Sidelobe Attenuation and Suppression: Some Further Notes on 12-Element Yagis

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In the preceding discussion of sidelobe attenuation, we focused our work on strategies for reducing both E-plane (horizontal) and H-plane (vertical) sidelobes of longer-boom Yagis set up for horizontal polarization.

In these notes, I shall aim at identifying--perhaps incompletely--some of the factors that go into reducing the strength of sidelobes. The plan is to use examples of 12-element and 20-element Yagis designed for 146 MHz in order to sample a number of phenomena that appear to be associated with both sidelobe attenuation and sidelobe suppression. We shall eventually look at designs that aim for maximum broadband forward gain with little regard for sidelobes, designs that attempt to the degree possible to suppress sidelobes, designs that trade sidelobe suppression for seemingly improved performance, and designs that aim simply to attenuate sidelobes.

Investigators such as David Tanner, VK3AUU, and Fred Griffee, N4GF, have shown that it is possible to attenuate sidelobes to a level that rivals the level so far achieved by suppression techniques. Indeed, it may turn out in the future that the suppression achieved by some OWA designs is simply a consequence of certain design decisions and has no ultimate resolution, or at least no level of improvement that attenuation cannot match. That is one of the possible outcomes of any challenge driven by curiosity. But the investigation is perhaps as informative and useful as the outcome, so the trip is worth taking--at least for me.

In the preceding notes, I drew a distinction between sidelobe attenuation and sidelobe suppression. The general idea of sidelobe attenuation includes the reduction in sidelobe strength. Each sidelobe may not reduce is strength in exact proportion to the other sidelobes, but each sidelobe remains a distinct lobe marked by a clear reduction in strength on either side of the main lobe bearing. In contrast, sidelobe suppression involves the elimination or near elimination of a sidelobe in addition to a reduction in sidelobe strength. The left two detail E-plane patterns in **Fig. 1** allow us both to identify the sidelobes in a 12-element Yagi of standard design and to see what difference suppression makes, relative to simply reducing the strength of the standard-design sidelobes.

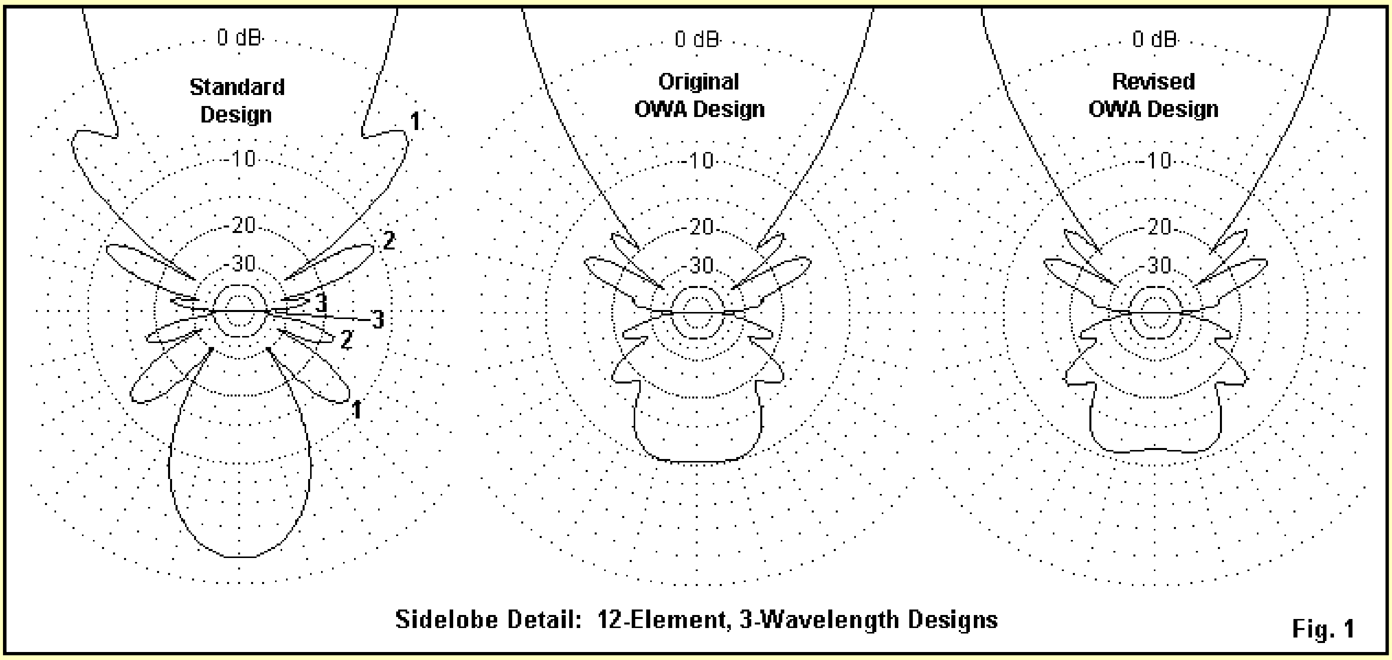


Fig. 1

The left-most detail identifies the sidelobes, both forward and rearward, that appear with 3-wavelength Yagi designs. The number of forward and the number of rearward sidelobes on each side of the boom-line tends to equal the boom length in wavelengths. The left detail uses a boom just under 3 wavelengths, and one of the rear sidelobes is too small to see clearly, although it shows up definitively on a suitably detailed azimuth pattern of the antenna's model.

A Yagi design that seeks to attenuate sidelobes will end up with the same number of distinctly identifiable sidelobes as the left detail, although the strengths may be considerably lower. A standard design tends to show the most strength in the forward-most sidelobe, with decreasing strength in sidelobes that diverge further and further from the bearing of the main forward lobe. Designs that aim only at attenuation may either replicate this pattern at reduced sidelobe levels, or one or more sidelobes will show a reduction in strength that is greater than the attenuation achieved by other lobes. This last condition tends to represent the ill-defined "frontier" between attenuation and suppression.

Sidelobe suppression has additional characteristics besides reduced sidelobe levels. Sidelobes may disappear, almost always due to merging by redirection of one or more of them. The center pattern shows the nearly complete merger of the second and third forward sidelobes in addition to the much reduced sidelobe strength.

We may also use both the center and right detail patterns to note that rearward sidelobes can sometimes create confusions. The center pattern seems to show a main, somewhat square, rearward lobe with only two sidelobes. However, the right version shows that the main rearward lobe is composed of 3 overlapping lobes, a main lobe and a sidelobe each side of the main lobe. The right detail shows a condition where the main lobe is further reduced in strength--a periodic feature of Yagis. The sidelobes now show their peaks.

