An OWA Family of 2-Meter Yagis From 6 to 12 Elements: Part 2: The Entire Family

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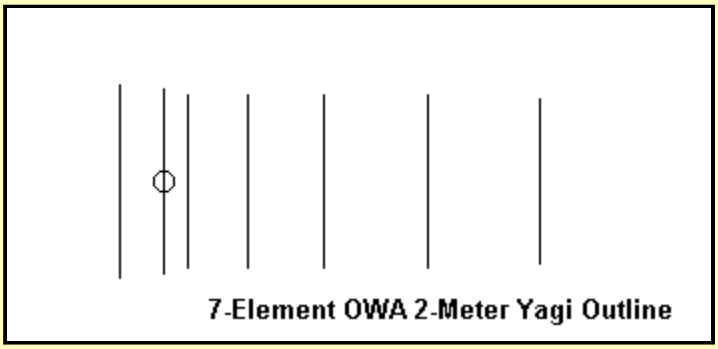
The family of Yagis that are directly linked by the use of the OWA core described in Part 1 of these notes begins with a 7-element design. The remaining members of the family were developed by the addition of a new director. The addition required readjustment of both the length and the spacing for the two forward-most directors. The general trend required that the former lead director be lengthened and spaced further forward in order to retain the desired SWR curve that is indicative of reducing the reactance excursions to a minimum across the 2-meter band. The interactive process required that one adjust the length and the spacing of new forward-most director to center the gain curve within the passband and to achieve the 20-dB front-to-back ratio across the band. One of the interesting features of the family members is that each succeeding array is just about 30" longer than its shorter kin.

All of the following designs presume that the elements are well insulation and isolated from a metallic boom, although some of the shorter ones might be placed on non-metallic booms. There is a further issue: the designs were considered complete when they met all of the specifications outlined in detail in Part 1. Virtually every individual design can be further perfected within that specification set by running them through an optimizing program of one or another sort. In addition, one can achieve better gain or better front-to-back ratios by additional optimizing, although the cost may be slight degradations of the SWR curves or pattern control. The levels of control on these two factors allow considerable room for some performance improvements by simply reducing these requirements. All of the designs show less than a 1.25:1 SWR across the band and better than -22 dB secondary lobe strength (with some exceptions noted in the text). Where these values are not required by a set of operational specifications, the other performance parameters may be improved.

For each design step, we shall present an outline sketch of the Yagi and a brief narrative, followed by both dimensional and performance tables. An SWR curve and a set of free-space azimuth patterns will complete the description. As a point of reference early in the progression, you may wish to have at hand the information on the separately designed 6-element OWA Yagi described at the end of Part 1.

A 7-Element OWA 2-Meter Yagi



The 7-element version of the OWA provides the core of the family, as described in Part 1. The first 5 elements are common to all of the family members. These particular elements, along with their spacing, creates an independent array that is just under 7' long. Especially noticeable is the gain increase over the 6-element Yagi in Part 1--better than 1.25 dB on average. This increase is considerably more than one might expect from the addition of a single element if we also sustain

all of the specifications in the set we examined. For example, the SWR curve is fundamentally a well-behaved OWA curve.

The reason for the increase in gain is a shift in the operating curve with respect to forward pattern shape. The 146 and 148 MHz patterns show a tendency toward the bullet shape. As a result, the -3 dB beamwidth changes across the band by 4 degrees, a 50% increase over the change in beamwidth that accompanies the wholly "normal" patterns of the 6-element array. As a consequence of moving toward bullet patterns, the emerging secondary lobe devolves from a definitive lobe into a bulge. As with the succeeding versions of this Yagi family, the "-s" in the secondary lobe column of the performance data indicates that the lobe is a "swelling" of the main forward lobe; therefore, a value for the lobe is a rough estimate. When the final column gives a dash rather than a value, the bulge is too small for quantification. Although that bulge-shaped lobe may seem an advantage in terms of its integration into the main forward lobe, it reduces the beamwidth of the main lobe. As well, the gain change across the band increases to about 0.26 dB (compared to 0.1 dB for the 6-element Yagi). Whether these levels of reduction in pattern control are acceptable for any particular application is a user judgment based on operational specifications. For the present design exercise, these limitations were considered acceptable.

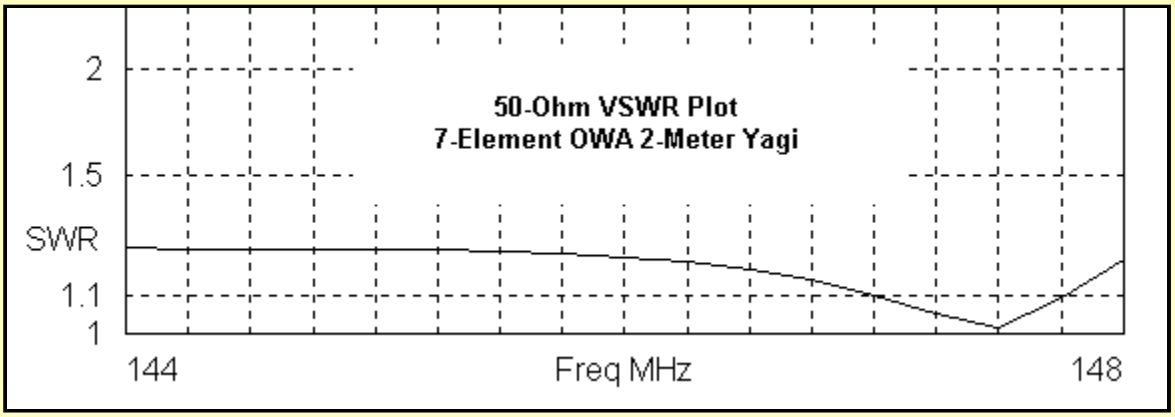
No. of elements: 7
Element diameter: 0.1875" (3/16")
Boom length: 83.67 (6.97')
Maximum 50-Ohm SWR: 1.24:1

