Sidelobe Attenuation and Suppression: Some Further Notes on 20-Element Yagis

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In the exploration of 12-element Yagis and their ability to attenuate or suppress sidelobes, we ended with 4 factors that appear to affect the outcome:

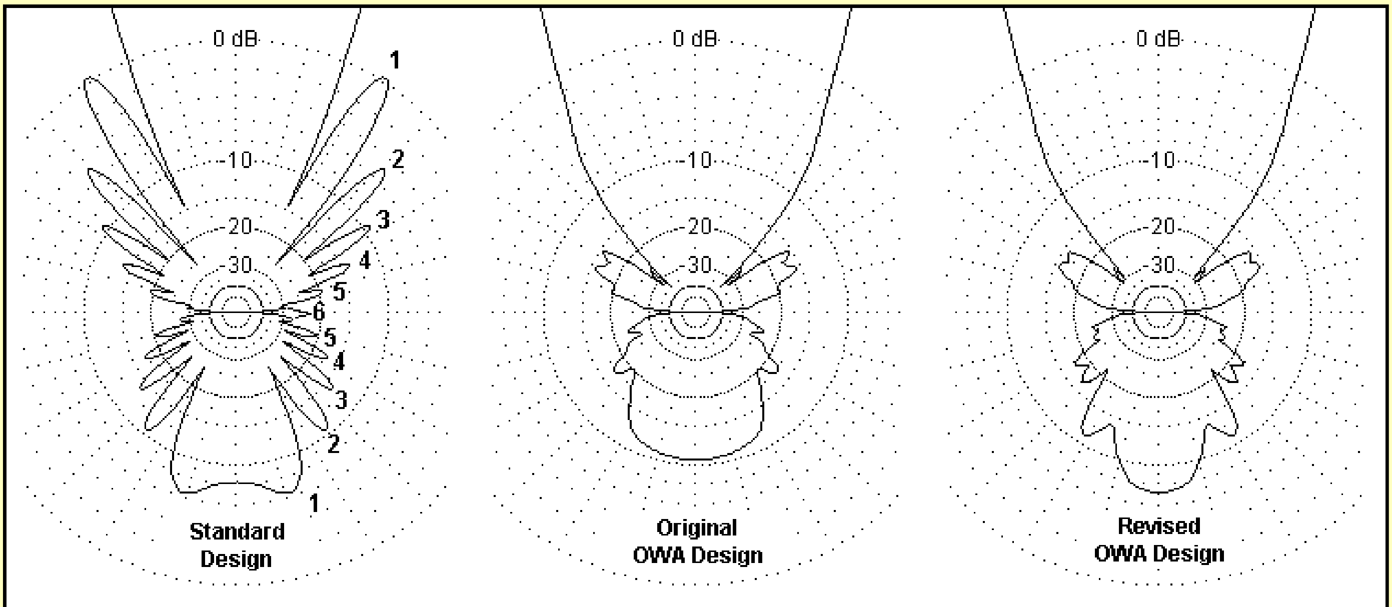
- 1. The close frequency-coincidence of the forward gain anf 180-degree front-to-back ratio peak values;
- 2. A higher than usual element taper ratio;
- 3. A smooth descending curve of relative current magnitude along the directors from the rear-most to the forward-most; and
- 4. The presence of control directors.

High sidelobe attenuation tends to be associated with at least 2 of the properties, namely, the element taper ratio and the smooth descending relative current magnitude as we move forward along the train of directors. Of course, the first director tends to act as a secondary driver and will have a varying current level depending upon the operating frequency's relationship to the design frequency. The presence of properly dimensioned control directors seems to mark the difference between sidelobe attenuation and sidelobe suppression, where the latter term shows merged and missing lobes in addition to high sidelobe suppression.

For many practical purposes, sidelobe attenuation and suppression may not be needed, while for other purposes, sidelobe attenuation alone may be sufficient. We have noted that sidelobe suppression so far seems to be a relatively unique Yagi property belonging to OWA designs. It comes at a cost of forward gain. Nevertheless, since curiosity rather than practicality drives this investigation, we might move forward. The set of 12-element Yagis provides indicators of the properties of sidelobe suppressing Yagis. Perhaps a different set of arrays may confirm the initial indications. To that end, I have examined a series of 6-wavelength Yagis. Although twice as long as the first set of Yagis, these beams carry 20 elements--with one final exception that carries 25. The designs are similar enough to the 12-element designs to have a potential for showing the same features. At the same time, they have some differences that may allow us to confirm a few suspicions raised by the initial set.

A Selection of 20-Element Yagis

A typical standard design 20-element Yagi on a 6-wavelength boom shows 6 forward and 6 rearward sidelobes on each side of the boom line. The left detail pattern in **Fig. 1** shows the sidelobes. The higher gain of these arrays may make the last of the 6 sidelobes--both fore and aft--somewhat minuscule, but they are all definite.



Sidelobe Detail: 20-Element, 6-Wavelength Designs **Fig. 1**

The center detail pattern shows the sidelobes of an OWA-design 20-element Yagi. We can easily count only 4 definite forward and 3 definite rearward sidelobes, where the large rear lobe is composed of an actual main lobe and 2 sidelobes. The gain of the forward sidelobes is very small indeed. (We shall turn to the right pattern in **Fig. 1** shortly.)

The OWA 20-element design uses a 6.21 wavelength boom and is part of a series of OWA Yagis ranging from 7 to 20 elements. The array has the following dimensions. Note especially the position and lengths of the control directors (D2 and D3), with the forward control director being longer.

Dimensions of "Original" 20-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**	**40.73**
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	**32.20**	**243.00**
D11	**30.80**	**276.00**
D12	**30.40**	**309.00**
D13	**30.00**	**342.00**
D14	**29.20**	**375.00**
D15	**28.80**	**408.00**
D16	**28.40**	**441.00**
D17	**28.40**	**475.00**
D18	**27.40**	**502.00**

Although the 12-element version of the array showed a gain deficit of about a half-dB relative to standard designs, the 20-element version is about 2 dB shy of DL6WU designs using the same boom length and number of elements. The checkpoint data table confirms this deficit.

Modeled Performance: "Original" 20-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	15.19	24.51	29.73 (bulge)	
			31.80 (lobe)	20.95
146	15.61	26.18	31.06	20.61
148	15.68	25.11	26.73	19.66

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
144	33.8	36.2	42.9 + j4.5	1.20
146	32.4	34.6	46.8 + j6.6	1.16
148	31.2	33.4	45.1 - j4.0	1.14

However, the front-to-back ratio is very good across the 2-meter band, and the sidelobe suppression is very high--approaching 30 dB on average. Like the 12-element arrays, the 20-element arrays are considered wide-band antennas and deserving of a scan from 140-150 MHz. **Fig. 2** shows the modeled performance information for the array's free-space forward gain and the 180-degree front-to-back ratio.