We shall continue our use of **Fig. 1** in the discussion of 12-element Yagi designs as we examine in more detail the design features that produce suppression as well as attenuation.

A Selection of 12-Element Yagis

The original Yagi design that gave rise to my curiosity about sidelobe suppression is an extension of the Optimized Wideband Array (OWA) designs for HF, originated by NW3Z. Let's note at the outset that the OWA terminology is only a label. OWA Yagis do not have the widest operating passbands possible--that honor appears to go to DL6WU designs that we shall visit along the way. Rather, the OWA concept includes a passband showing a very low 50-Ohm SWR across a designated set of frequencies--usually a specific amateur band. As well, the design concept includes gain and front-to-back peak values that occur within the passband as near to the design frequency as feasible. Alternative to centering the peak values is to place them on a frequency within the passband so that performance at the upper and lower edges of the band is about the same--within very close limits compared to more standard designs. Standard Yagis up to 5 or 6 elements tend to show a rising gain with increases in frequency, even if the front-to-back ratio occurs within the passband. The OWA design allows both peaks to occur within the passband.

OWA designs have several features that work together to achieve the desired operating features. The first OWA design element is the use of a direct 50-Ohm feed system composed of the reflector, the driver, and the first director. The three elements together largely (but not exclusively) establish the feedpoint impedance. The OWA system uses a reflector-driver spacing of about 0.11 wavelength together with a driver-director1 spacing of about 0.058 wavelength to establish the impedance. Since the first director operates as a secondary driver, energized by close coupling to the fed driver, element lengths are also critical to arriving at the desired impedance across the passband. In fact, the secondary driver has a higher current magnitude for about 2/3 of the passband, with the fed driver dominant only for the lower third of the passband.

The second aspect--perhaps unique or nearly so with the OWA design--is the use of directors 2 and 3 as control elements. Director 3 is the same length as director 2 or slightly longer. Together, these elements permit the designer to center the peak gain and peak front-to-back ratio at or near the center of the passband. The result tends to be nearly equal front-to-back ratio values at the band edges and the minimum feasible change of gain across the antenna's operating passband.

The third feature has the greatest affect on the sidelobe emergence in the array. By tapering all elements--with some equal length pair exceptions--to shorter lengths as we move forward along the line of directors (from about director 4 onward), we obtain lower sidelobe levels at the cost of some gain compared to more standard designs. As we shall see, the element taper schedule does not guarantee sidelobe suppression, but acts in concert with the balance of the first two features of the design.

We may begin with the original 12-element OWA Yagi design for 146 MHz. The following table provides the dimensions in inches. Multiply by 25.4 to arrive at the dimensions in millimeters. The boomlength is 2.94 wavelengths.

Dimensions of "Original" 12-Element OWA Yagi

Notes: Element diameter: 0.1875" (3/16" or 4.76 mm). For dimensions in millimeters, multiply by 25.4

Element	Length inches	Space from Reflector inches
Reflector	**40.90**	**-----**
Driver	**39.50**	**8.79**
D1	**37.00**	**13.47**
D2	**36.33**	**25.38**
D3	**36.40**	**40.72**
D4	**36.21**	**61.38**
D5	**35.20**	**86.49**
D6	**34.30**	**116.00**
D7	**33.60**	**146.60**
D8	**32.90**	**178.40**
D9	**32.20**	**210.00**
D10	**31.20**	**238.00**

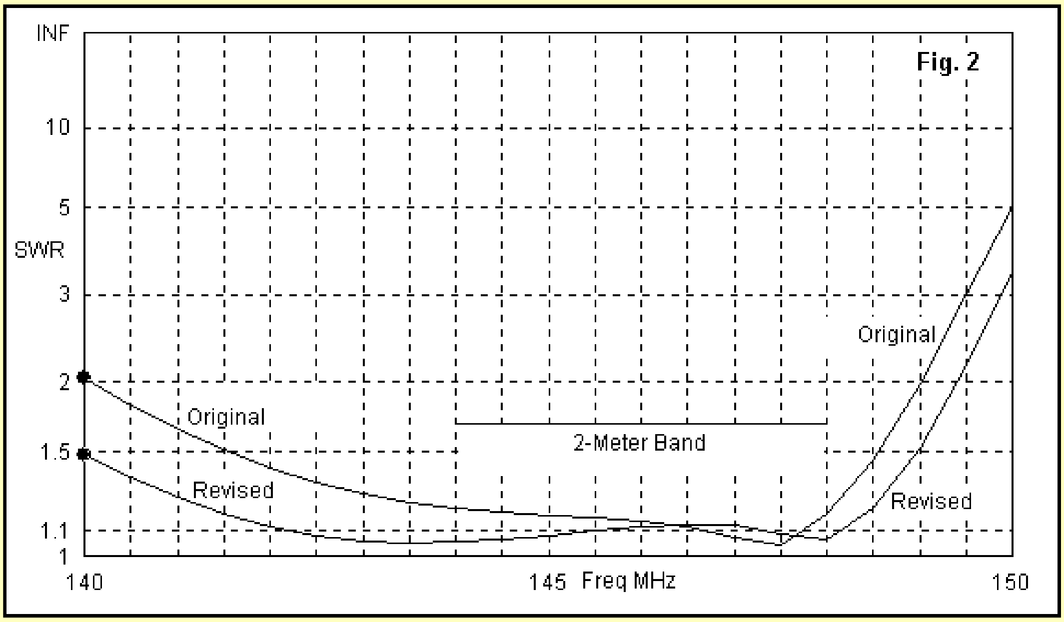
To facilitate comparisons, I shall present both graphic and tabular modeled performance data. The tabular data will use 144, 146, and 148 MHz as check points. The data will include free-space gain, 180-degree front-to-back, and the front-to-forward-sidelobe value in the horizontal plane. Vertically, the sidelobe ratio will use simply the strongest H-plane sidelobe, which may be the forward-most lobe or a lobe more tangential to the plane of the array. Unlike the preceding notes, this discussion will only make passing note of vertical or H-plane sidelobes as we focus on the E-plane or horizontal sidelobes.