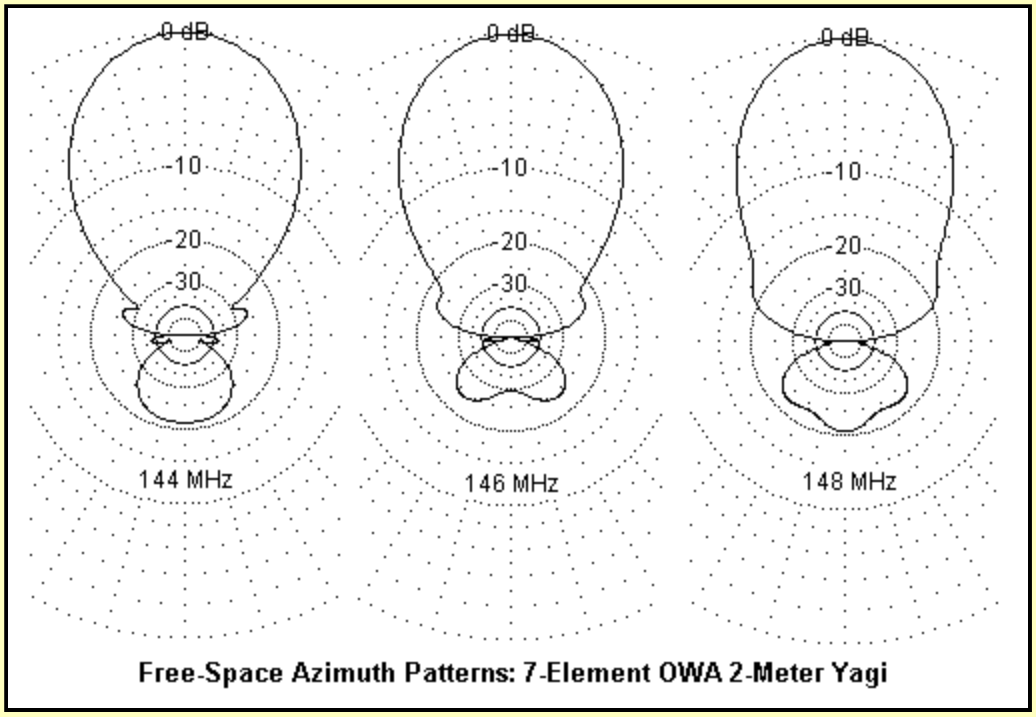
Dimensions (in inches):

Element	Length	Space from Reflector
Reflector	40.90	----
Driver	39.50	8.79
Director 1	37.00	13.47
Director 2	36.33	25.38
Director 3	36.40	40.72
Director 4	36.21	61.38
Director 5	34.54	83.67

Modeled Performance

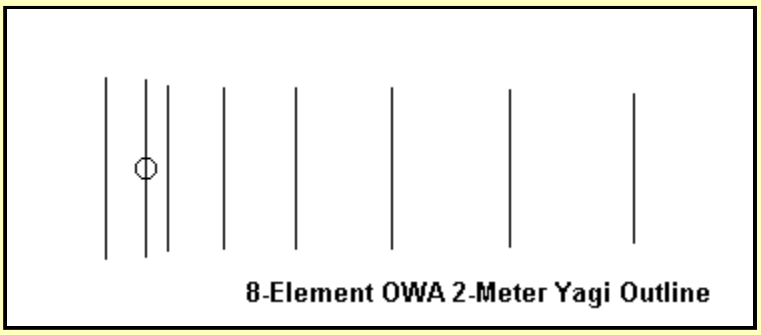
Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	11.46	11.56	11.30
Max. 2ndary Lobe	-26.16	-22.98-s	(See text)
180-deg F-B	21.26	29.62	20.70
-3dB Beamwidth	48.0	46.2	44.0
Impedance (R+/-jX)	40.7 + j 2.8	46.2 + j 8.5	44.0 - j 6.2
50-Ohm SWR	1.24	1.21	1.20





Free-Space Azimuth Patterns: 7-Element OWA 2-Meter Yagi

An 8-Element OWA 2-Meter Yagi


8-Element OWA 2-Meter Yagi Outline

The 8-element Yagi required readjustment of the 5th director, moving it about 3" forward and lengthening it by over an inch. The new director is shorter than the previous forward-most director. The final length is a bit over 29" longer than the 7-element version and will fit nicely on a 10' boom. Nevertheless, the SWR curve has remained virtually unchanged. There are inevitable slight movements in the exact frequency at which the lowest SWR occurs, but the dip is within the last half MHz at the upper end of the band. The forward portions of the azimuth patterns for the 8-element Yagi are similar to those for the 7-element array, but the rearward patterns show the more definite emergence of the secondary lobes. To some degree, the shift toward a bullet forward pattern disguises the secondary lobe emergence in that direction, and the 3.8-degree change in beamwidth tends to confirm the disguise. However, the array shows a nearly 0.8 dB increase in average gain across the band, although the change in gain across the band remains above 0.2 dB.

