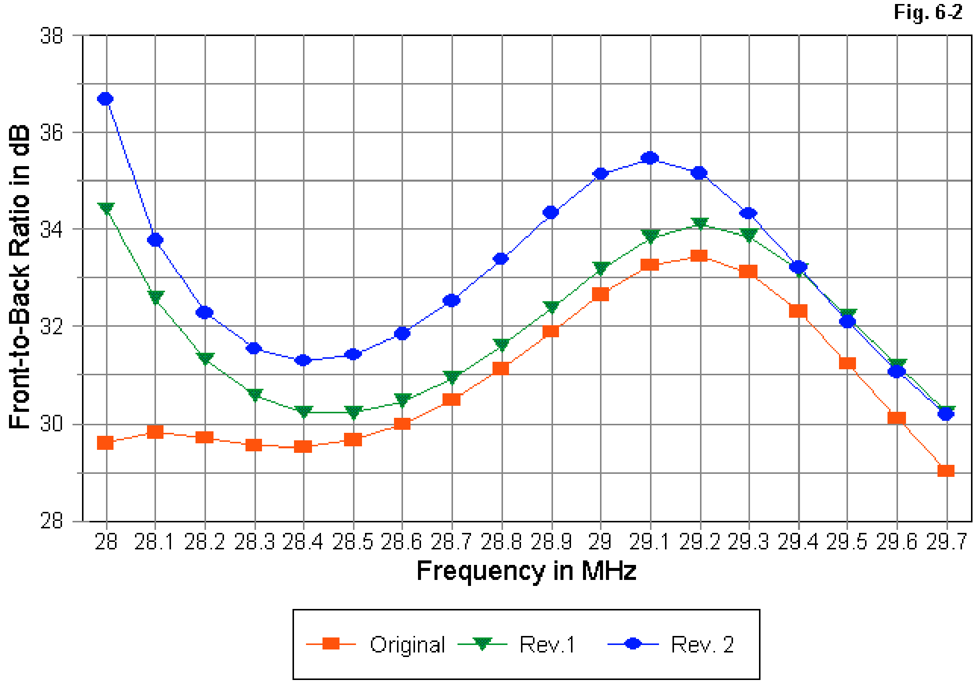


Fig. 6-1 shows the effects of the changes on the array gain. Lengthening the log-cell elements gradually centers the gain peak well within the pass band of the beam. One consequence of this movement is that the gain at the lower end of the band increases. However, as the peak gain approaches the mid-band 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.

Model 520: Original & Revised
Front-to-Back Ratio

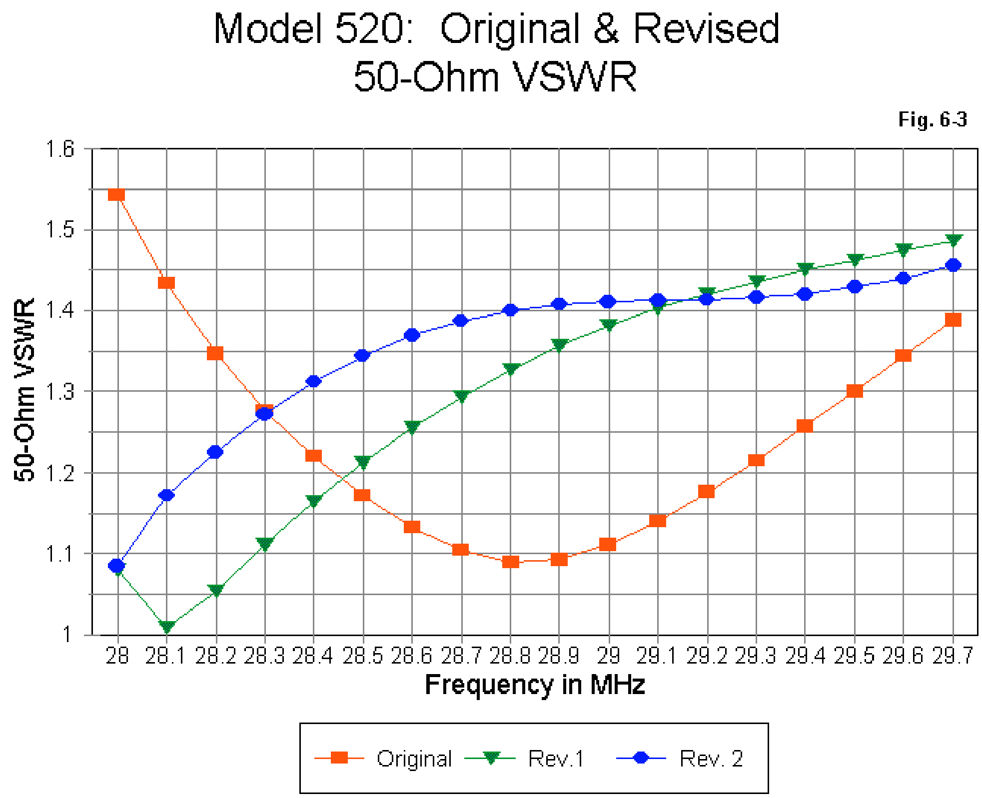
Fig. 6-2



Higher peak gain also results in a somewhat lower front-to-back value across the band, as revealed in **Fig. 6-2**. Changing the log-cell element length to smooth out the gain actually produces greater variations in the front-to-back ratio across the band. One conclusion we may reach from these curves is that the smooth front-to-back 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 Zo remains constant. See **Fig. 6-3**. 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.