Modeled Performance: "Original" 12-Element OWA Yagi

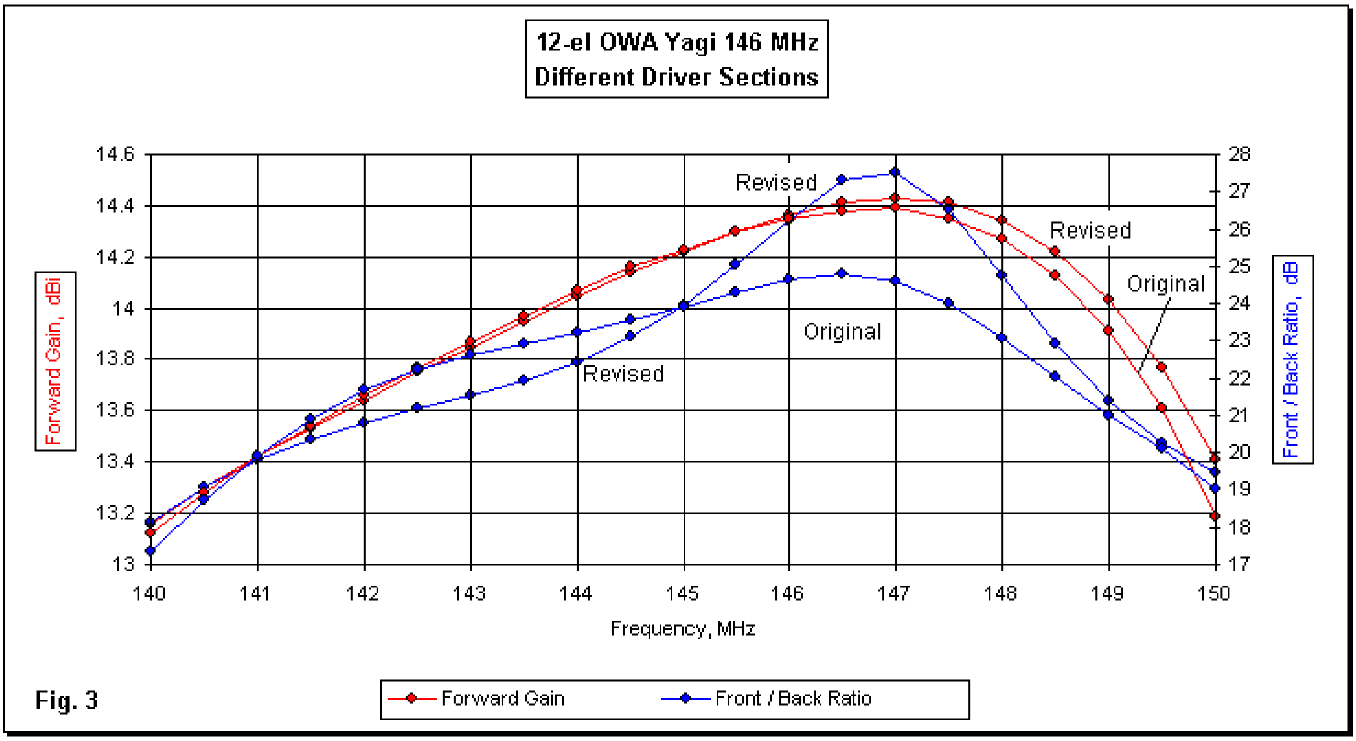
Freq. MHz	Free-Space Gain dBi	180-Deg. Front-Back Ratio dB	Hor. F-S/l Ratio dB	Vert F-S/l Ratio dB
144	**14.07**	**25.19**	**25.19**	**18.95**
146	**14.35**	**24.65**	**27.91**	**18.15**
148	**14.27**	**23.09**	**25.00**	**16.43**

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
144	**38.4**	**42.6**	**43.1 + j4.9**	**1.20**
146	**36.8**	**40.5**	**47.5 + j6.2**	**1.15**
148	**35.5**	**39.0**	**43.8 - j4.1**	**1.17**

Since all of our subject antennas offer broadband performance, graphical data will use a 140-150-MHz passband. In some cases, the graphs will show information for multiple designs in order to conserve space. For example, the 50-Ohm SWR curves in **Fig. 2** show the original design and a revised OWA design that we shall discuss shortly.



Note that the original OWA design curve has a very slow-rising characteristic below the 2-meter band, but rises rapidly above 148 MHz. This characteristic attaches to many, but not all wide-band Yagis. The SWR within the 2-meter band does not exceed 1.2:1 and reaches a value of 2:1 at 140 MHz. However, it passes the 2:1 mark at 149 MHz on the other end of the band.



Using the graph lines marked "original," note that the peak gain occurs at 147 MHz, while the peak front-to-back ratio occurs at 146.5 MHz, a fairly close coincidence. The gain is about 0.5 dB shy of the gain achievable with a standard (DL6WU) design. However, the sidelobes are diminished and suppressed to the level shown both in the center of **Fig. 1** and the table of performance values. Across the 2-meter band, the E-plane forward sidelobes are down by at least 25 dB relative to the array's main lobe. Vertical sidelobes remain less attenuated, although as we shall see, they are lower than comparable sidelobes in standard designs.

Because some wide-band Yagi designs achieve SWR levels even lower than those shown by the original OWA design, I revised the design to seek a lower maximum SWR value within the 2-meter band. The chief strategy was to change the spacing of driver from the reflector and the first director from the driver. The original reflector-driver spacing was 0.1087 wavelength, and the driver-director1 spacing was 0.0579 wavelength. The new spacing values are 0.1262 wavelength and 0.0529 wavelength, respectively. These changes forced changes to the length of all three elements and a minor revision of the most forward director, including an extension of the boom length to 2.97 wavelengths. The following table shows the revised dimensions.

Dimensions of "Revised" "Original" 12-Element OWA Yagi

Notes: Element diameter: 0.1875" (3/16" or 4.76 mm). For dimensions in millimeters, multiply by 25.4

Element	Length inches	Space from Reflector inches
Reflector	**40.97**	**-----**
Driver	**39.62**	**10.20**
D1	**36.91**	**14.48**
D2	**36.33**	**26.38**
D3	**36.38**	**41.72**
D4	**36.10**	**62.38**
D5	**35.22**	**87.49**
D6	**34.30**	**117.00**
D7	**33.60**	**147.60**
D8	**32.90**	**179.40**
D9	**32.20**	**211.00**
D10	**31.22**	**240.00**

In terms of SWR bandwidth, **Fig. 2** shows the improvement. The 50-Ohm SWR at 140 MHz drops to 1.5:1, while the upper end of the band shows only a slight improvement. The following checkpoint table of modeled performance values shows the in-band improvements. The highest in-band SWR value is 1.12:1.