No. of elements: 8
Element diameter: 0.1875" (3/16")
Boom length: 113.00 (9.42')
Maximum 50-Ohm SWR: 1.20:1

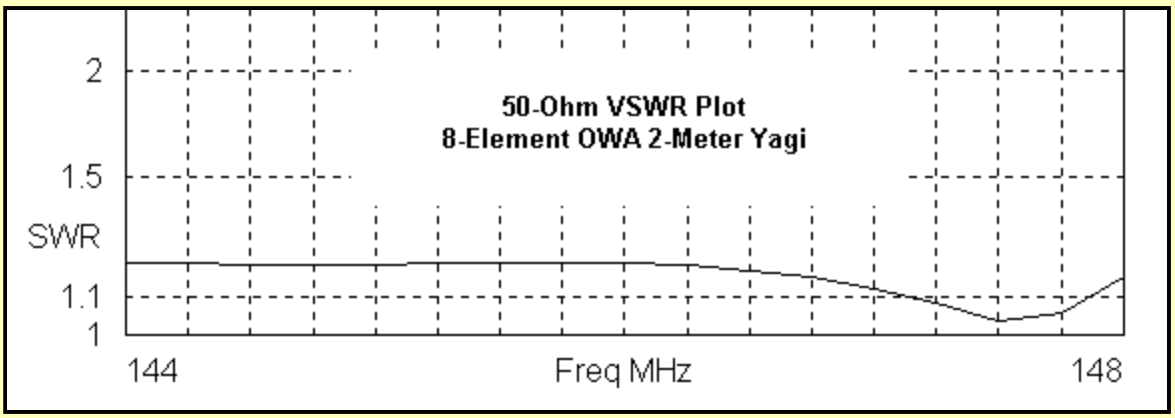
Dimensions (in inches):

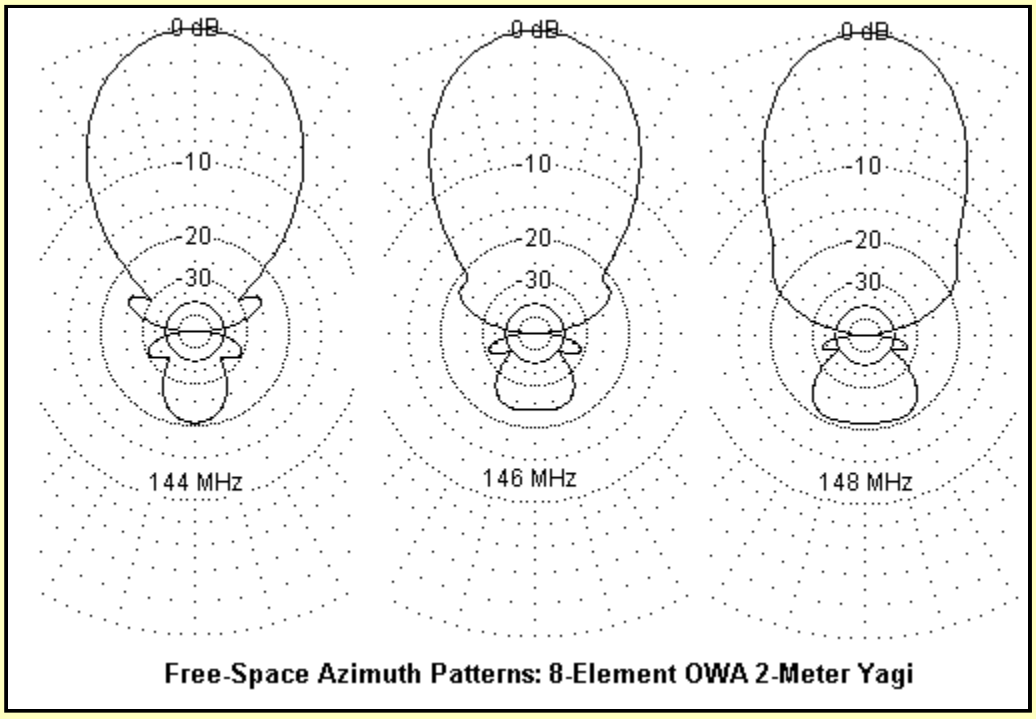
Element	Length	Space from Reflector
Reflector	40.90	----
Driver	39.50	8.79
Director 1	37.00	13.47
Director 2	36.33	25.38

Director 3	**36.40**	**40.72**
Director 4	**36.21**	**61.38**
Director 5	**35.20**	**86.49**
Director 6	**33.20**	**113.00**