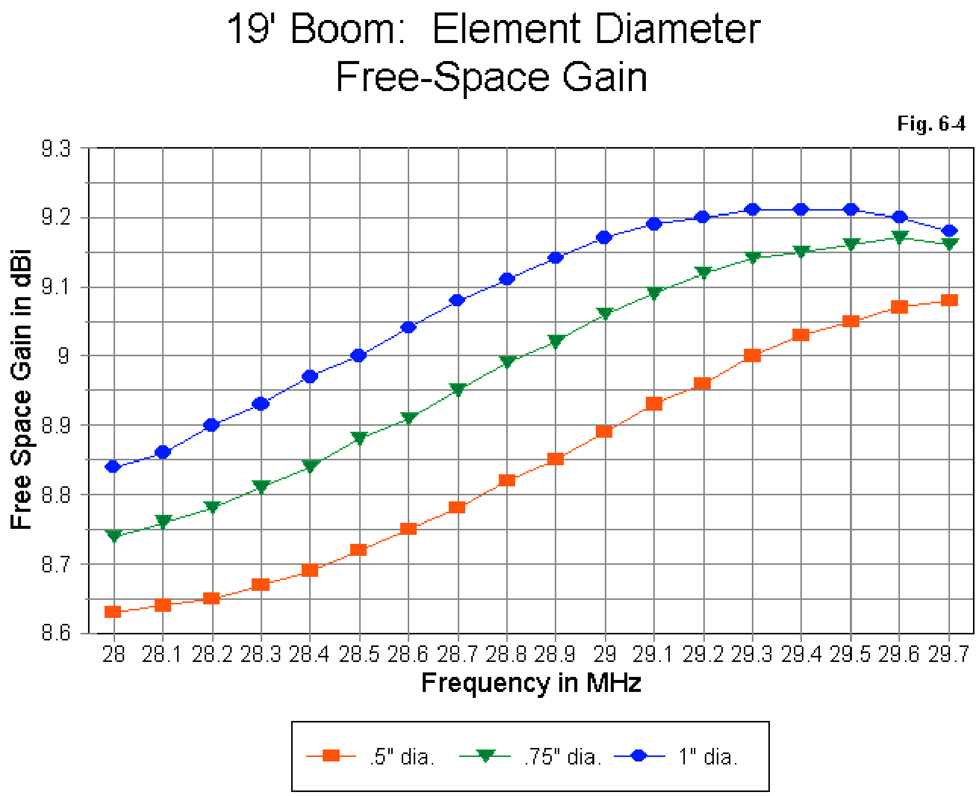
The gain-centering effect of modifying the lengths of the log-cell elements can be examined by modeling the log cell alone, without the parasitic elements. Because the director and reflector are dimensioned to smooth log-cell Yagi performance across the operating bandwidth, the log cell alone will show more variation in gain across the band. However, the frequency at which we find gain peaks will closely coincide with peak gain frequency for 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. However, at band edges, the gain difference may well exceed a full 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.

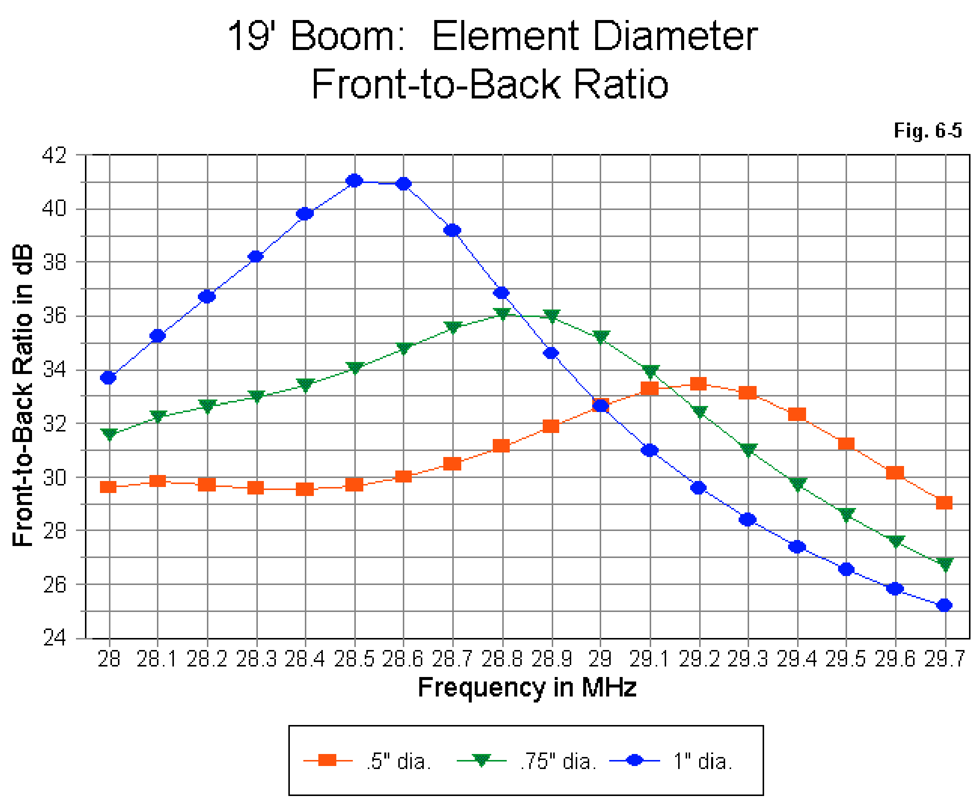


2. Element Diameter: As one would expect, increasing the diameter of the elements in a log-cell Yagi has the consequence of lowering the center frequency of the curves in all of the categories we have been using to express array performance: gain, front-to-back ratio, and 50-Ohm VSWR. As a demonstration of the phenomenon, I used the original model 520, the dimensions of which appear at the top of **Table 6-1**, as the basis for a number of variations. I increased the initial 0.5" diameter elements first to 0.75" and then to 1.0" without changing any other physical or electrical property of the beam.