Modeled Performance: "Revised" "Original" 12-Element OWA Yagi

Freq. MHz	Free-Space Gain dBi	180-Deg. Front-Back Ratio dB	Hor. F-S/l Ratio dB	Vert F-S/l Ratio dB
144	**14.05**	**22.44**	**24.62**	**18.79**
146	**14.36**	**26.24**	**28.14**	**18.31**
148	**14.34**	**24.75**	**25.54**	**16.90**

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
144	**38.4**	**42.6**	**49.4 + j2.6**	**1.06**
146	**36.8**	**40.4**	**51.0 + j5.6**	**1.12**
148	**35.4**	**38.8**	**52.0 - j2.7**	**1.07**

Operationally, we find virtually no change in array performance. In part, this result stems from the fact that the revised gain and front-to-back curves in **Fig. 3** remain closely aligned. Both the free-space gain and the 180-degree front-to-back ratio occur at 147 MHz. The original and revised designs have gain curves that almost overlay each other. The front-to-back curves have different shapes, but most of the differences in shape occur at ratio values above 20 dB. The right detail in **Fig. 1** shows how well matched the revised array is to the original, with only the 180-degree front-to-back heading showing any notable difference.

At this point, we cannot show the significance of keeping the gain and front-to-back curves well aligned with each other. We shall later have contrasting examples to show the effects of misalignment. For the moment, we can note that the control elements, that is, directors 2 and 3, play a prominent role in this result, but those elements are not wholly independent of the impedance-setting elements behind them. In a Yagi, if you change something, you usually end up changing everything to match or to compensate. The fact that we effected the improved SWR curve with minimal changes to other aspects of the array is a result of the relative shortness of the array (less than 3-wavelength long) and good luck.

One contrast that we can make at this point is between so-called standard Yagi designs and the OWA Yagis that we have just examined. We shall in fact look at both the "official" DL6WU design and a variant by VK6AUU. In addition, we shall examine a highly refined Yagi by N4FG that strives only for maximum sidelobe attenuation. All of these Yagis use 12 elements on 3-wavelength booms.

The "official" DL6WU design emerges from the self-executing DOS program DL6WU-GG.EXE, which is available from the web site maintained by Ian White, G3SEK (http://www.ifwtech.co.uk/g3sek). The algorithms in the program are updated from an earlier version. You may calculate any size DL6WU design up to 40 or so elements, but we shall restrict ourselves at the moment to 12 elements, which require for the element diameter a 2.85 wavelength boom. The design table presents the dimensions in millimeters, using an element diameter of 4.7625 mm, which translates into 0.1875", the same size as the OWA designs. Divide the dimensions by 25.4 to arrive at their equivalents in inches.

Dimensions of DL6WU (GG) 12-Element OWA Yagi

Notes: Element diameter: 0.1875" (3/16" or 4.76 mm). For dimensions in inches, divide by 25.4

Element	**Length millimeters**	**Space from Reflector millimeters**
Reflector	**1004.92**	**-----**
Driver	**994.74**	**410.7**
D1	**924.21**	**564.7**
D2	**916.71**	**934.3**
D3	**908.07**	**1375.8**
D4	**899.54**	**1889.1**
D5	**891.86**	**2664.1**
D6	**885.15**	**3080.1**
D7	**879.30**	**3726.9**
D8	**874.16**	**4404.5**
D9	**869.60**	**5112.9**
D10	**865.51**	**5852.1**

Within the 4 MHz of 2 meters, the beam exhibits modest performance in every category except forward gain. The peak in-band gain occurs at 148 MHz at 14.9 dBi (free-space), while the peak 180-degree front-to-back ratio appears at 149.5 MHz, above the upper band limit. The following table shows the modeled performance characteristics, including the relatively low attenuation of sidelobes, both horizontal and vertical.

Modeled Performance: DL6WU (GG) 12-Element OWA Yagi

Freq. MHz	**Free-Space Gain dBi**	**180-Deg. Front-Back Ratio dB**	**Hor. F-S/I Ratio dB**	**Vert F-S/I Ratio dB**
144	**14.60**	**17.52**	**18.26**	**13.80**
146	**14.80**	**14.98**	**17.51**	**13.48**
148	**14.89**	**17.31**	**16.27**	**12.88**

Freq. MHz	**Hor BW degrees**	**Vert BW degrees**	**Feedpoint Impedance R +/- jX Ohms**	**50-Ohm SWR**
144	**35.2**	**38.2**	**61.7 + j3.4**	**1.25**
146	**33.4**	**36.0**	**57.6 - j9.4**	**1.25**
148	**31.8**	**34.0**	**39.5 + j11.2**	**1.41**

Over the enlarged passband, the design shows typical DL6WU design fluctuations in both gain and front-to-back ratio. **Fig. 4** shows The double-hump front-to-back curve. As you add elements to the DL6WU design, the humps change in frequency so that some lengths place the maximum front-to-back ratio at the design frequency, while others place a near front-to-back minimum at the design frequency.