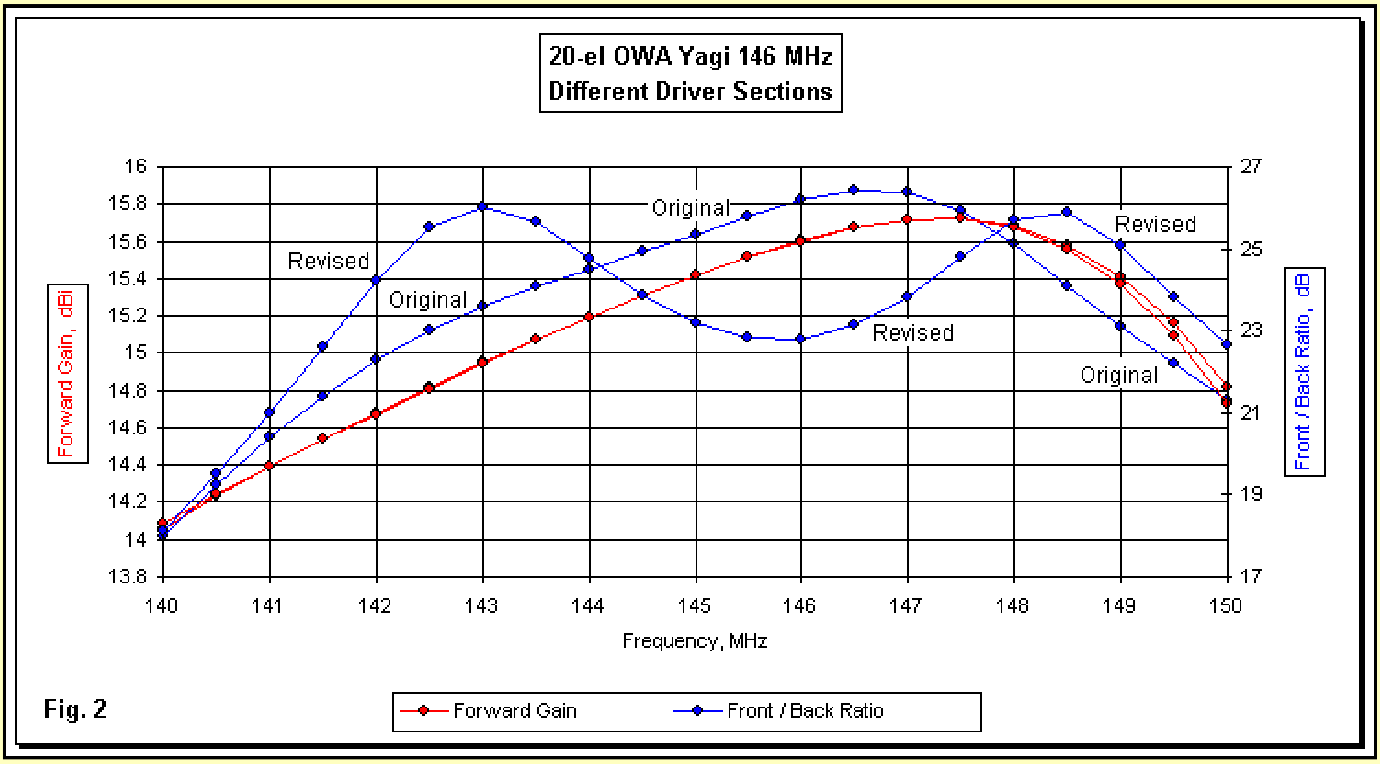
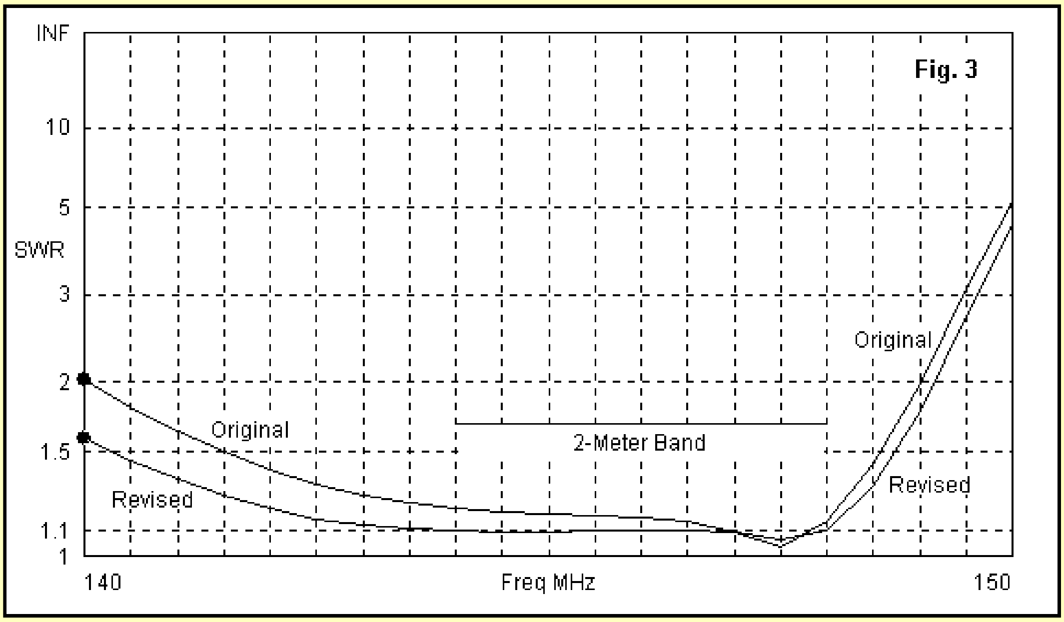


Fig. 2

The gain curve peaks within a MHz of the front-to-back peak, with both peaks well within the primary passband (144-148 MHz). The 20-element OWA Yagi has a 50-Ohm SWR curve almost identical to that of the 12-element version of the design. (As was the case with the 12-element Yagis, all of the 20-element Yagis are designed for a direct 50-Ohm feedline with no required matching network.) The SWR curve of the original design appears in **Fig. 3**.



In answer to a challenge to further reduce the SWR levels across the 2-meter band, I revised the design with this goal in mind. Unlike the 12-element Yagi, which responded well to mutual adjustments between the reflector and the final director, the 20-element version seemed insensitive to final director changes. Therefore, reducing the SWR level across the band required more significant changes to the lengths and spacing of the reflector-driver-director1 assembly. However, the "revised" line in **Fig. 3** shows that SWR improvements were possible. The dimension tables shows the physical consequences of the adjustments needed to obtain the new curve. The boomlength is now 6.37 wavelengths.

Dimensions of "Revised" "Original" 20-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	40.95	-----
Driver	39.62	9.88
D1	36.94	14.18
D2	36.32	25.98
D3	36.40	41.32
D4	36.21	61.98
D5	35.20	87.09
D6	34.30	116.60
D7	33.60	147.20
D8	32.90	179.00
D9	32.20	210.60
D10	32.20	243.60
D11	30.80	276.60
D12	30.40	309.60
D13	30.00	342.60
D14	29.20	375.60
D15	28.80	408.60
D16	28.40	441.60
D17	28.40	476.60
D18	27.60	514.60

The in-band performance is indicated by the following checkpoint data.

Modeled Performance: "Revised" "Original" 20-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	15.19	24.77	27.98 (bulge)	

			32.04 (lobe)	20.70
146	15.60	22.79	31.07	20.46
148	15.67	25.69	26.87	19.69

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
144	33.6	36.2	49.3 + j4.7	1.10
146	32.4	34.6	51.5 + j4.7	1.10
148	31.2	33.2	50.8 - j4.8	1.10

Overall, the revised design approximates the performance of the original OWA design. However, the sidelobe suppression is not as strong, although attenuation remains high. The right pattern in **Fig. 1** shows at least 5 of the rearward sidelobes. The reason for this small degradation in sidelobe suppression has an indicator in the lower front-to-back value for the design frequency in the checkpoint data. The "revised" lines in **Fig. 2** show that the gain peak coincides with neither of the two front-to-back peaks that emerged from the revisions. Whether or not sidelobe attenuation requires a coincidence of gain and front-to-back peaks remains an open question at this stage of the exploration. However, the revision gives us good evidence that sidelobe suppression suffers when the two peaks do not coincide closely in frequency.

In an effort to increase the gain of the OWA design, I redesigned it. The "improved" design removes about half of the gain deficit shown by the original OWA Yagi relative to standard 20 element designs. The following table shows the physical dimensions of the improved design on its 6.08-wavelength boom.