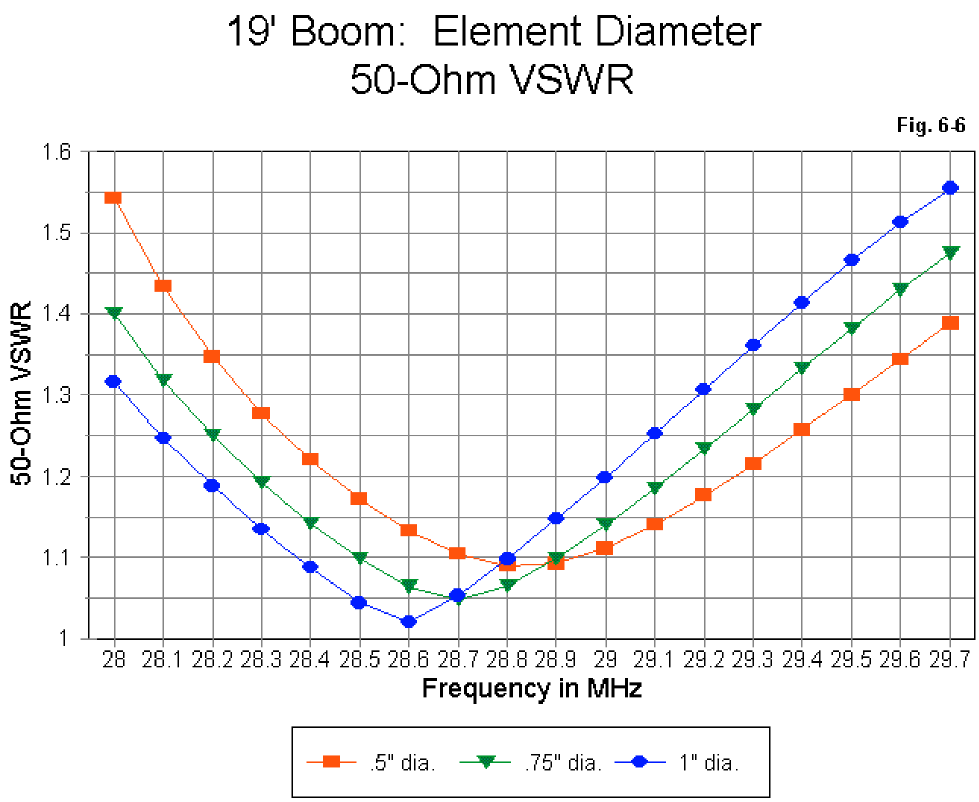
Fig. 6-4 shows the effects of the increases upon the free-space gain of the array. Although the peak gain of the 0.5" design occurs above the 10-meter band, the larger diameter models reveal peak gain vales within the band, with an approximate 0.25 MHz decrease in frequency per 0.25" increase in diameter. 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-degree front-to-back ratio as we increase element diameter alone. In **Fig. 6-5**, we note a larger shift down the band as we move from 0.5" to 1.0" elements. As well, the maximum front-to-back peak for the 1.0" element model is much higher than for the smaller elements. However, the range of front-to-back values also increases. To smooth the curve for the front-to-back element for the larger diameter elements would require other modifications to the design, including readjustments to the parasitic elements.





As shown in **Fig. 6-6**, the 50-Ohm VSWR curves are nearly congruent, with the larger element 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 Ohms at the 28.0 MHz to about 65 Ohms 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 Ohm anywhere in the pass band. 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 VSWR minimum is lower.



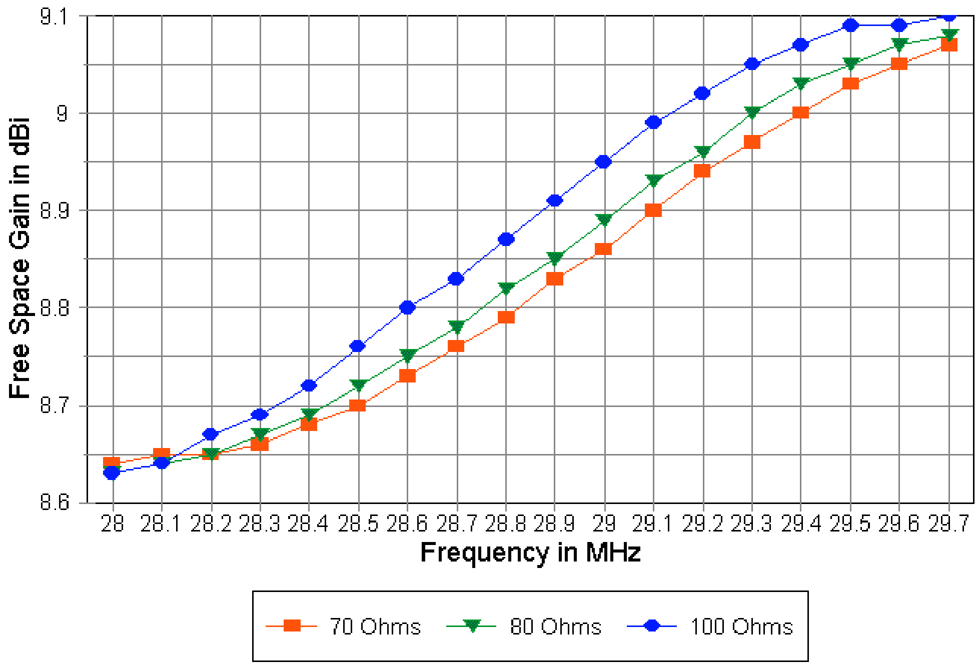
In every respect, the effects of increasing the element diameter in a log-cell Yagi can be classified as normal to the LPDA behavior of the log cell.

3. 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 6-1**–I changed the characteristic impedance of the phase line, using a low value of 70 Ohms and a high value of 100 Ohms. The small pull on the gain curve toward a lower frequency and very slightly higher peak value shows up on **Fig. 6-7**.