Modeled Performance

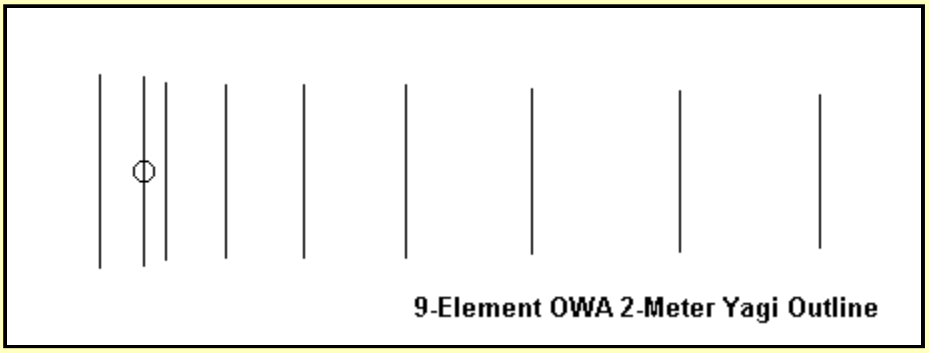
Parameter	**144 MHz**	**146 MHz**	**148 MHz**
Gain dBi	**12.24**	**12.36**	**12.07**
Max. 2ndary Lobe	**-24.45**	**-21.64-s**	**(See text)**
180-deg F-B	**20.54**	**23.51**	**41.40**
-3dB Beamwidth	**45.2**	**43.2**	**41.4**
Impedance (R+/-jX)	**42.5 + j 3.9**	**46.4 + j 7.9**	**47.1 - j 6.2**
50-Ohm SWR	**1.20**	**1.20**	**1.15**





Free-Space Azimuth Patterns: 8-Element OWA 2-Meter Yagi

A 9-Element OWA 2-Meter Yagi



9-Element OWA 2-Meter Yagi Outline

The 9-element member of the family shows the same growth symptoms as the preceding Yagi. The 6th director is moved forward by about 3" and increased in length. The most forward director winds up at the 12' mark, a relatively convenient building size. The SWR curve shows the small dip near the lower end of the band, since the deeper minimum has been shifted upward in frequency be about 0.25 MHz. This move gives some idea of the room the individual designer has for "tweaking" any design to achieve more favorable numbers, in this case, an SWR value that does not exceed 1.17:1 across the band. Design flexibility does not mean that a builder will achieve the precise modeled figures in the constructed version. However, it does indicate that a builder has room for maneuver in obtaining acceptable measured performance from an array. The gain increment of the 9-element Yagi over its 8-element brother averages 0.65 dB. We should expect lesser gain increases with each added director. An additional feature to notice from the azimuth patterns is the first hint at the emergence of a second secondary lobe at the upper end of the band. As well, the patterns show a trend toward "normalization" at all frequencies tested.

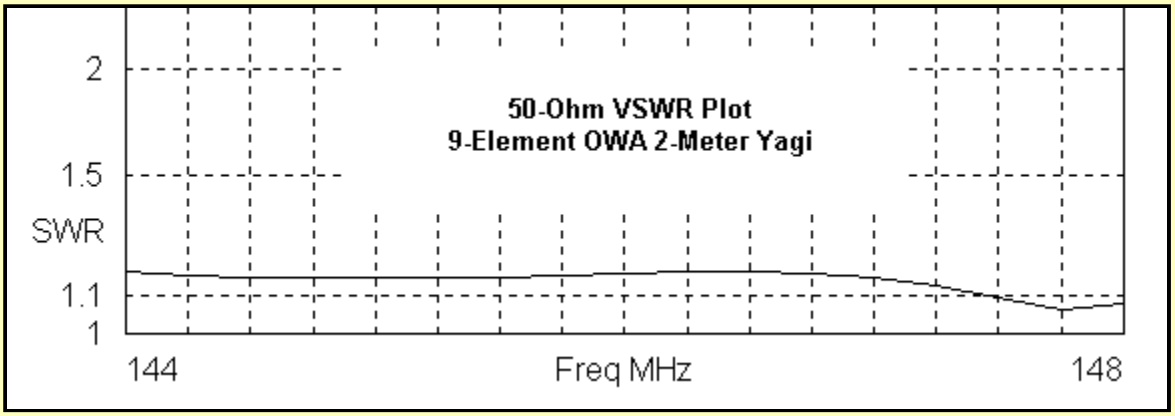
No. of elements: 9
Element diameter: 0.1875" (3/16")
Boom length: 144.00 (12.00')
Maximum 50-Ohm SWR: 1.17:1