Dimensions of "Improved" 20-Element OWA Yagi

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

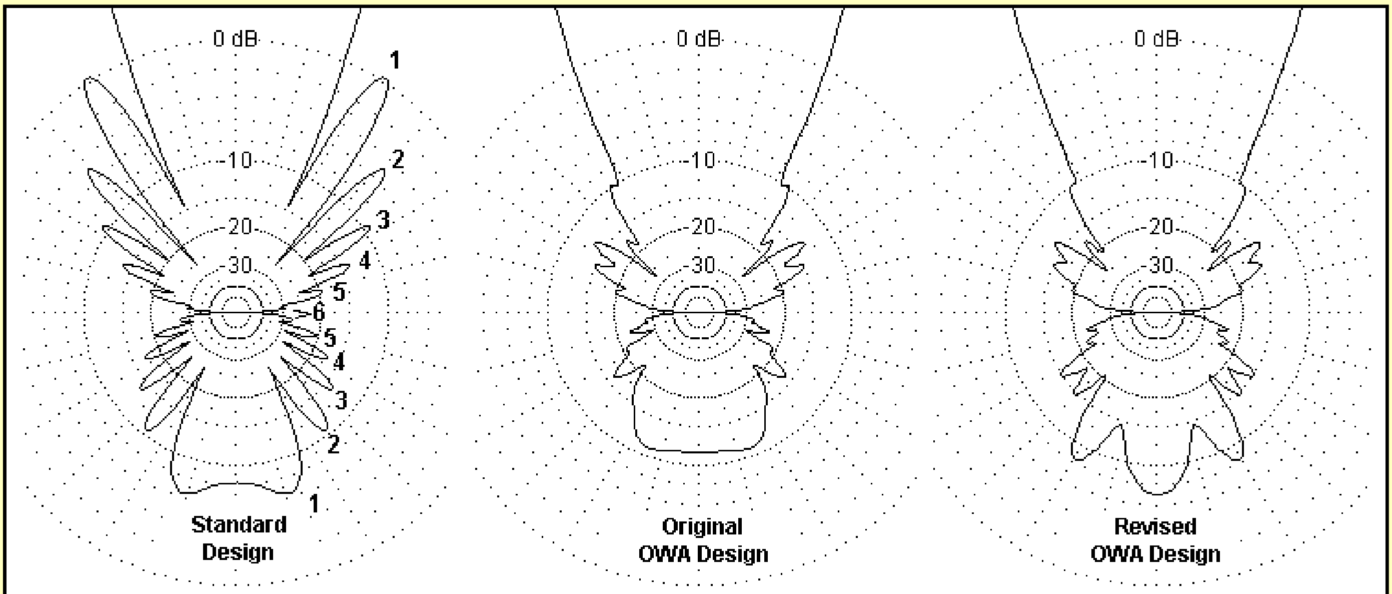
Element	Length inches	Space from Reflector inches
Reflector	40.90	-----
Driver	39.50	8.79
D1	37.06	13.47
D2	36.48	25.37
D3	36.54	40.35
D4	36.41	60.56
D5	35.61	85.10
D6	34.90	113.96
D7	34.34	143.87
D8	33.80	174.96
D9	33.25	205.85
D10	33.25	238.11
D11	32.15	270.38
D12	31.83	302.64
D13	31.52	334.90
D14	30.88	367.16
D15	30.57	399.42
D16	30.25	431.68
D17	30.25	464.92
D18	29.46	491.32

Within the 2-meter band, the array shows significant improvement in the gain category. The front-to-back ratio remains high. However, sidelobe suppression has slipped.

Modeled Performance: "Improved" 20-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	16.03	24.53	20.89 (bulge)	
			29.27 (lobe)	21.67
146	16.39	27.93	26.21	21.13
148	16.20	24.85	23.79	19.63

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
144	31.2	33.2	42.7 + j3.7	1.19
146	30.0	31.6	45.6 + j7.5	1.20
148	29.2	31.0	47.2 - j7.8	1.19



Standard Design

Original OWA Design

Revised OWA Design

Sidelobe Detail: 20-Element, 6-Wavelength "Improved" Designs **Fig. 4**

The center detail pattern in **Fig. 4** shows that the redesign has moved the Yagi to the fringes of sidelobe suppression, although compared to the standard pattern on the left, attenuation remains quite high. We can count at least 5 forward sidelobes in the pattern. Over the broader passband, The array shows the characteristics of **Fig. 5**, which indicate a good coincidence between the gain and the front-to-back peaks.

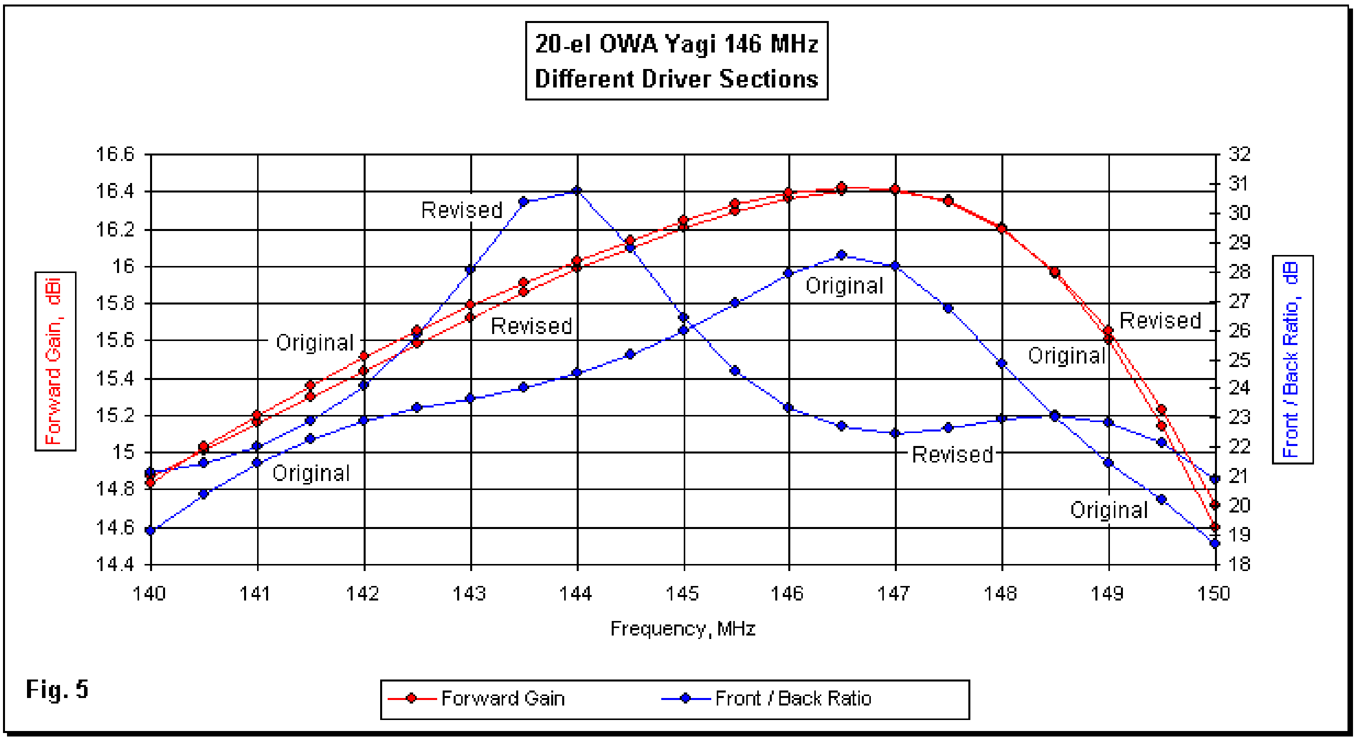


Fig. 5

Fig. 6 shows the 50-Ohm SWR curves for both the improved array and for its revision that attempts to achieve a lower SWR across the operating passband.

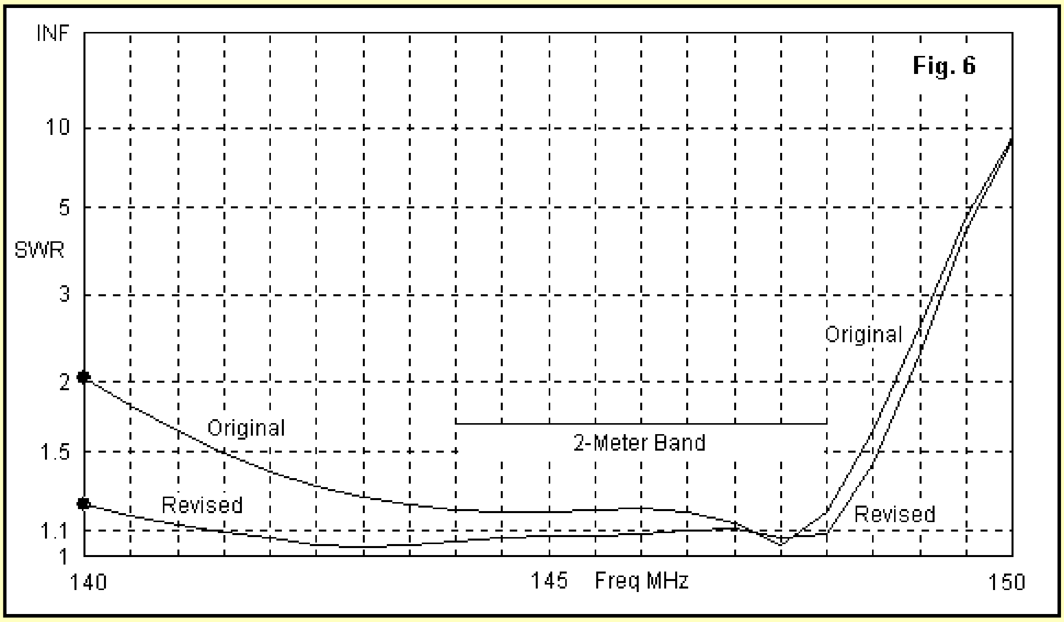


Fig. 6

The SWR curve of the revised version of the improved array shows a considerable improvement over the original improved array. All of the revised (SWR-improved) versions of the arrays required longer booms than the originals, and the improved array is no exception. As the following dimension table shows, the boomlength is now 6.23 wavelengths.