Much more profound is the effect of the phase-line impedance on the 180-degree front-to-back curve in **Fig. 6-8**. As the phase-line impedance increases, so too does the peak front-to-back ratio and the rate of change in value from one frequency to the next. In general, the smoothest front-to-back curves for long-boom log-cell Yagis occur with the lowest obtainable phase-line characteristic impedance.

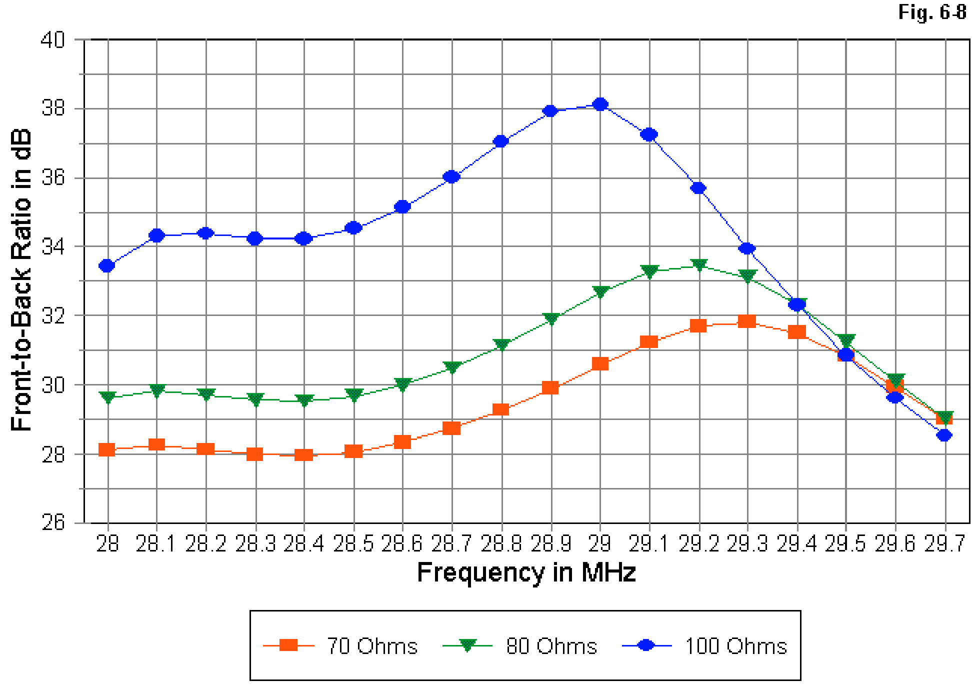
19' Boom: Phase-Line Impedance
Free-Space Gain

Fig. 6-7

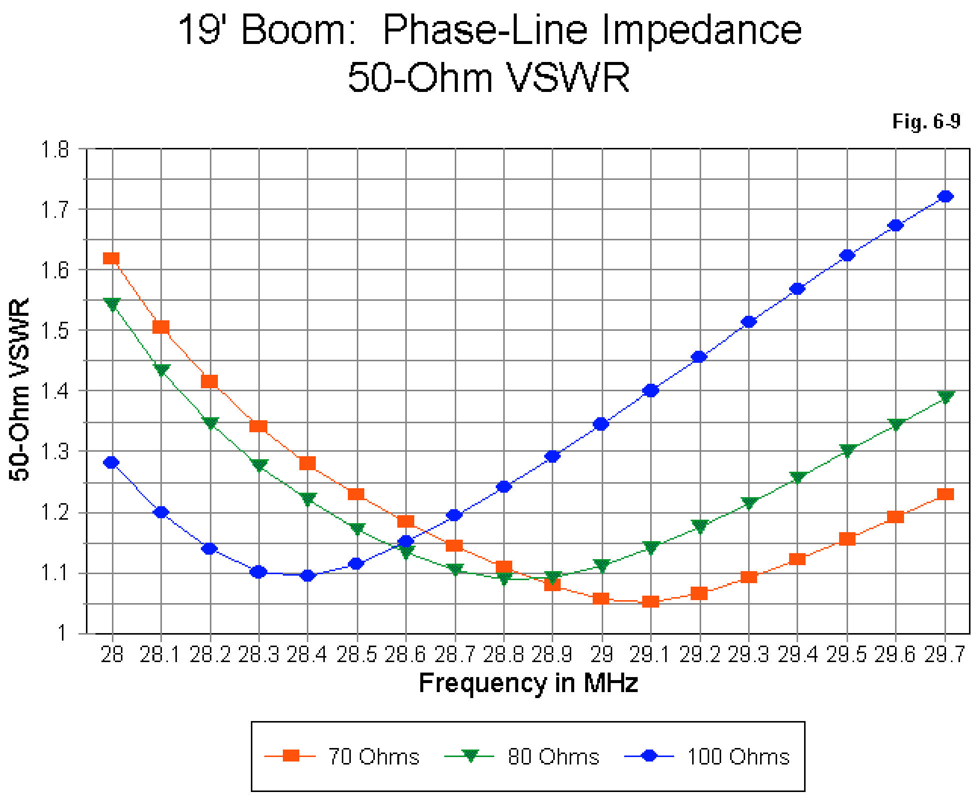


19' Boom: Phase-Line Impedance
Front-to-Back Ratio

Fig. 6-8



The characteristic impedance of the phase line is directly related to the resistive component of the cell feedpoint impedance. The higher the line Zo, the higher will be the resistive part of the impedance. At the mid-band frequency (28.85 MHz), the feedpoint impedance is 50 - j4 Ohms for the 70-Ohm design, 53 - j3 Ohms for the 80-Ohm model, and 63 + j1 Ohms for the 100-Ohm version of model 520. Moreover, the lowest feasible characteristic impedance for the log-cell also tends to yield the smoothest SWR curve. See **Fig. 6-9**.