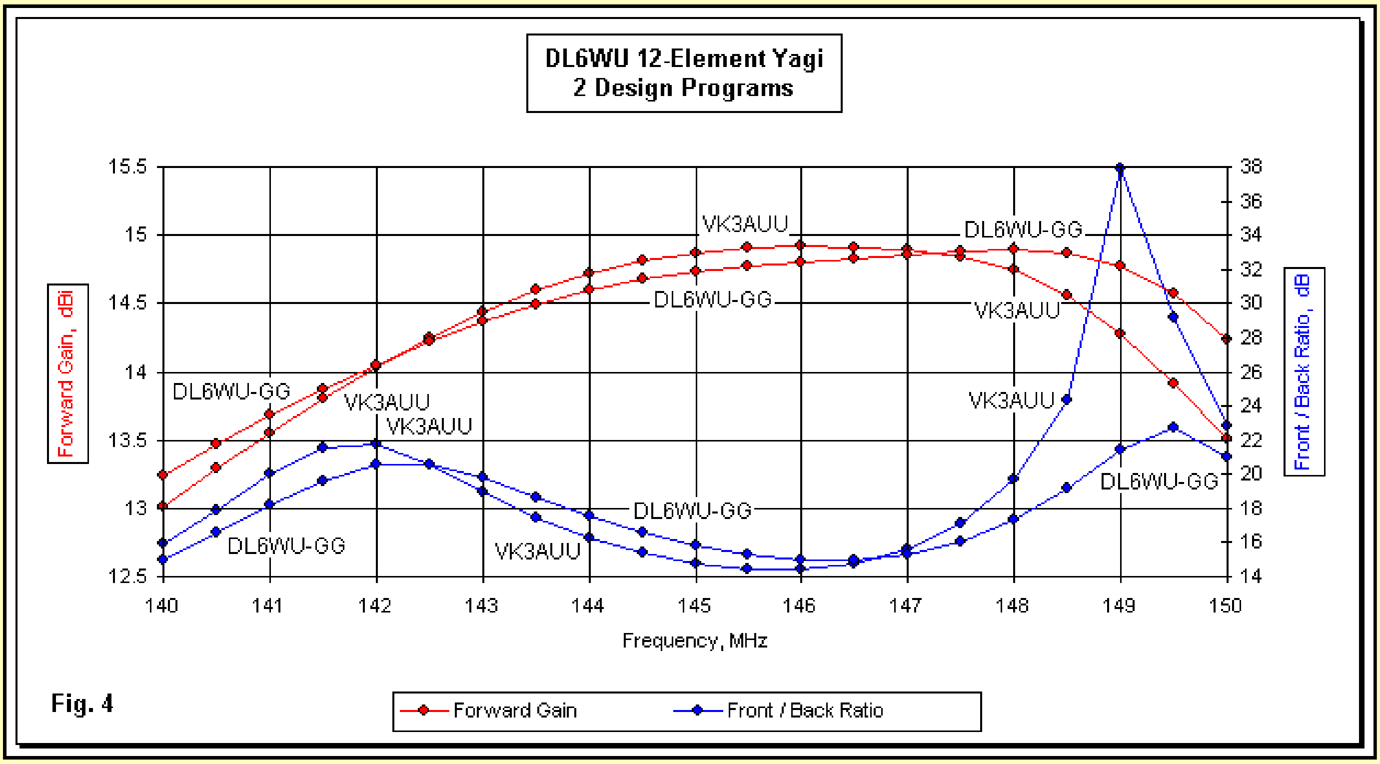


Fig. 4

One special design feature is notable in this context. In contrast to the relatively close spacing of the reflector-driver-director1 assembly in the OWA design, the DL6WU design achieves a direct 50-Ohm feedpoint by using a 0.20-wavelength reflector-to-driver spacing. The distance between the driver and the first director is 0.275 wavelength. As a consequence, the DL6WU official design achieves an exceptionally wide SWR passband, as evidenced in the "GG" SWR curve in **Fig. 5**. The curve has multiple peaks and nulls in contrast to the simple 2-null curve of the OWA design. The original DL6DU design was aimed at fatter elements than are used in these models, and the SWR curves gets flatter up to at least a 10-mm element diameter.

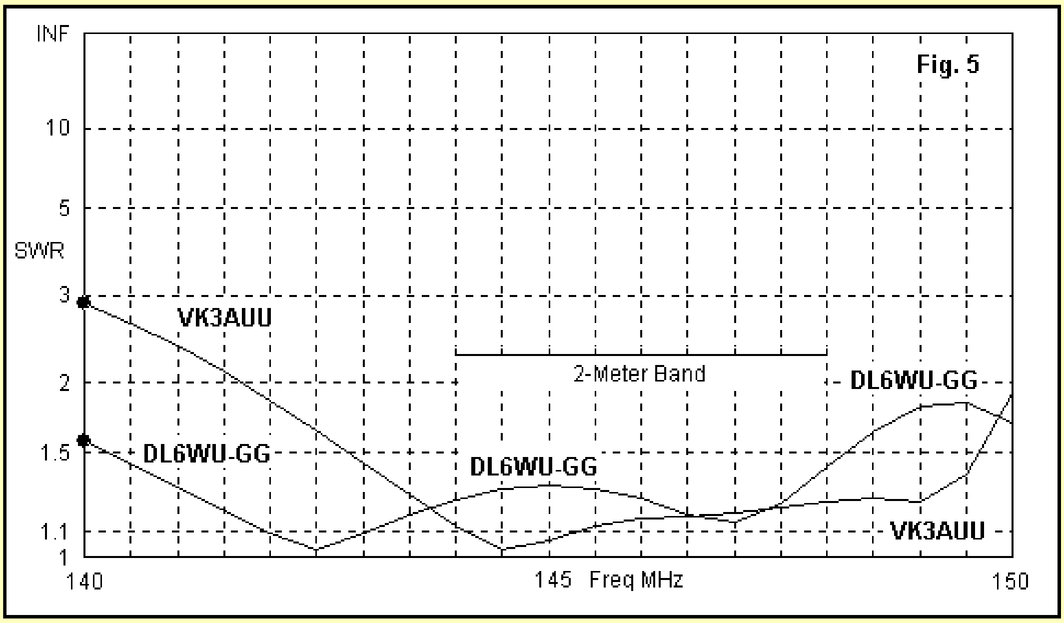


Fig. 5

As an alternative to the official DL6WU design. VK3AUU revised the algorithms to achieve best performance at 19 elements. The major revision in his design falls in the region of the reflect-driver-director1 assembly. Like DL6WU, VK3AUU aimed his work at 10-mm elements, so the 4.76-mm elements in my recalculation of his elements does not necessarily represent the best performance of which the array is capable. The dimension table shows the physical results of using the VK3AUU variant on DL6WU design. The boomlength is 2.84 wavelengths.

Dimensions of DL6WU (VK3AUU) 12-Element OWA Yagi

Notes: Element diameter: 0.1875" (3/16" or 4.76 mm). For dimensions in inches, divide by

25.4

Element	Length millimeters	Space from Reflector millimeters
Reflector	992	-----
Driver	972	375
D1	904	543
D2	894	884
D3	886	1326
D4	877	1840
D5	870	2410
D6	863	3026
D7	856	3680
D8	850	4368
D9	844	5085
D10	839	5829