Dimensions of "Revised" "Improved" 20-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	**41.50**	**-----**
Driver	**39.82**	**10.50**
D1	**37.06**	**14.80**
D2	**36.48**	**26.17**
D3	**36.54**	**41.15**
D4	**36.41**	**61.36**
D5	**35.61**	**85.90**
D6	**34.90**	**114.76**
D7	**34.34**	**144.67**
D8	**33.80**	**175.76**
D9	**33.25**	**206.65**
D10	**33.25**	**238.91**
D11	**32.15**	**271.18**
D12	**31.83**	**303.44**
D13	**31.52**	**335.70**
D14	**30.88**	**367.96**
D15	**30.57**	**400.22**
D16	**30.25**	**432.48**
D17	**30.25**	**465.72**
D18	**29.50**	**503.30**

The in-band check data show that improved performance does not accompany improved SWR curves automatically. As the right pattern in **Fig. 4** reveals--confirmed by the data table--the revision to the so-called improved Yagi worsens the sidelobe suppression. We can count 5 rearward sidelobes, and the 6th forward sidelobe is just beginning to appear.

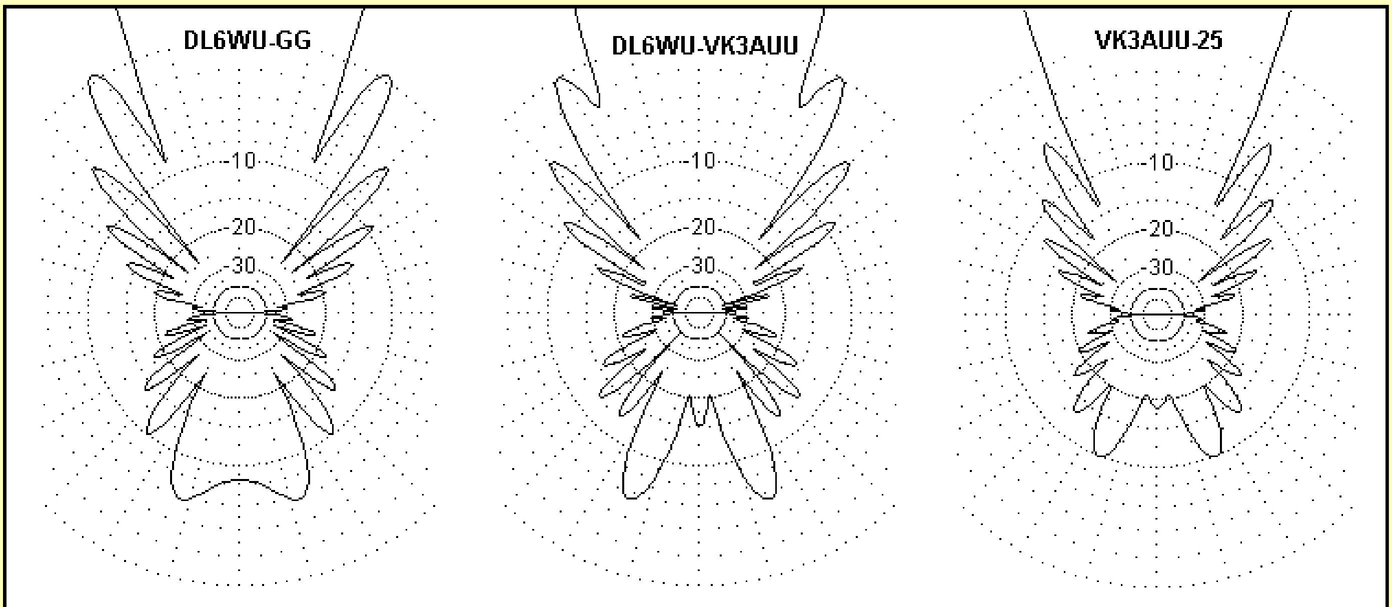
Freq. MHz	**Free-Space Gain dBi**	**180-Deg. Front-Back Ratio dB**	**Hor. F-S/I Ratio dB**	**Vert F/S/I Ratio dB**
144	**15.99**	**30.77**	**20.47 (bulge)**	
			29.01 (lobe)	**21.04**
146	**16.36**	**23.36**	**26.21 (bulge)**	

			30.00 (lobe)	21.14
148	16.21	22.95	24.31	20.02

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
144	31.2	33.0	50.4 + j4.1	1.09
146	29.8	31.6	50.9 + j4.9	1.10
148	29.0	30.8	51.4 - j4.5	1.10

Again, part of the reason for the movement from sidelobe suppression to sidelobe attenuation appears to result from the failure of the gain and front-to-back peaks to coincide with respect to frequency. The "revised" lines in **Fig. 5** show just how far apart these peaks are for the present design (over 2 MHz).

We have so far examined at least two ways in which high sidelobe suppression degrades into sidelobe attenuation. However, all of the examples so far have begun with a basic 20-element OWA design. For comparison--as we did when examining 12-element designs--we should examine some standard, that is, DL6WU 20-element Yagis. In the following notes, I shall look at designs derived from the DL6WU-GG program and from the VK3AUU modification that aimed for maximum performance from a 19-element Yagi. Like the OWA designs, the element are 3/16" in diameter, but since metrics are in use for these designs, the diameter is 4.7625 mm.



Sidelobe Detail: 20-Element, 6-Wavelength Designs

Fig. 7

The DL6WU-GG version of the array shows the details on the left of **Fig. 7**. These details emerge from the following dimensions.

Dimensions of DL6WU (GG) 20-Element 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
D11	861.81	6622.1
D12	858.43	7423.0
D13	855.32	8244.3
D14	852.44	9065.7
D15	849.76	9887.0
D16	847.25	10708.4
D17	844.89	11529.7
D18	842.67	12351.1

The 12.3-meter boom translates into 6.02 wavelengths at 146 MHz. Within 2 meters, the following table records check-point data.

Modeled Performance: DL6WU (GG) 20-Element 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	16.98	17.26	16.47	14.38
146	17.57	25.95	17.12	15.22
148	17.60	19.00	16.42	14.87

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
144	26.8	28.2	51.9 - j5.7	1.13
146	25.2	26.2	51.9 + j1.5	1.26
148	23.8	24.6	60.5 - j5.2	1.24

Unlike the 12-element version of the array, the design frequency coincides with a front-to-back peak frequency. The gain is about a dB better than for even the improved OWA Yagi. However, horizontal sidelobe attenuation is mediocre at best, and vertical sidelobe attenuation is even worse. For a broader view of the antenna's performance, see **Fig. 8**.