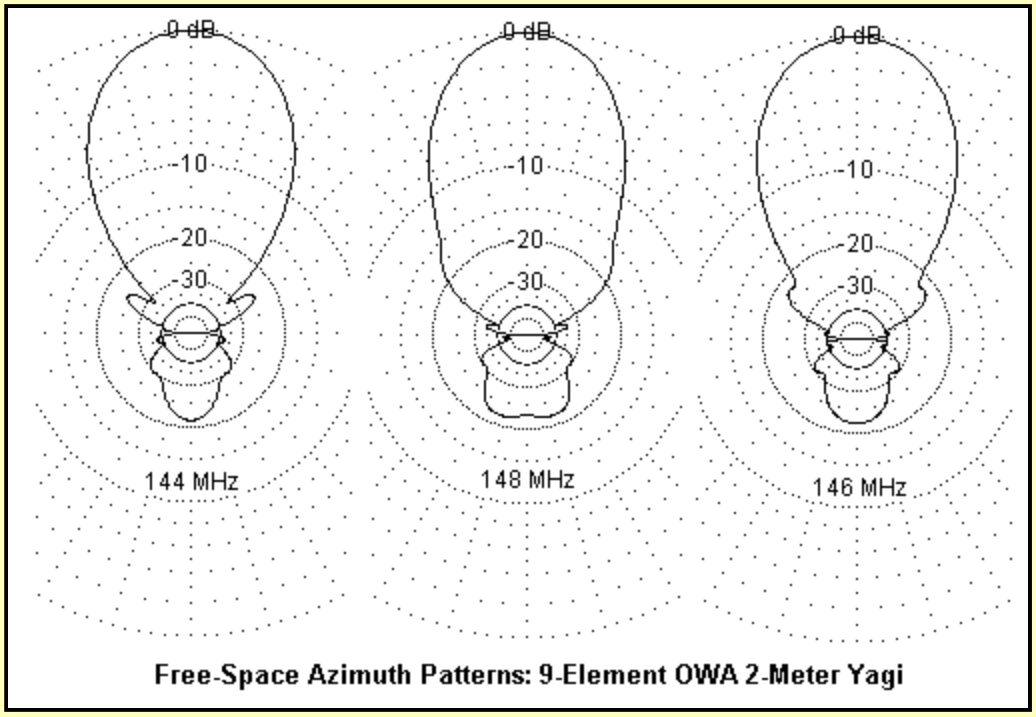
Dimensions (in inches):

Element	Length	Space from Reflector
Reflector	40.90	----
Driver	39.50	8.79
Director 1	37.00	13.47
Director 2	36.33	25.38
Director 3	36.40	40.72
Director 4	36.21	61.38
Director 5	35.20	86.49
Director 6	34.30	116.00
Director 7	32.20	144.00

Modeled Performance

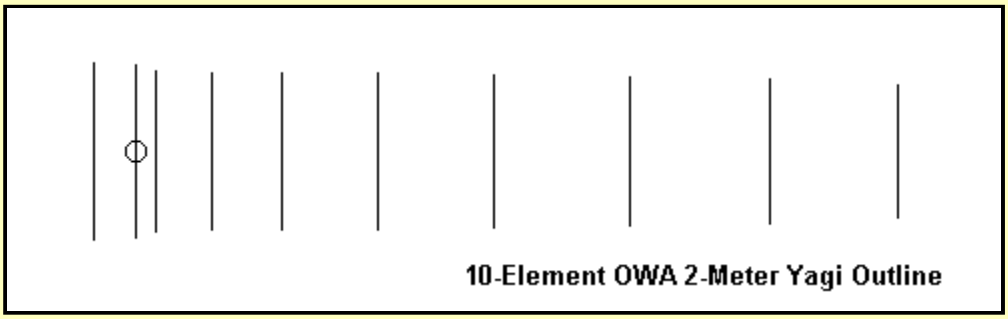
Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	12.85	13.01	12.80
Max. 2ndary Lobe	-24.46	-22.21-s	(See text)
180-deg F-B	21.32	21.91	22.73
-3dB Beamwidth	43.0	41.2	39.5
Impedance (R+/-jX)	43.8 + j 3.8	45.2 + j 5.4	46.6 - j 0.8
50-Ohm SWR	1.17	1.17	1.08





Free-Space Azimuth Patterns: 9-Element OWA 2-Meter Yagi

A 10-Element OWA 2-Meter Yagi



10-Element OWA 2-Meter Yagi Outline

The 10-element Yagi adds about 0.5 dB gain over the 9-element version for an increase in length to a 14.5' boom. The pattern shapes continue the trend toward normalization. In this particular case, note the very shallow SWR curve. Achieving such constancy has a cost, in this instance, a very slight reduction in the total gain that one might be able to glean from the array. Additional markers of this fact at the mere 2.6" movement of the 7th director and the very short length of the 8th (forward-most) director. I have left this condition as another indicator of the flexibility available to the builder who may revise the design by additional adjustments to the two most forward directors.