Although element diameter and phase-line Zo 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.

4. 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 pass band. As well, reducing the phase-line Zo to about 70 Ohms would reduce the front-to-back 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 front-to-back ratio, despite a small "bump" in the curve near 28.2 MHz. The model's impedance ranges from about 38 to 65 Ohms resistance and from -13 to + 20 Ohms reactance. Hence, its VSWR curve will not match that of model 526.

526 manages the smoothest composite set of performances curves of any of the initial models. The gain varies by under 0.25 dB across the band, while the front-to-back ratio varies by under 0.8 dB. The 50-Ohm SWR is under 1.5:1 across the band. In exchange for the smooth performance, the front-to-back ratio 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 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 wavelengths, respectively. In general, the use of these spacing values will net a working log-cell Yagi, with two provisos: a. The lengths of these elements will change as the value of σ increases, and b. The spacing–especially of the director–will increase with increases in the value of σ.

Close spacing of the director and reflector tends to yield the highest values of front-to-back ratio. The front-to-back ratio will be somewhat erratic with close spacing of the parasitic elements, and gain will not be maximum. Smoothing the front-to-back ratio across a wide pass band 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 wavelengths from the rear element of the log cell, while the reflector is about 0.19 wavelengths 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 6-1** 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 Zo to 65 Ohms and increased the element diameter to 0.75".

Table 6-2. Dimensions of Wide-Band Log-Cell Yagis

5-Element Log-Cell (7-Element Array): Model 526

	Element Half-Length Feet	Element Half-Length Wavelengths	Spacing from Reflector Feet	Spacing from Reflector Wavelengths
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 Zo = 65 Ohms

Revision 1 to Model 520

	Element Half-Length Feet	Element Half-Length Wavelengths	Spacing from Reflector Feet	Spacing from Reflector Wavelengths
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 Zo = 80 Ohms

Wide-Band Version of Model 520

	Element Feet	Half-Length Wavelengths	Spacing from Reflector Feet	Wavelengths
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 Zo = 65 Ohms

Of course, in the process of increasing the parasitic element spacing, the total model length for 520 grew to about 21.1'. **Table 6-2** summarizes 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 also is about 0.12 wavelengths behind the log cell. 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.

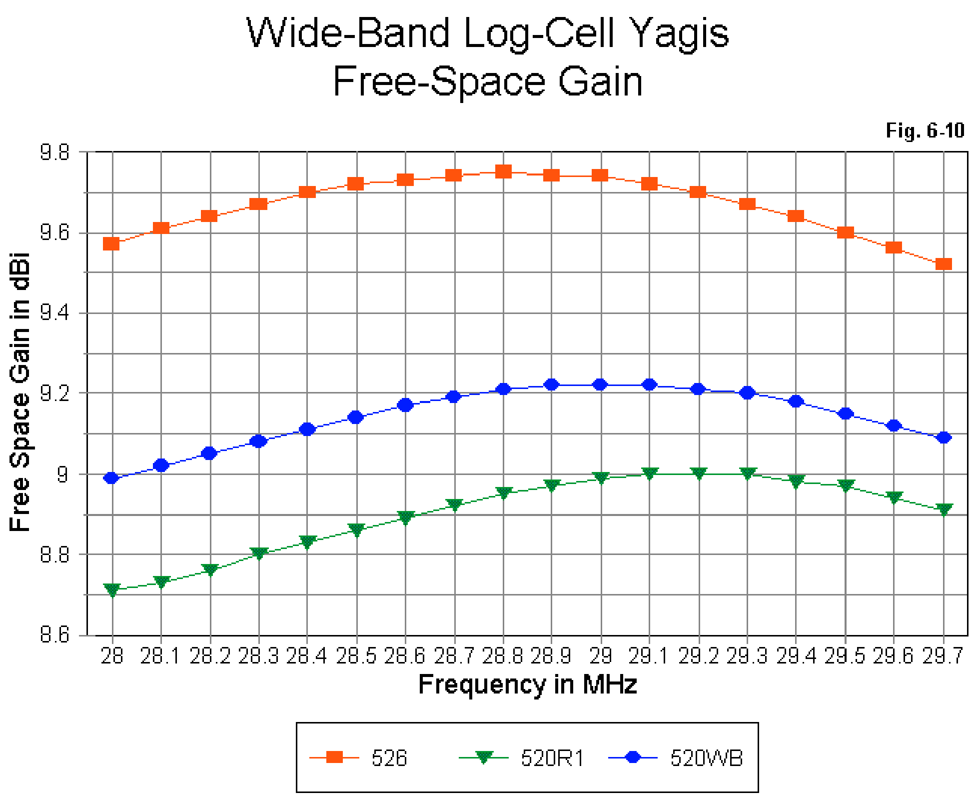
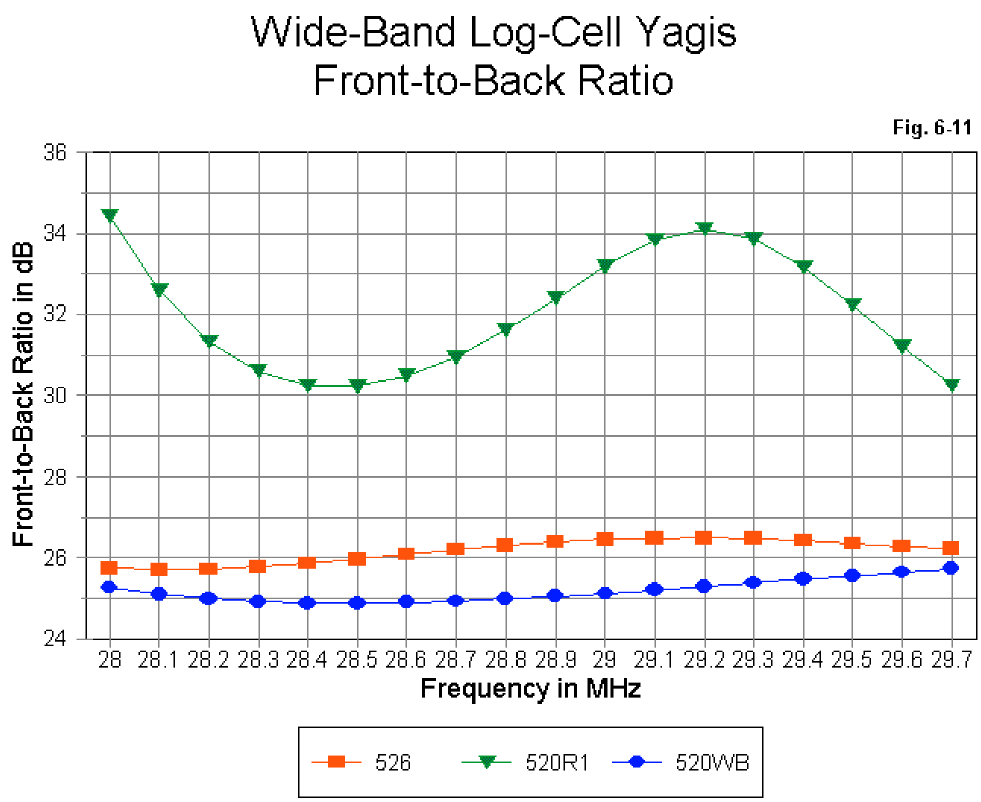