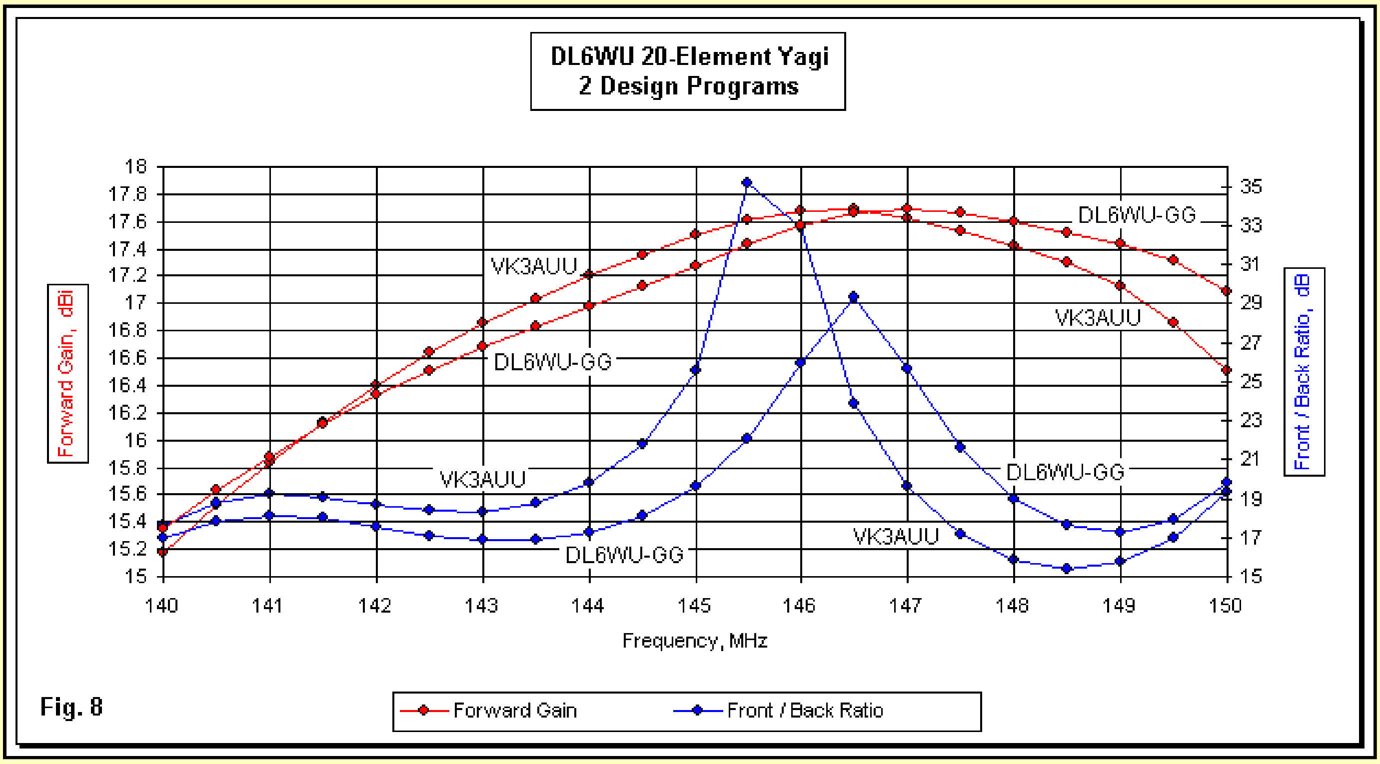
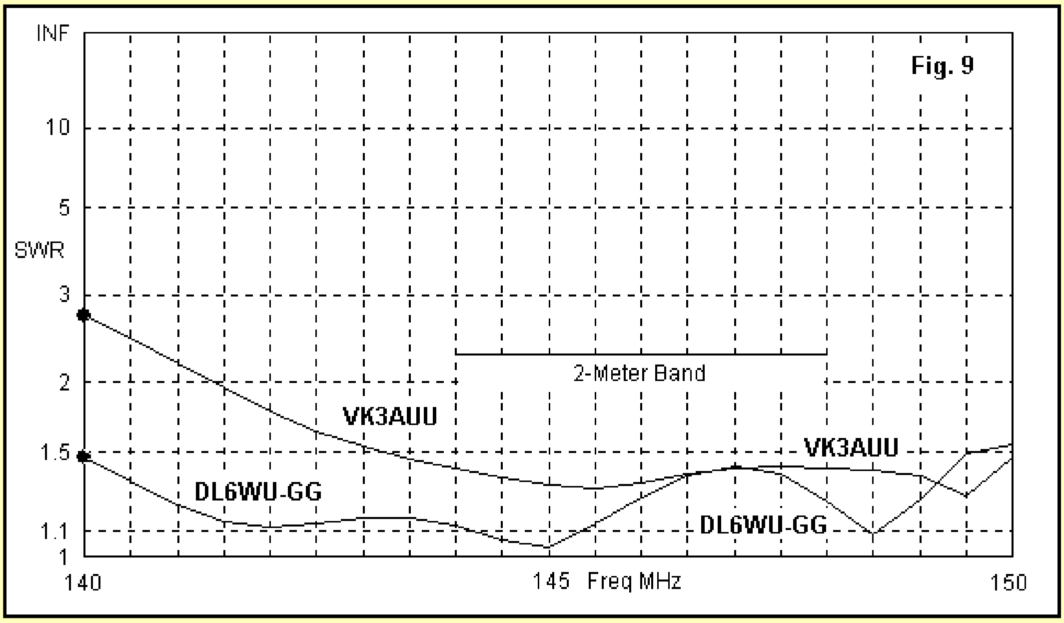


Fig. 8

One of the hallmarks of standard DL6WU designs is the exceptional SWR bandwidth that all boomlengths achieve. **Fig. 9** shows the rippling low 50-Ohm SWR across the expanded passband. The 10-MHz or 7% bandwidth of the scan does not show an SWR value greater than 1.5:1. For this reason, DL6WU designs lend themselves to relatively easy replication in modest home workshops.



The VK3AUU revised algorithms do not yield the same bandwidth as the original design equations, as the SWR curve in **Fig. 9** clearly shows. Using a different wide-band reflector-driver-director1 assembly, the VK3AUU version of the antenna has the following dimensions on a 6.01 wavelength boom. Most of the variations from the original design are a function of the revised 50-Ohm driving assembly.

Dimensions of DL6WU (VK3AUU) 20-Element 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**
D11	**834**	**6596**
D12	**830**	**7385**
D13	**826**	**8194**
D14	**822**	**9022**
D15	**818**	**9850**
D16	**815**	**10677**
D17	**812**	**11505**
D18	**802**	**12333**

As a measure of in-band performance, the following modeled performance table may be useful.

Modeled Performance: DL6WU (VK3AUU) 20-Element 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	**17.20**	**19.82**	**17.34**	**15.31**
146	**17.68**	**32.86**	**17.62**	**15.84**
148	**17.42**	**15.83**	**15.83**	**16.95**

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
144	26.4	27.6	36.5 - j5.5	1.41
146	24.8	25.8	50.5 + j14.27	1.32
148	23.6	24.4	48.7 - j16.8	1.40

The gain across the 2-meter band is more level than with the original DL6WU design, but the front-to-back ratio shows a sharper peak. Horizontal sidelobe attenuation tends to follow the pattern of the front-to-back ratio, although the vertical sidelobe attenuation shows the opposite trend. **Fig. 8** shows not only the greater front-to-back ratio peak, but as well the fact that it is offset by about 1 MHz from the forward gain peak. In the end, with respect to sidelobe attenuation, there is little to choose between these versions of the DL6WU 20-element Yagi, as shown by comparing the left and center portions of **Fig. 7**.

A special Note on a 25-Element 6-Wavelength Yagi

David Tanner, VK3AUU, has been developing an interesting variation of the 6-wavelength 2-meter Yagi without realizing that fact. His basic work involves a computer-generated design for the 70-cm band. Like the DL6WU designs, one can trim the number of elements without adversely affecting basic performance, except--of course--for the inevitable reduction in gain. When scaled to 146 MHz and trimmed to 6 wavelengths (6.11 wavelengths, to be more precise), the array holds 25 elements, a higher element population density than most other designs. To make the array design match the others in this group, I reduced the element diameter to 3/16". The following table shows the dimensions of this adaptation of the VK3AUU high-density design.

Dimensions of VK3AUU 25-Element 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	41.41	-----
Driver	40.60	16.10
D1	37.15	18.88
D2	36.66	28.63
D3	36.23	41.29
D4	35.81	56.01
D5	35.38	72.34
D6	35.03	89.95
D7	34.68	108.69
D8	34.39	128.38
D9	34.04	148.93
D10	33.83	170.21
D11	33.54	192.16
D12	33.33	214.77
D13	33.12	237.94
D14	32.91	261.63
D15	32.97	285.84
D16	32.55	310.49
D17	32.34	335.58
D18	32.20	361.07
D19	32.06	386.96
D20	31.99	413.21
D21	31.85	439.83
D22	31.71	466.76
D23	31.63	494.03

The following in-band chart of modeled performance data shows that the array design achieves two significant goals that appear to be in conflict when using only 20-elements on the same 6-wavelength boom. First, his design retains almost all of the DL6WU gain, with a very solid front-to-back ratio. Second, the sidelobe reduction values are excellent, almost at the OWA level. Hence, the design represents a very good compromise that gives us nearly the best of both worlds of design.