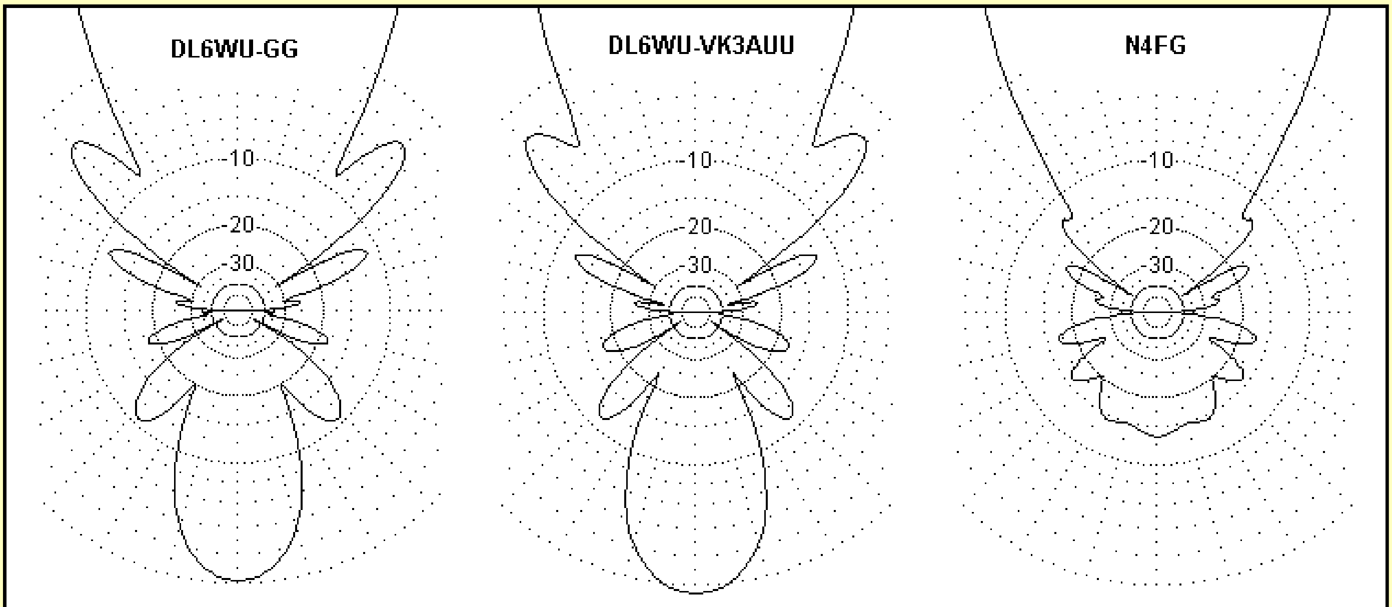
The revised design moves the gain peak to the design frequency. The front-to-back peak remains above the limit of the 2-meter band, as shown in the second set of curves in **Fig. 4**. The designer uses a reflector-to-driver spacing of 0.1826 wavelength, with a driver-to-director1 spacing of 0.2644 wavelength. The result is a wide-band SWR curve, as shown in the alternative line in **Fig. 5**. However, the curve now has only a central region of low SWR, with steep rises at the low and high ends of the expanded passband. The checkpoint table shows the modeled performance within the 2-meter band.

Modeled Performance: DL6WU (VK3AUU) 12-Element OWA Yagi

Freq. MHz	Free-Space Gain dBi	180-Deg. Front-Back Ratio dB	Hor. F-S/I Ratio dB	Vert F-S/I Ratio dB
144	14.72	16.27	18.02	13.73
146	14.92	14.43	16.97	13.18
148	14.74	19.70	14.91 (Bulge)	11.78

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
144	34.4	37.2	46.5 + j1.2	1.13
146	32.6	35.1	51.1 - j7.3	1.16
148	31.2	33.4	44.1 + j8.2	1.24

Fig. 6shows the detail of the sidelobe structure of 3 arrays. For the moment, we may focus on the two left patterns for the DL6WU designs. As the modeled performance tables show, both versions of the DL6WU design have strong sidelobes. In fact, the vertical sidelobes are very strong, averaging under 14 dB reduction relative to the main forward lobe. Compare these numbers to the OWA designs that average about 18 dB vertical sidelobe reduction. The improvement in the horizontal sidelobe reduction of the OWA over the DL6WU design is closer to 7 dB.



Sidelobe Detail: 12-Element, 3-Wavelength Designs

Fig. 6

The third pattern detail in **Fig. 6** belongs to an N4FG design that aims at maximum sidelobe attenuation (in contrast to suppression). Like the DL6WU design, the pattern shows all 3 lobes, both forward and rearward, and their strength has the standard order in which both the most forward and most rearward lobes are the strongest. Compare **Fig. 6** to **Fig.1**, in which the OWA forward sidelobes show a considerable reduction in the forward-most sidelobe and a merging of the second and third forward sidelobes. Nevertheless, as we shall see, the N4FG design does a remarkable job at sidelobe attenuation.

Physically, N4FG places 12 elements on a 2.97-wavelength boom. He employs a reflector-to-driver spacing of 0.1339 wavelength and a driver-to-director1 spacing of 0.0521 to achieve excellent broadband performance. The resulting array dimensions appear in the following table.

Dimensions of N4FG 12-Element OWA Yagi

Notes: Element diameter: 0.1875" (3/16" or 4.76 mm). For dimensions in millimeters, multiply by 25.4

Element	Length inches	Space from Reflector inches
Reflector	40.66	-----
Driver	39.67	10.83
D1	37.40	15.04
D2	36.96	27.14
D3	36.58	39.88
D4	35.97	57.25
D5	35.53	85.20
D6	35.50	110.95
D7	33.72	142.81
D8	33.65	177.01
D9	32.66	211.28
D10	32.15	240.00

Within the 2-meter band, the N4FG array--which is not the ultimate design in his continuing design explorations--shows the following performance characteristics.

Modeled Performance: N4FG 12-Element OWA Yagi

Freq. MHz	Free-Space Gain dBi	180-Deg. Front-Back Ratio dB	Hor. F-S/l Ratio dB	Vert F/S/l Ratio dB
144	14.33	29.55	25.47	18.22
146	14.55	28.03	27.15	16.87
148	14.37	25.31	31.55	16.70

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR

144	37.2	41.0	46.3 + j3.9	1.12
146	35.6	39.0	49.0 + j2.2	1.05
148	34.6	38.0	53.0 + j5.8	1.14