Fig. 6-10 compares the gain of the three models on which we are focused. 526 has the highest and best-centered gain curve. However, the wide-band version of 520 shows increased gain and better curve centering relative to the design version on which it is based. Part of the

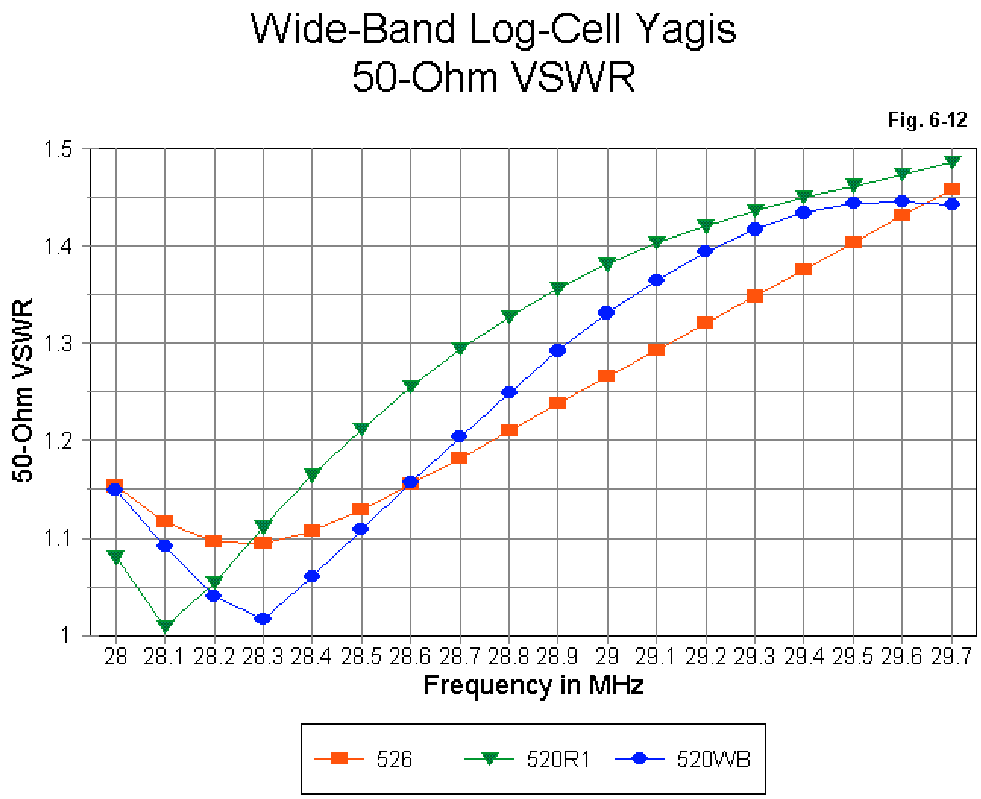
centering derives from the decrease in phase-line Zo, while part of the gain increase stems from the use of larger diameter elements. However, some of the increase can also be ascribed to the overall lengthening of the array. The gain differential across the 10-meter band for 520 has fallen to 0.23 dB.

The front-to-back ratio of the wide-band version of 520 exhibits a similar levelness, as shown in **Fig. 6-11**. The differential is less than 0.85 dB across the band, which is far smoother than provided by the base-line model, whose front-to-back curve is also traced in the graphic. The cost of such even performance is, of course, a lowering of the intrinsic front-to-back values by an average of 7 dB down to the 25-dB level. Note also that the front-to-back ratio of the wide-band version of 520 is about a half 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-Ohm VSWR curve in **Fig. 6-12** has a slightly different shape than the corresponding curve for model 526. However, the SWR never rises above 1.45:1 across 10 meters and the curves reach their minimum values at the same frequency.

The exercise establishes that achieving flatter performance curves, especially for gain and front-to-back ratio, is possible for virtually any boom length that is feasible with a 5-element log cell. Spreading the reflector and director elements provides added gain but decreased front-to-back ratio in the process of smoothing the performance curves. In contrast, closer spacing of the reflector and director yield higher but more erratic front-to-back 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 which 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 either to 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.