Modeled Performance: VK3AUU 25-Element 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	16.91	25.01	20.10	18.03
146	17.22	35.59	22.29	20.37
148	17.27	23.61	24.25	21.89

Freq. MHz	Hor BW degrees	Vert BW degrees	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
144	28.2	29.6	56.5 + j2.8	1.14
146	27.0	28.4	59.6 + j3.9	1.21
148	26.4	27.6	49.6 + j6.6	1.14

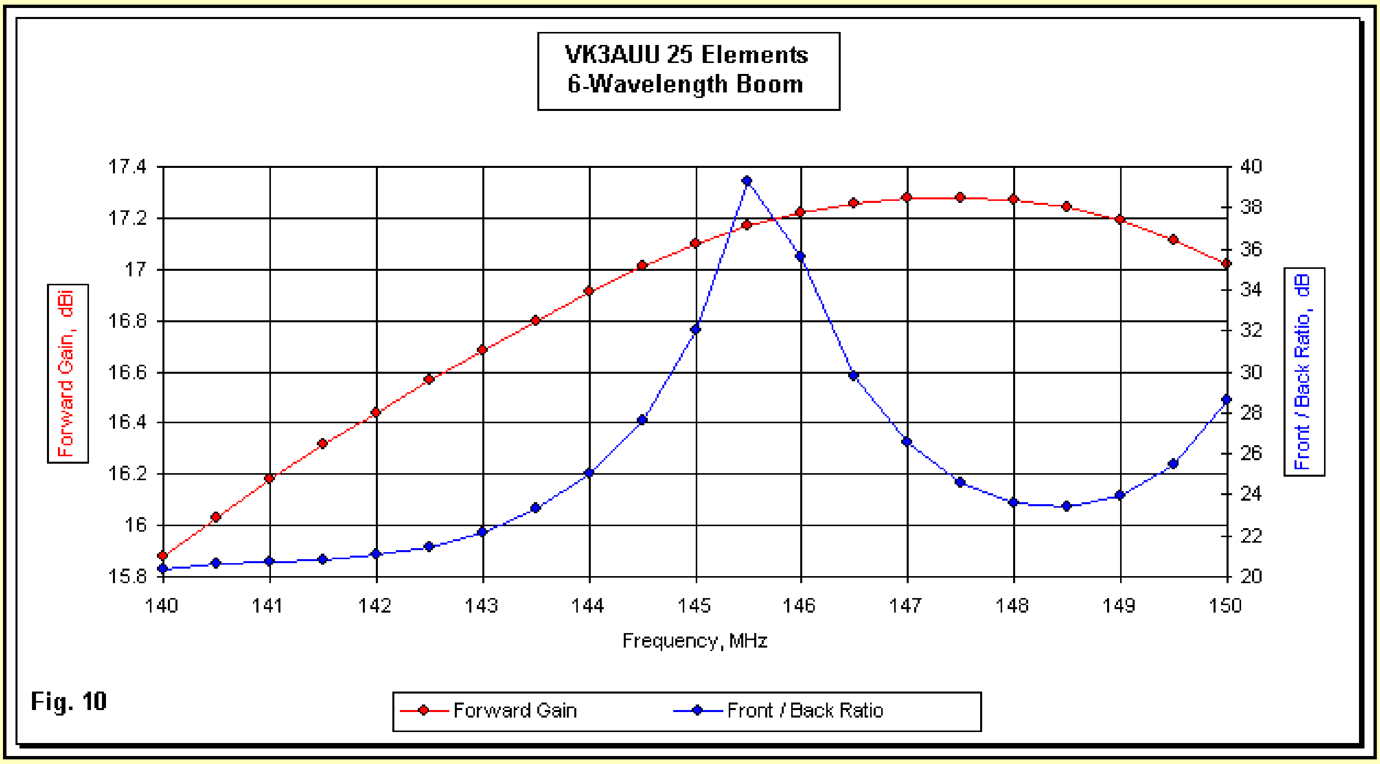
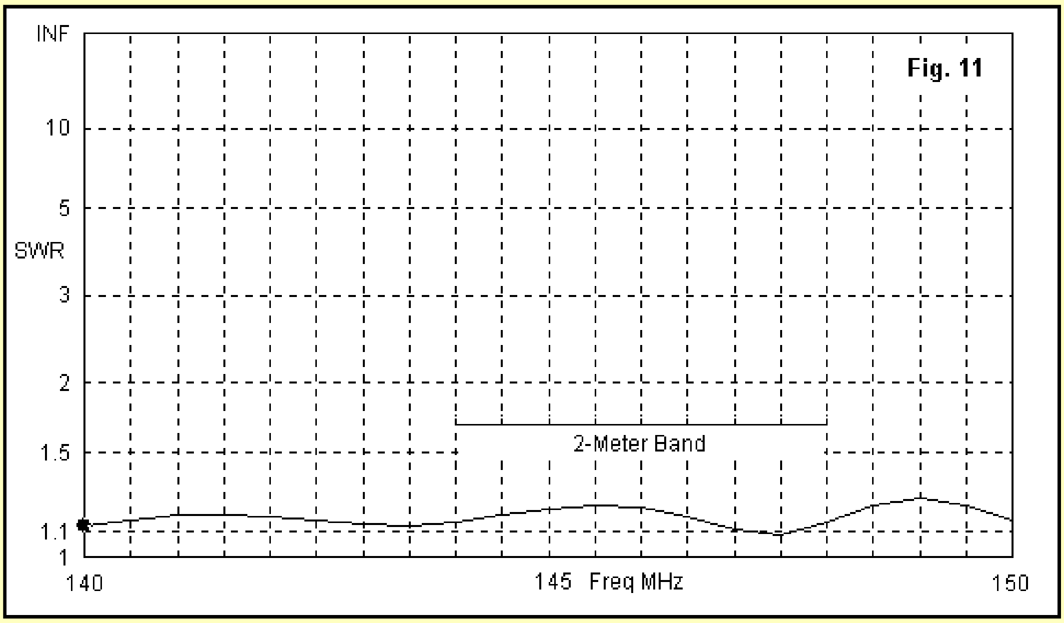


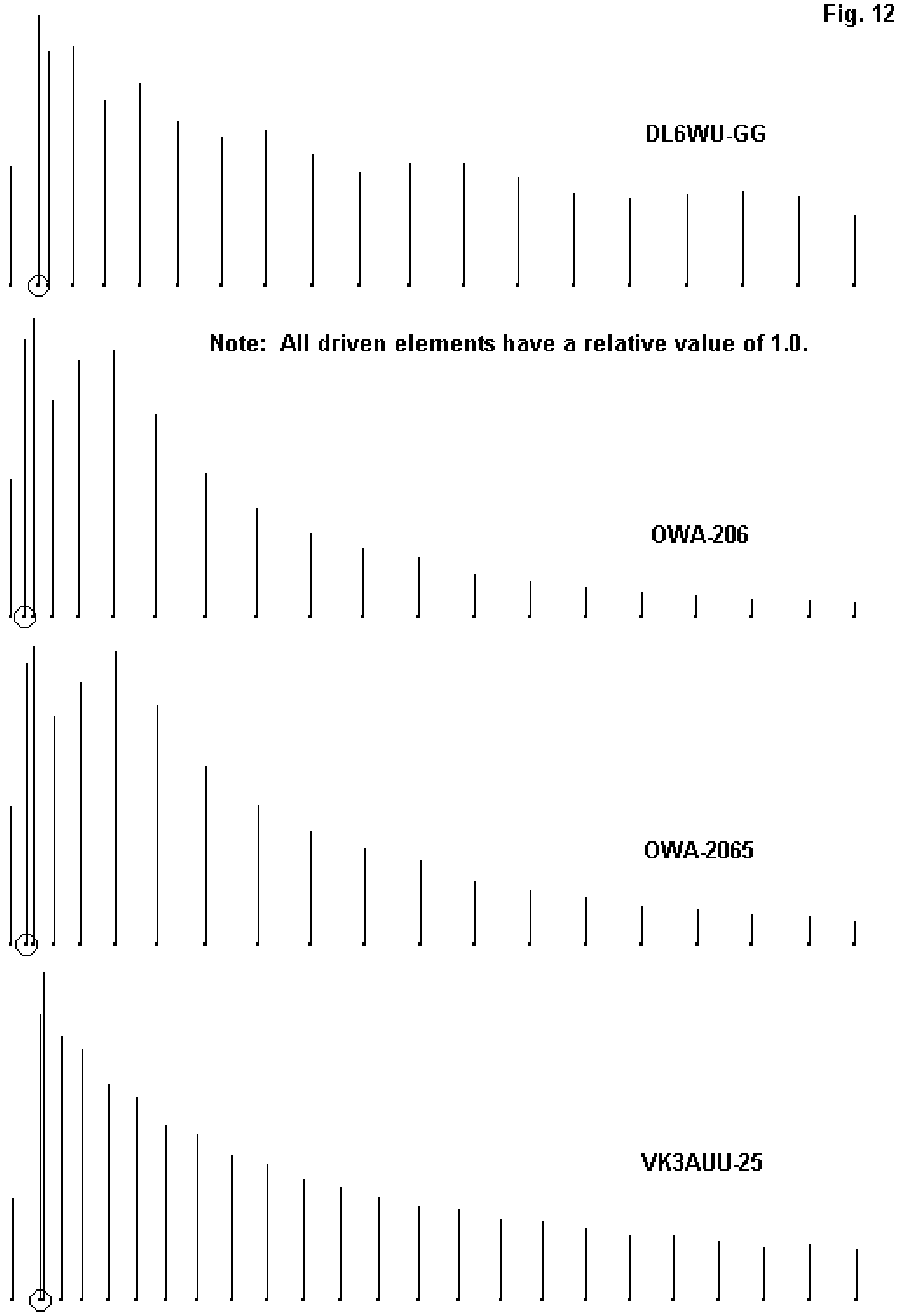
Fig. 10

As shown in **Fig. 10**, the broadband performance curves for the array are very respectable, although the gain and front-to-back peaks are separated by 2 MHz. The right-most detail patterns in **Fig. 7** shows that the design achieves high attenuation without suppression. We can count all 6 sidelobes, both forward and rearward. The 50-Ohm SWR curve is also excellent, as shown in **Fig. 11**. The peak value does not reach 1.3:1 anywhere in the expanded passband.