No. of elements: 10
Element diameter: 0.1875" (3/16")

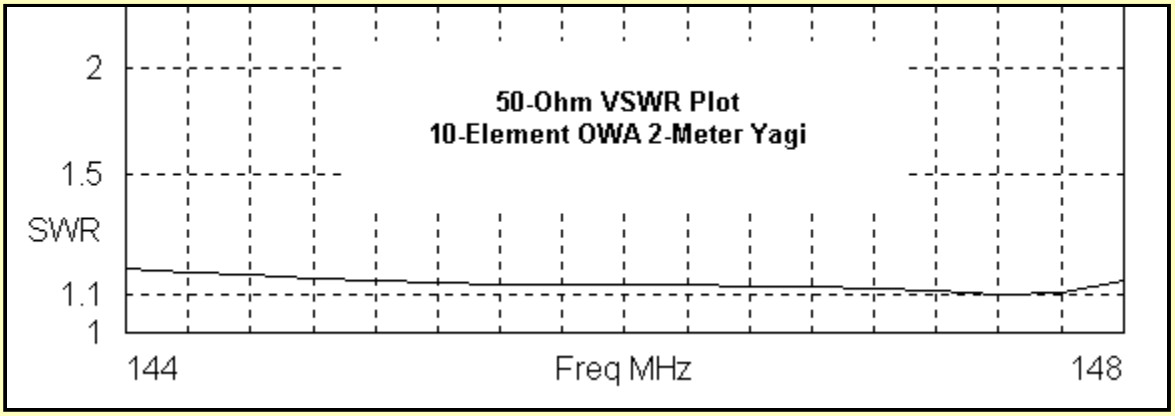
Boom length: 174.00 (14.50')
Maximum 50-Ohm SWR: 1.18:1

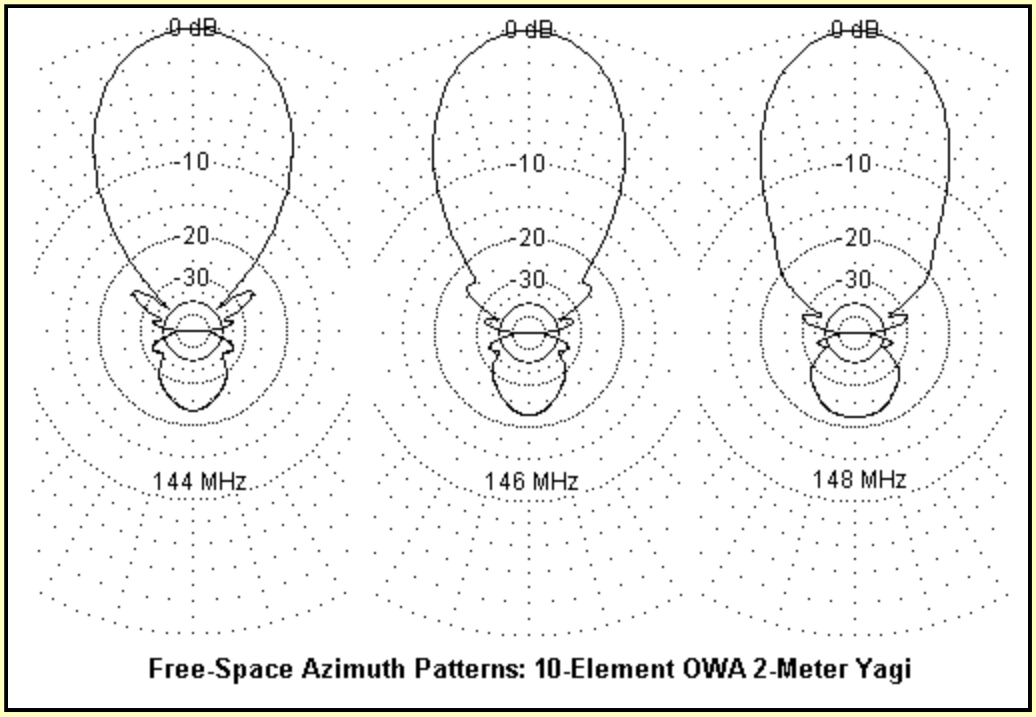
Dimensions (in inches):

Element	Length	Space from Reflector
Reflector	40.90	----
Driver	39.50	8.79
Director 1	37.00	13.47
Director 2	36.33	25.38
Director 3	36.40	40.72
Director 4	36.21	61.38
Director 5	35.20	86.49
Director 6	34.30	116.00
Director 7	33.60	146.00
Director 8	30.80	174.00

Modeled Performance

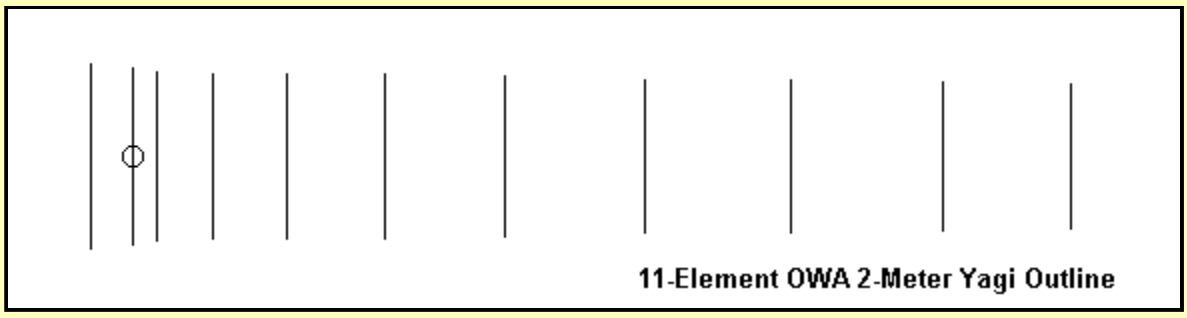
Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	13.29	13.49	13.33
Max. 2ndary Lobe	-24.91	-23.58	(See text)
180-deg F-B	22.91	22.41	22.07
-3dB Beamwidth	41.4	39.6	38.2
Impedance (R+/-jX)	43.8 + j 4.5	46.4 + j 4.6	43.8 - j 0.7
50-Ohm SWR	1.18	1.13	1.14