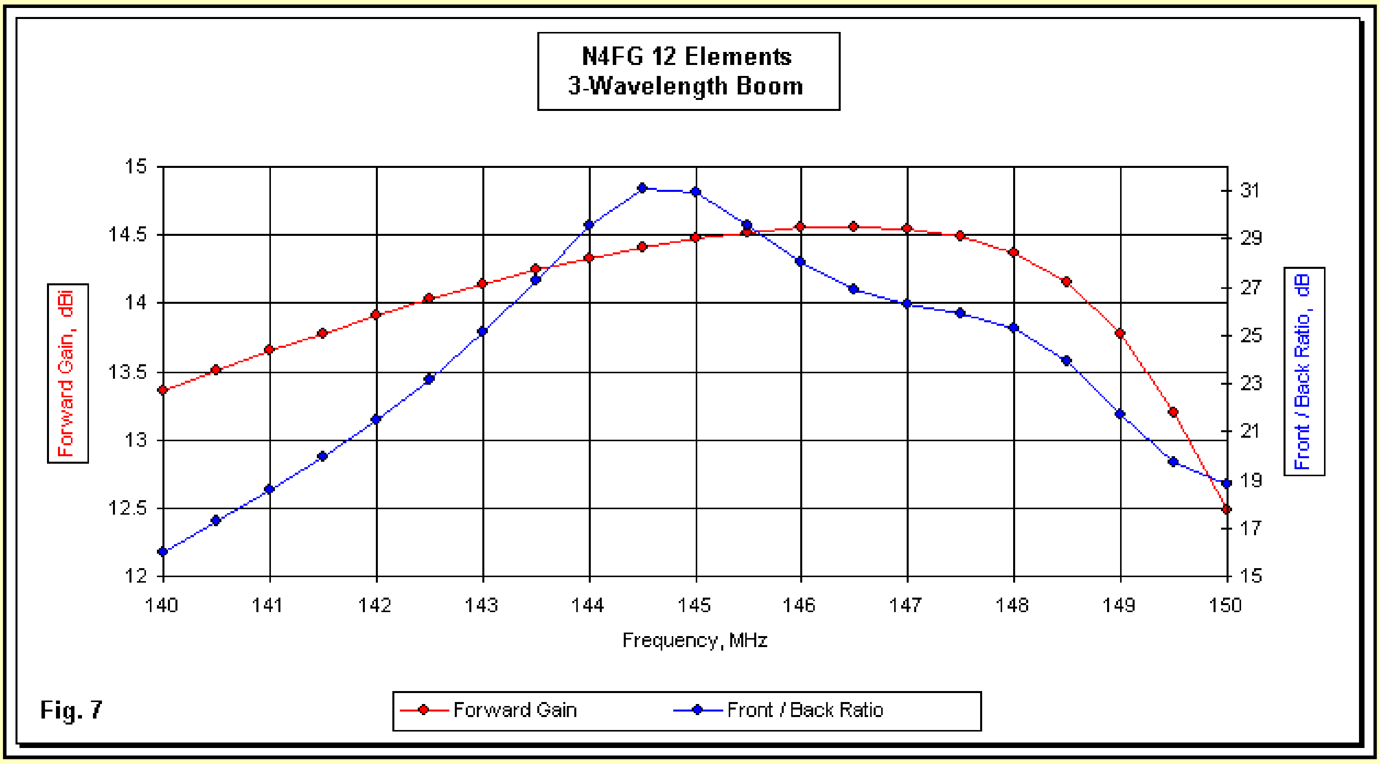


Fig. 7

Fig. 7 shows the performance of the array over the expanded passband. The performance is comparable to the OWA designs, with about a 0.2-dB gain advantage to N4FG. However, amount of change for both gain and front-to-back ratio is greater in the N4FG design. In part, this higher amount of overall change in values within the 10-MHz expanded passband results from the fact that the peak values of gain and front-to-back ratio do not closely coincide with respect to frequency. The peaks are 2 MHz apart, compared to 0.5 MHz or less for the two OWA designs.

Nevertheless, the N4FG design achieves two important results. First, the horizontal sidelobe attenuation is excellent. Even though all sidelobes have standard form, their level averages very close to the levels achieved in the OWA design. The average vertical sidelobe attenuation is far superior to the DL6WU designs, but not quite at the OWA level. The second achievement of the N4FG design is a very broad 50-Ohm SWR curve. **Fig. 8** tells the story on this phenomenon. The curve has much the same shape as the VK3AUU version of the DL6WU design.