It is interesting to compare the relative current magnitude values on the strings of elements making up each of the major strains of Yagi design covered in this exploration. We may also compare the forms created by these values with those of the 12-element Yagis in the preceding episode. **Fig. 12** shows the current magnitudes as vertical lines extending from each element upward. The driver element in each case has a relative value of 1.0. In all four samples, the first director or secondary driver shows a higher current level.

Fig. 12



Relative Current Magnitudes: 4 6-Wavelength Boom Yagis

The DL6WU 20-element design produces a curve that resembles a damped sine wave, an extended version of the curve presented by the 12-element Yagi. In contrast, the original and "improved" OWA design shown a steady downward progression in relative current magnitude. Both versions of the array show the typical pattern of control director currents. However, the rate of decrease in the improved design is smaller, resulting in that array's higher gain.

At first sight, the VK3AUU 25-element design appears to follow the OWA pattern of current magnitudes. However, if you create a smooth curve with some sort of linear object, you will discover that the curves actually show traces of the DL6WU sine-wave, that is, the periodic rises and falls of the current level as we move from the first the the last director. Like the performance values--and perhaps as one source of them--the current magnitude curves arrive at a compromise between the DL6WU and OWA curves.

I have in the past created hybrids by grafting the VK3AUU set of directors onto the OWA drive section. The results of these test configurations have been disappointing, yielding essentially only the performance of the VK3AUU array without improvement to the sidelobe suppression. However, those test designs made no attempt to significantly alter the dimensions of the control directors to see what these elements might do to improve sidelobe reduction. As a proof-of-principle only design, I approached the hybrid Yagi once more. The goal was to see if adjusting the control directors (D2 and D3) might improve the sidelobe suppression to at least 25 dB and from that point, to also see if there would be a tendency toward sidelobe suppression as well as attenuation.

One limitation of the exercise is the element length ratios used by the various designs. The gain-oriented DL6WU designs use for 20 elements a ratio of about 1.19:1 for 20 elements on a 6-wavelength boom. At the opposite end of the scale, the original OWA uses a ratio of about 1.49:1, comparing the longest to the shortest element in the array. The so-called improved version drops the ratio to about 1.39:1, showing that even a small drop in the element ratio can result in a degradation of sidelobe suppression. However, both ratios are well above the 12-element OWA ratio of 1.31:1, a fact that tracks the increased gain deficit in the longer OWA designs relative to the DL6WU standard.

The original VK3AUU 25-element array uses a ratio of about 1.26:1, which is not far distant from the ratio employed by the N4FG 12-element array. Hence, the exercise was unlikely to produce the full sidelobe suppression achieved by the original OWA 20-element design. Since the directors from #4 though #23 would remain essentially unchanged, the slight damped sine-wave appearance of the current magnitudes would also likely remain. So the questions boiled down to these three: 1. Could the adjustment of control directors within the hybrid result in sidelobe improvements? 2. If so, at what cost to the array gain and other performance values? 3. What other side effects might result from the exercise? One factor not optimized in the design work was the SWR curve for the array. The effort aimed to see if the combination of ingredients--with special attention to the control elements--might effect changes to the sidelobe suppression level. The original VK3AUU design is perfectly satisfactory for most practical uses requiring very low sidelobes.

The dimensions for the VK3AUU/OWA hybrid appear in the following table. The new driver section produced a 6.14-wavelength boom, requiring a 2.5" displacement of the VK3AUU directors. Otherwise, only the dimensions of the first 5 elements differ from the VK3AUU original.

Dimensions of VK3AUU/OWA Hybrid 25-Element 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	**40.70**	**-----**
Driver	**39.22**	**9.80**
D1	**36.28**	**14.00**
D2	**36.62**	**26.20**
D3	**36.98**	**42.00**
D4	**35.81**	**58.51**
D5	**35.38**	**74.84**
D6	**35.03**	**92.45**
D7	**34.68**	**111.19**
D8	**34.39**	**130.88**
D9	**34.04**	**151.43**
D10	**33.83**	**172.71**
D11	**33.54**	**194.66**
D12	**33.33**	**217.27**
D13	**33.12**	**240.44**
D14	**32.91**	**264.13**
D15	**32.97**	**288.34**
D16	**32.55**	**312.99**
D17	**32.34**	**338.08**
D18	**32.20**	**363.57**
D19	**32.06**	**389.46**
D20	**31.99**	**415.71**
D21	**31.85**	**442.33**

D22	**31.71**	**469.26**
D23	**31.63**	**496.53**

Element D2 and D3 are the control directors. In the original OWA design, their lengths are 36.48" and 36.54", respectively. To obtain a minimum 25-dB front-to-sidelobe level in the hybrid design, D2 became 36.62" and D3 grew to 36.98". Both elements are much longer than in the original, a fact that is the likely source of not experimenting with them extensively in past hybrid experiments. As well, ratio of lengths in the original is only about 1.002:1. In the new hybrid, the ratio of D3 to D2 is 1.01:1. Further extensions of the control directors is possible for a gradual improvement on sidelobe performance, but the stopping point in this exercise produce a front-to-sidelobe ratio of 25 dB.

Modeled Performance: VK3AUU/OWA Hybrid 25-Element 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	**16.41**	**26.28**	**21.86**	**19.81**
146	**17.02**	**27.38**	**25.00**	**20.48**
148	**16.91**	**26.90**	**22.68**	**19.66**

Freq. MHz	**Hor BW degrees**	**Vert BW degrees**	**Feedpoint Impedance R +/- jX Ohms**	**50-Ohm SWR**
144	**27.8**	**29.2**	**46.2 + j0.6**	**1.08**
146	**26.8**	**28.2**	**45.1 - j3.1**	**1.13**
148	**26.9**	**27.8**	**30.4 + j12.4**	**1.82**

Fig. 13 compares the detailed patterns of the original VK3AUU and the hybrid. Although only on the fringe of true sidelobe attenuation, the pattern shows only 5 rearward lobes. As well, the forward sidelobes show signs of merging into two groups.

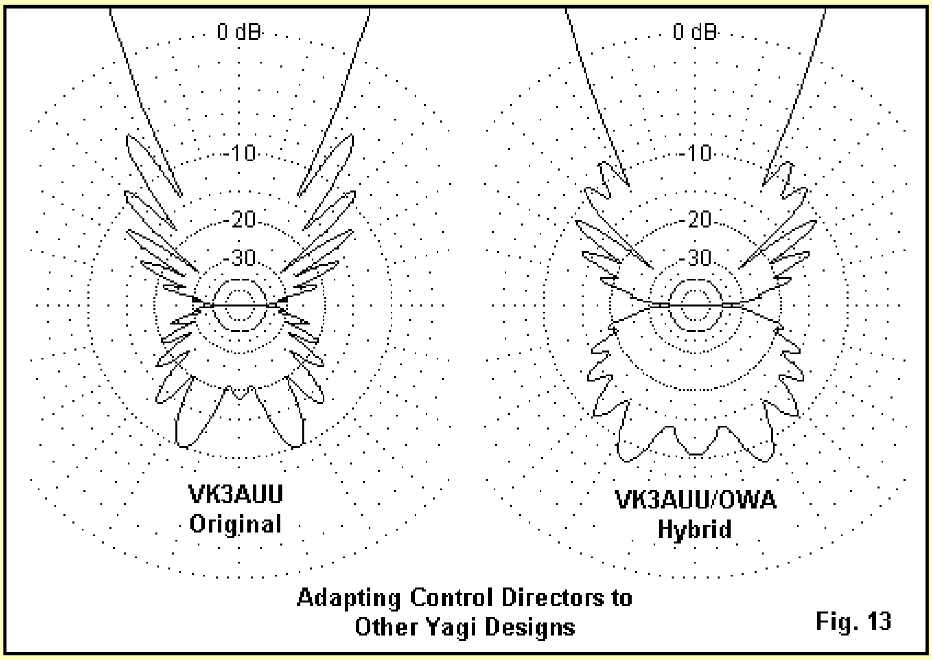


Fig. 14 shows the current magnitude pattern for the array. Because the SWR curve is not well controlled in this model, the driver current is higher than the current on the first director. The directors past the control directors show the same characteristic curve as the original VK3AUU. That curve is largely responsible for the hybrid model losing only about 0.2 dB gain relative to the original array.