Free-Space Azimuth Patterns: 10-Element OWA 2-Meter Yagi

An 11-Element OWA 2-Meter Yagi


11-Element OWA 2-Meter Yagi Outline

With the addition of the 9th director, we return to the typical OWA SWR curve, and we add another 0.5 dB gain to the array. Note, however, that from the 9-element version to this one, we have been moving the lowest gain from the high end of the band to the low end of the band--although the net difference remains 0.25 dB or lower. The shift sets the best front-to-back ratio at mid-band, aligned roughly with the highest gain figure. As well, the shift tends to shrink the first secondary lobe as we increase frequency on the band, yielding suppression of all secondary lobes to the -25 dB or better level. This 14-dBi Yagi is 17.1' long, with changes in the directors as well. The former forward-most director is 4.4" farther forward, and the new director is proportionally longer than the one on the 10-element array. Although maneuvers as precise as the ones made in these models are unlikely to be replicated with equal precision in the workshop, they do suggest that the performance of the model can be brought to the desired level with the manipulation of a very limited number of variables.

No. of elements: 11
Element diameter: 0.1875" (3/16")
Boom length: 205.00 (17.08')
Maximum 50-Ohm SWR: 1.20:1

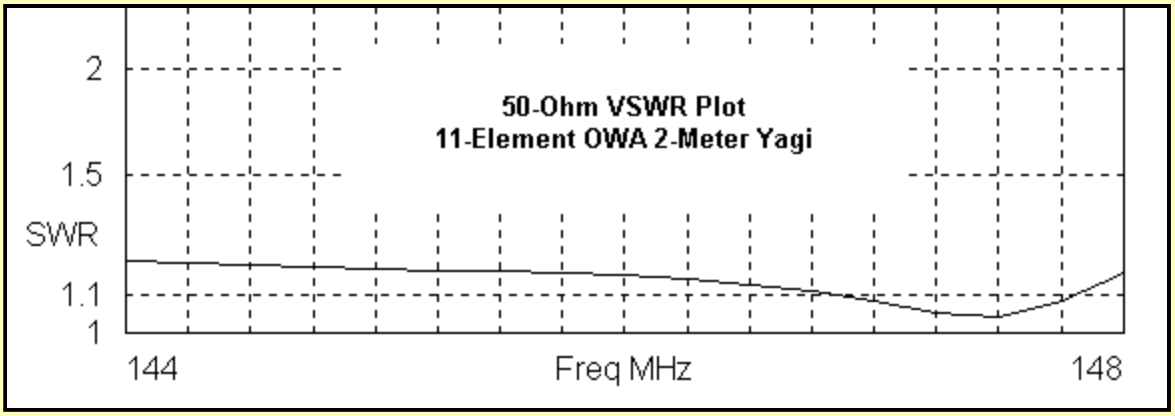
Dimensions (in inches):

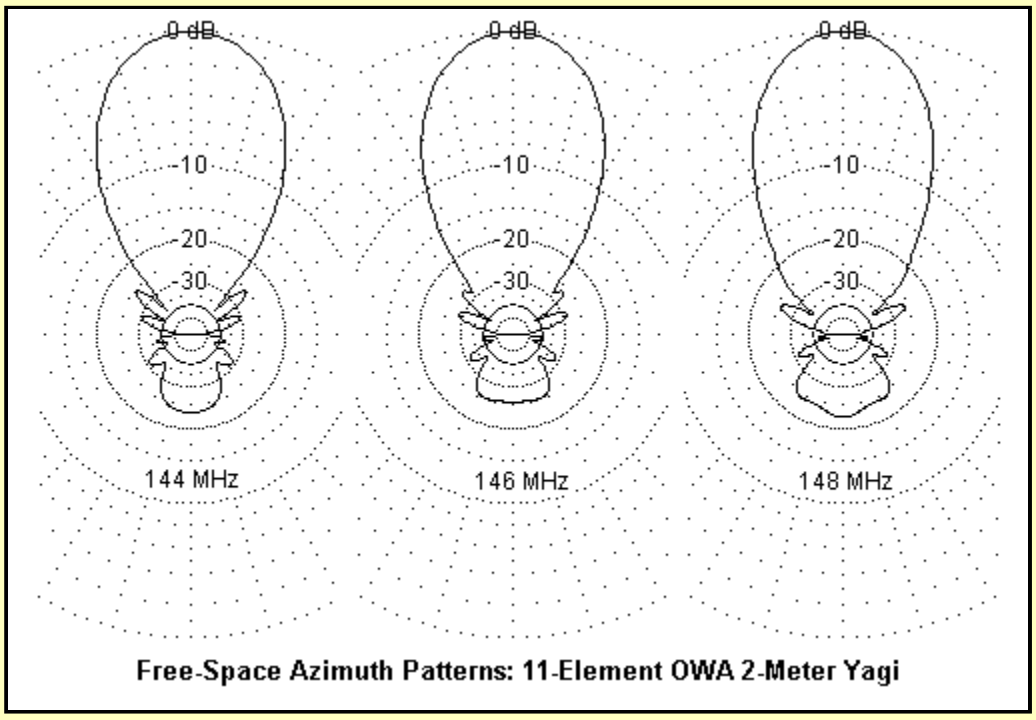
Element	Length	Space from Reflector
Reflector	40.90	----
Driver	39.50	8.79
Director 1	37.00	13.47