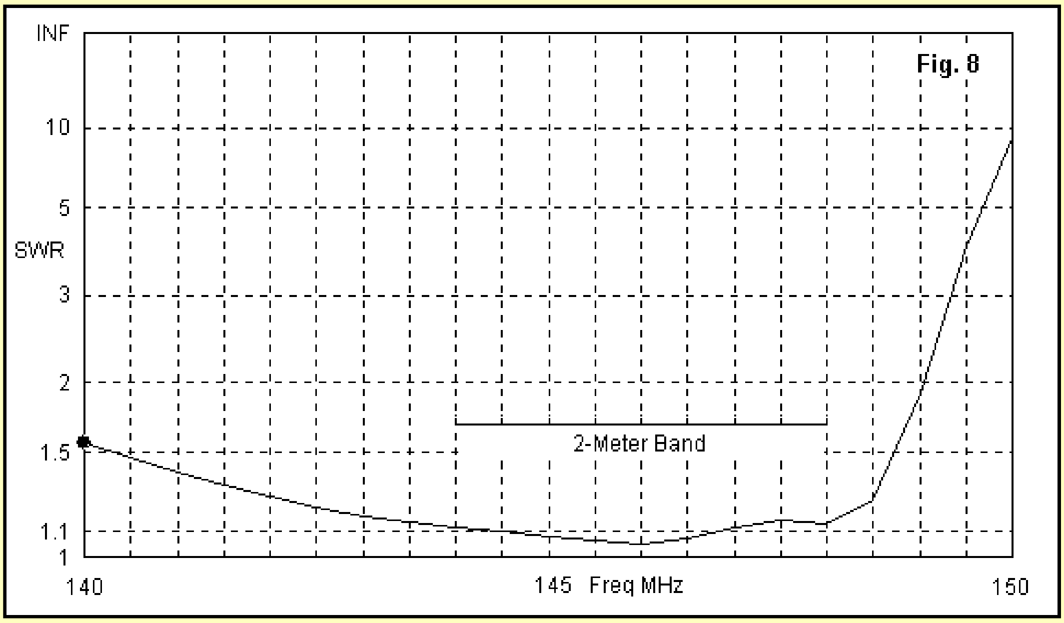


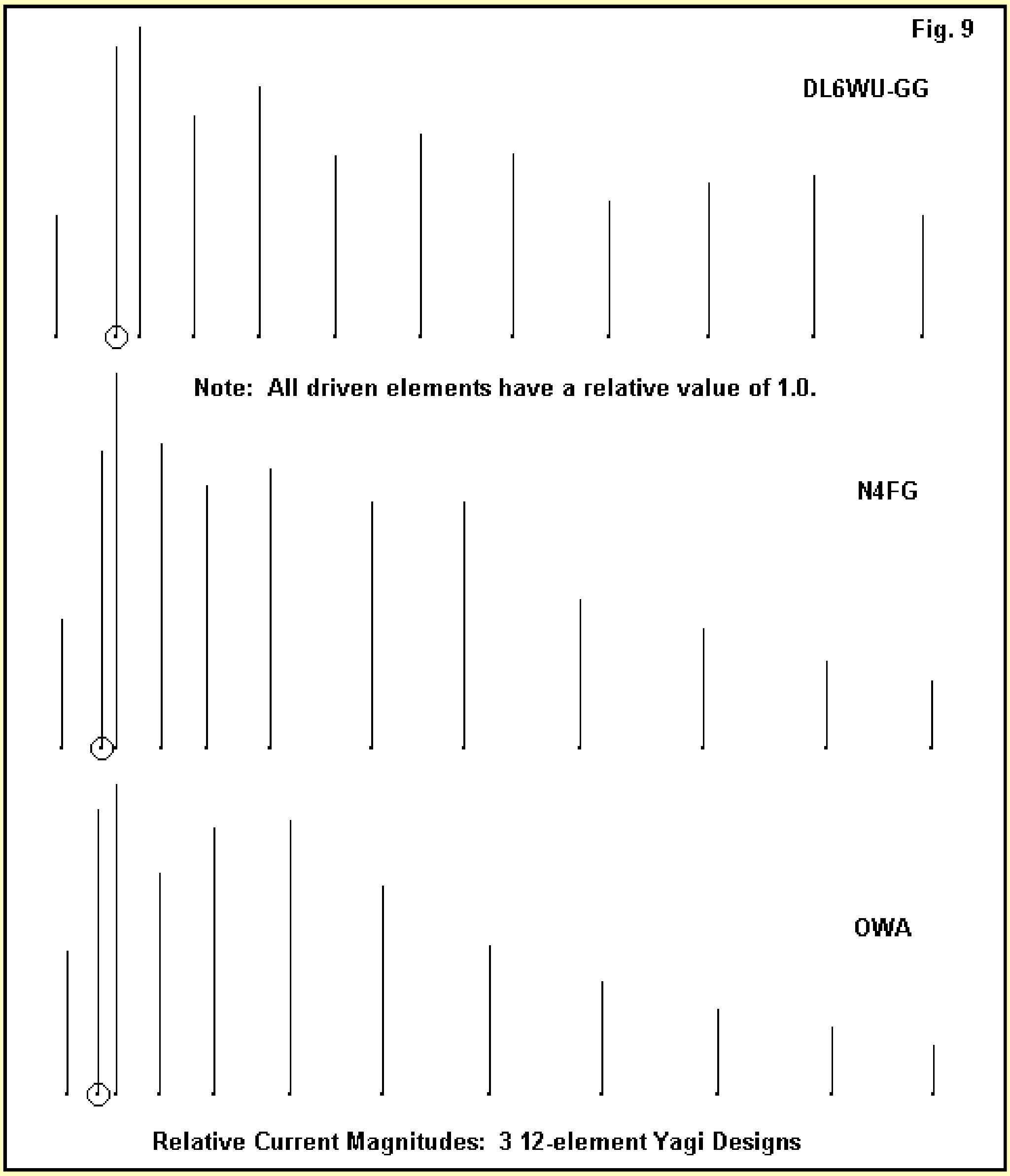
Fig. 8

The N4FG design achieves sidelobe strength comparable to the OWA designs, but does not so much suppress sidelobes as it attenuates them. The interesting question from the perspective of these notes is what design elements may differentiate the N4FG design from the OWA design. In fact, there are three differences of note.

First, let's consider the element length taper used in the collection of designs shown so far. All the designs are just under 3-wavelengths long and use 12 elements. Each design uses carefully calculated driver assembly spacing (and elements lengths) to achieve a wide-band 50-Ohm SWR curve. However, if we examine the dimensional tables, we can arrive at some interesting differences in the taper of the elements from the reflector to the most forward director. Let's use as a simple indicator the ratio of the longest element (reflector) to the shortest element (director 10).

The DL6WU designs employ a taper ratio of about 1.5:1 or 1.6:1. The N4FG design raises that value to about 1.26:1. As the taper ratio increases, gain decreases--from about 14.8 dBi to about 14.55 dBi. In contrast to these designs, the OWA models use element taper ratios of 1.39:1 and 1.41:1 for the original and revised versions, respectively.

The second factor is related to the first, but not in any simple way. As the taper ratio increases, the relative current magnitude on the forward elements decreases. The easiest way to portray this fact is via **Fig. 9**, which shows the relative current magnitudes as a series of vertical lines. In each case, the driven element current is 1.0.



The diagrams also show the relative element spacing, but not the element lengths. Both dimensions play a role in the current distribution. In all three cases, the first director (third element from the left) shows a higher relative current than the fed element or driver. This condition is a mark of almost all wide-band Yagis for the upper 2/3 of the operating passband.

Counting from the second director, the DL6WU design shows an interesting almost sinusoidal pattern of current magnitudes. In addition, the relative current on the forward elements remains high. The array shows a regular element taper with respect to length and an increasing director spacing, although this latter factor will become a constant within a few elements. In general, the lower taper ratio tends to indicate a higher gain array, but not exclusively of the relationships between adjacent directors.

The N4FG array shows some features of the DL6WU design with respect to the current magnitudes of the first few directors. However, the 5 forward-most directors shows a relatively constant decrease in current magnitude from element to element. The first consequence to note is the decrease in gain relative to the DL6WU array. Together, it would seem, the decrease in current magnitude and the higher element taper ratio show a much higher attenuation of sidelobes.

The OWA array shows a similar decreasing current magnitude along the directors past director 3. The array also contains the third notable difference from the other arrays: the use of control directors (2 and 3). The inner control director is slightly shorter than the outer control director, but their positions also contribute to the actual cirrent magnitude levels. Hence, the outer control director has a considerably higher current magnitude than the inner control director. This arrangement appears to redirect some of the sidelobes, allowing a bit of merging and possibly cancellation.

We have also viewed a fourth factor which may contribute something to the reduction of sidelobes: the coincidence of the coincidence of the gan and front-to-back peak values and hence of the remainder of the performance curves in these two categories. However, it is too soon in our exploration to reach any conclusions on a number of questions.

Which of these 4 differences among arrays counts as a necessary condition of sidelobe attenuation or of sidelobe suppression? The use of control directors is certainly not a necessary condition of sidelobe attenuation, since the N4FG array reduces sidelobe strength significantly, but does not use them. More likely candidates are the element taper ratio and the pattern of relative current magnitudes, although these two factors do not fit into directly comparable categories.

What is the role of coinciding frequency peaks of forward gain and front-to-back ratio in the attenuation of sidelobes? The examples that we have viewed here only suggest that the coincidence is desireable, but they do not establish it as in any way necessary.

Are the control elements in the OWA design necessary to sidelobe suppression? Of course, the relevantly similar performance figures for the OWA and N4FG arrays suggest that sidelobe suppression is not mandatory. But again, the curiosity factor rules this exploration. Perhaps we may arrive at some further indicators by looking at a new set of examples using a longer boom. To make the contrast as vivid as possible, let's double the boom length to 6 wavelengths. For many designs--but not for all--a 6-wavelength boom holds about 20 elements.

Unfortunately, space dictates that we shall need another episode to give each new example its fair share of discussion.

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