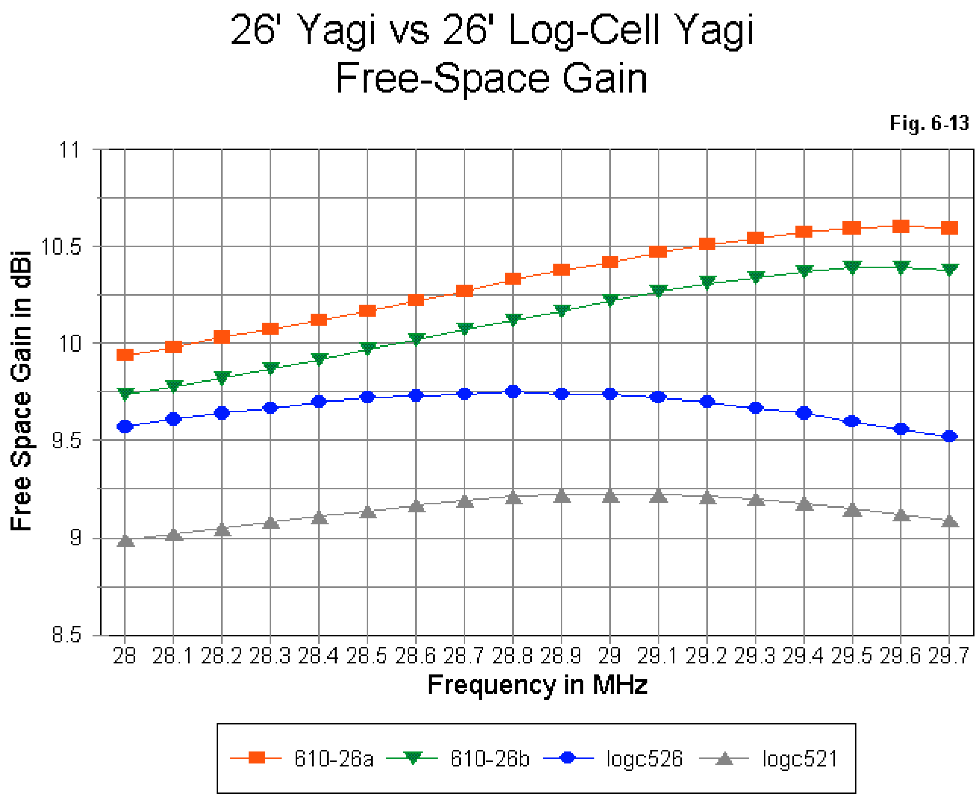
All of the log-cell Yagis we have examined use a total of seven elements. At the 26' boom length, it is possible to develop a wide-band 6-element Yagi. One preliminary design of promise has emerged from the work of Dean Straw, N6BV. The dimensions appear in **Table 6-3**. The design should be considered provisional and subject to further optimization.

Table 6-3. Dimension of a Wide-Band 6-Element 10-Meter Yagi

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

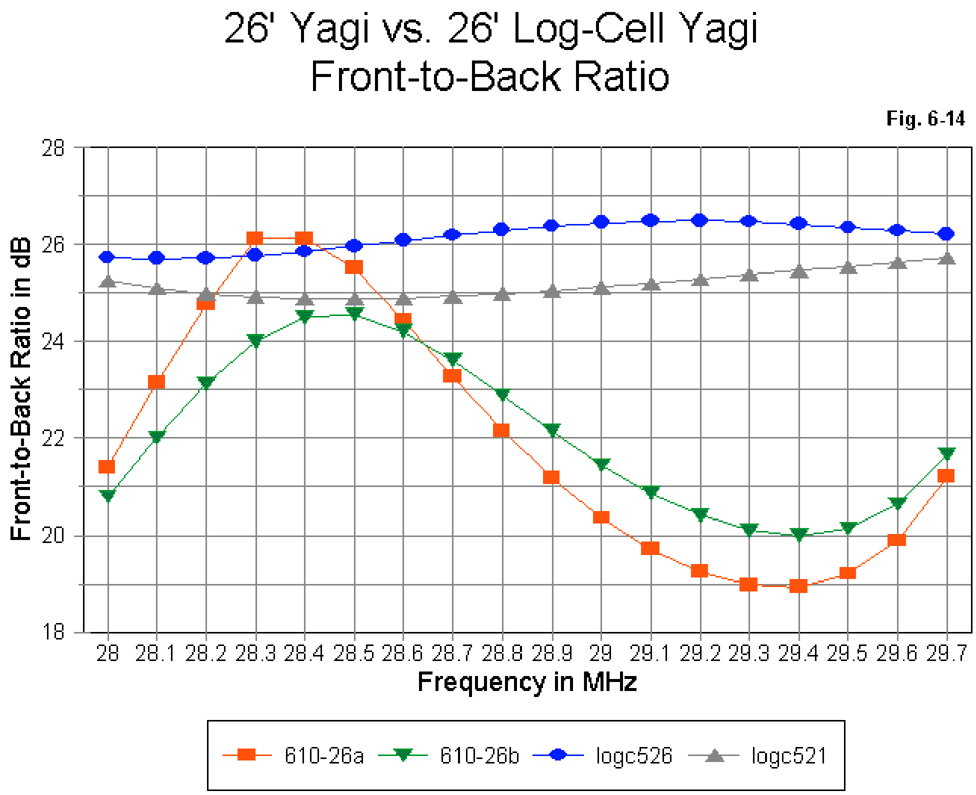
Note: This N6BV design is provisional and subject to further optimizing by its author.