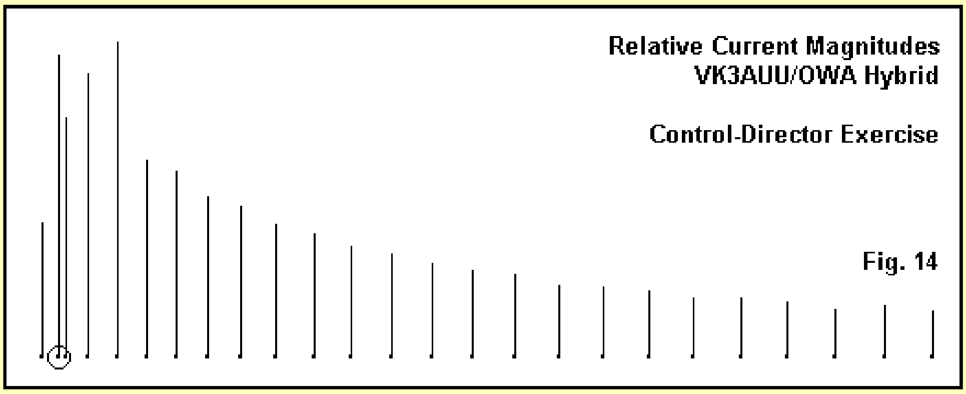


Fig. 14

The uncontrolled SWR characteristics of the experimental design also result in the gain and front-to-back peak values occurring lower in the passband than with other designs in this series. However, as shown in **Fig. 15**, the peaks are within 0.5 MHz of each other. In the course of working toward the target sidelobe reduction level, I found that the farther apart the two peak values were, the lower the sidelobe reduction level.

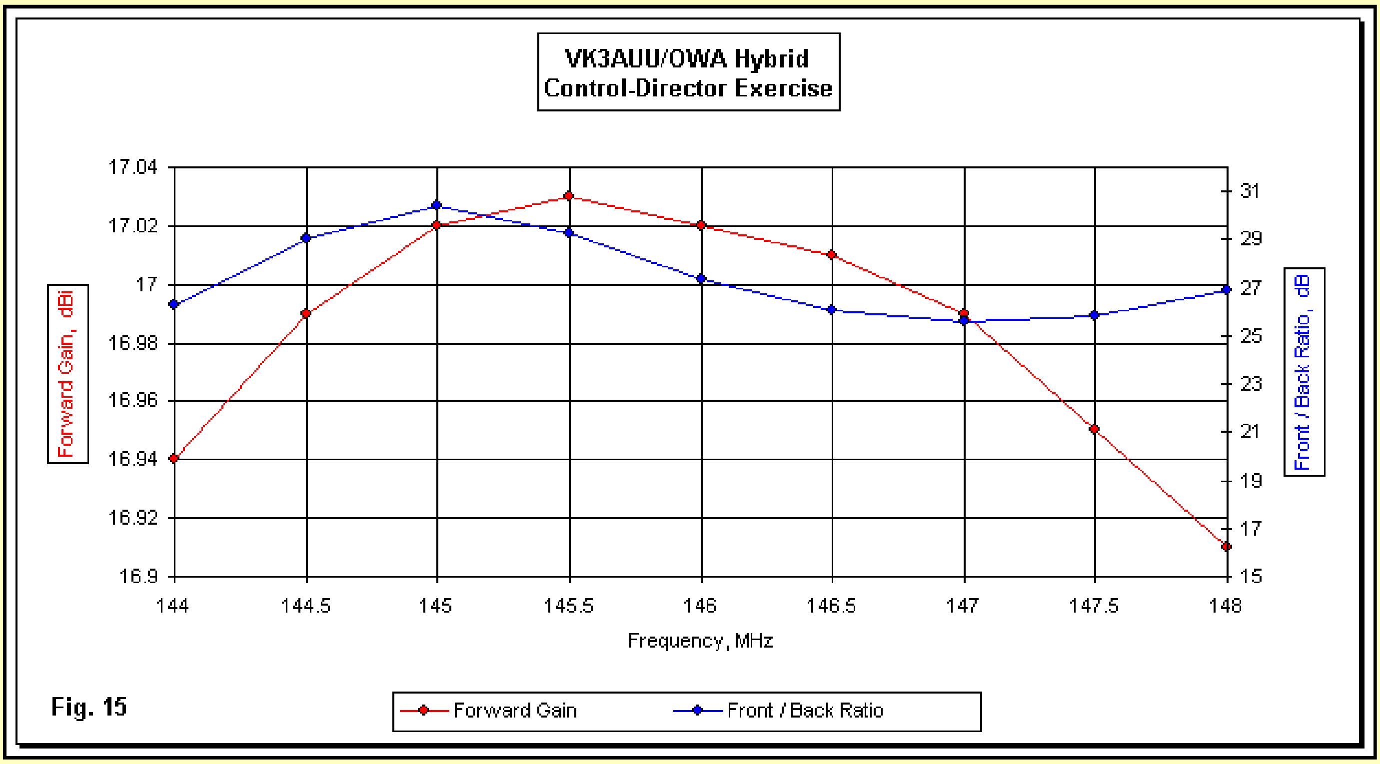


Fig. 15

Some Tentative Conclusions

The one assertion that does not fall among these conclusions is that anyone should in fact build an OWA or hybrid-OWA Yagi design. For practical purposes, sidelobe attenuation will likely satisfy any operational need where the level of sidelobes in a standard design are too strong. However, curiosity rather than practicality drove this exploration, so it is reasonable to carry matters to their conclusion.

1. Effective sidelobe suppression is possible on long boom Yagis. However, the element taper ratio required yields a current magnitude pattern that results in a relatively high gain deficit that grows as the boom length grows.

2. Effective sidelobe suppression requires an element taper ratio greater than 1.3:1 in shorter boom lengths and greater than 1.45:1 in longer boom lengths.

3. Maximum sidelobe suppression tends to occur if the peak gain and peak front-to-back values occur on the same or nearly the same frequency within the operating passband of the array.

4. The OWA control directors appear to be an essential ingredient in the move from sidelobe attenuation to sidelobe suppression, wherein sidelobes merge and/or disappear. The apparent mechanism lies in the re-direction of at least some sidelobe angles.

5. A high element taper ratio, a smooth descending current magnitude pattern, coincidence of gain and front-to-back peak values, and effective design of the control directors all appear to be necessary conditions of significant sidelobe suppression. However, no one of these factors is itself a sufficient condition of sidelobe suppression. Rather, the combination of the four factors together appears sufficient of suppress sidelobes at a value in the E-plane of about 30 dB or so at and near the design frequency for long boom Yagis. Such values are about 5-7 dB better than virtually all sidelobe attenuation techniques.

6. At present, it does not appear to be feasible to suppress all sidelobes in long-boom Yagis. However, even in the most critical situation, sidelobe attenuation greater than 20 dB appears to satisfy virtually any Yagi application need.

In the exploration of sidelobe suppression and attenuation, I have looked both forward and backward in time relative to Yagi design considerations for long boom arrays. For EME and similar operational needs calling for a 6-wavelength or longer design, the VK3AUU design is especially attractive for its combination of relatively high gain and relatively tiny sidelobes. The fact that it requires 5 extra directors should be no deterrent to its use, since the boom itself will weigh more than all of the elements combined. However, this expedition has not exhausted the range of long-boom Yagi designs by any means. For a survey of 70-cm band long-boom Yagis, see "Preliminary Studies of Long-Boom Yagis for 420-450 MHz."

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