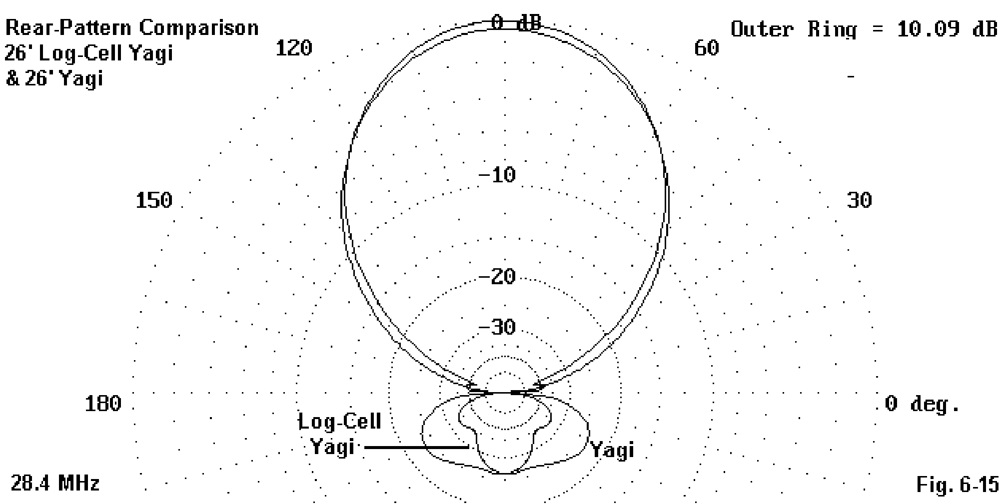
As shown in **Fig. 6-13**, the Yagi shows superior gain to the log-cell Yagi, despite the equivalency of boom length. The average gain of the Yagi is about 10.3 dBi, for an advantage over the log-cell Yagi of about 0.6 to 0.7 dB. Typical of Yagis with directors, the gain increases with frequency and does not peak until 29.6 MHz. The total variation in gain across the band is about 0.65 dB. In contrast, the 26' log-cell Yagi varies by less than 0.25 dB across the band.



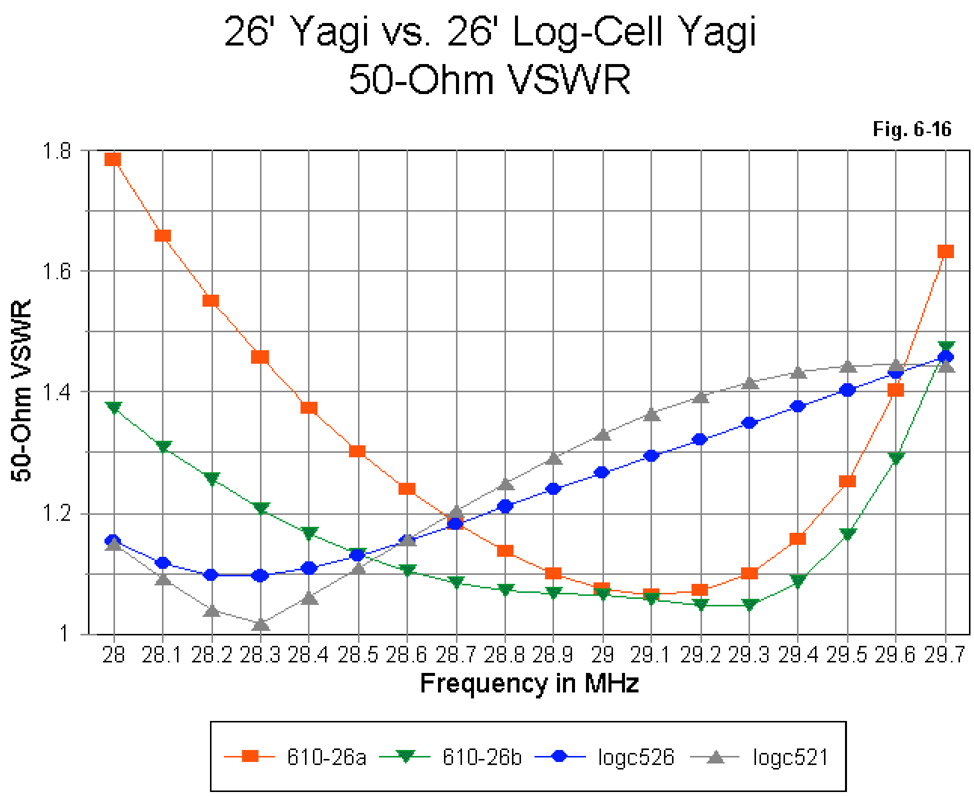
The front-to-back ratio of the log-cell Yagi is equally even across 10 meters, varying by less than 0.8 dB. As is evident in **Fig. 6-14**, the Yagi front-to-back ratio varies by more than 7 dB. It reaches the level of the log-cell Yagi for only a small portion of the pass band, near the lower end of the band. There is an additional advantage that accrues to the log-cell Yagi with respect to its rear lobes.

Fig. 6-15 overlays azimuth patterns at 28.4 MHz for the two antenna–near the Yagi peak front-to-back peak value. As we noted with respect to **Fig. 5-8**, the rear lobes of the log-cell Yagi tend to have a 180-degree front-to-back ratio that is also the worst case front-to-back ratio. Hence, an average front-to-rear ratio for the log-cell design would show a higher value. However, the Yagi rear pattern shows stronger radiation in quartering directions. Hence, the averaged front-to-rear ratio would show a lower value than the 180-degree front-to-back ratio. 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, wide-band Yagi and log-cell Yagi designs.





In **Fig. 6-16**, we find the 50-Ohm VSWR curves for the two 26' arrays. The Yagi SWR curve, which peaks at about 1.8:1, can be refined into a double humped curve with a lower peak value. However, the log-cell Yagi curve, with a peak value just above 1.45:1, would remain slightly superior.



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. However, the log-cell Yagi can be tailored to yield either very high front-to-back values or to have roughly equal gain and front-to-back 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-call 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.

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