Director 2	**36.33**	**25.38**
Director 3	**36.40**	**40.72**
Director 4	**36.21**	**61.38**
Director 5	**35.20**	**86.49**
Director 6	**34.30**	**116.00**
Director 7	**33.60**	**146.00**
Director 8	**32.90**	**178.40**
Director 9	**32.00**	**205.00**

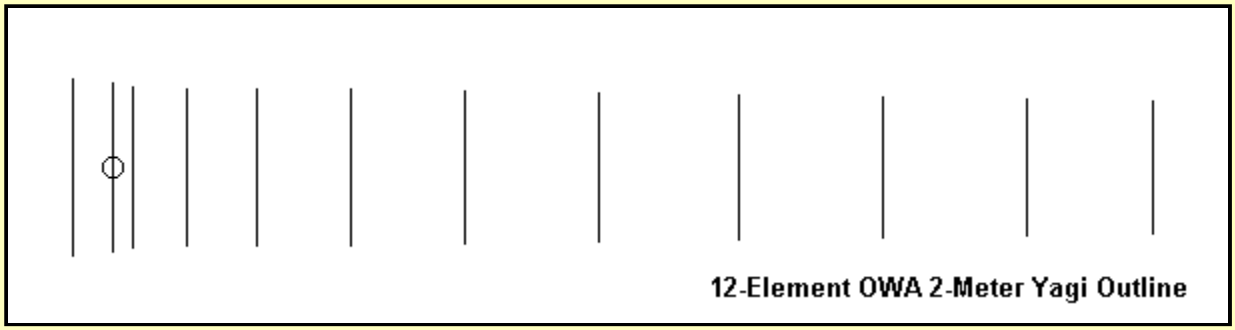
Modeled Performance

Parameter	**144 MHz**	**146 MHz**	**148 MHz**
Gain dBi	**13.77**	**14.02**	**13.90**
Max. 2ndary Lobe	**-25.17**	**-26.36**	**-25.76**
180-deg F-B	**23.27**	**25.72**	**22.35**
-3dB Beamwidth	**39.4**	**37.8**	**36.4**
Impedance (R+/-jX)	**42.8 + j 4.4**	**47.1 + j 6.4**	**44.1 - j 3.7**
50-Ohm SWR	**1.20**	**1.16**	**1.16**





A 12-Element OWA 2-Meter Yagi



12-Element OWA 2-Meter Yagi Outline

For family unity, the 12-element Yagi graphics and tables are repeated from Part 1. With a length just under 20', the 12-element array provides only about 0.35 dB additional gain, although pattern control continues to improve. The strongest secondary lobe is -25 dB compared to the main lobe. Fuller discussion of the features of this member of the family appears in Part 1.

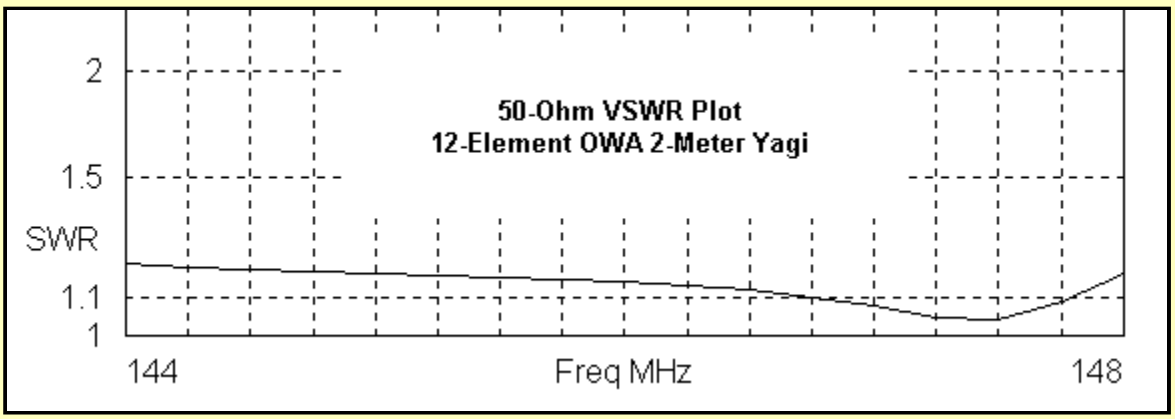
No. of elements: 12
Element diameter: 0.1875" (3/16")
Boom length: 238.00 (19.67')
Maximum 50-Ohm SWR: 1.20:1

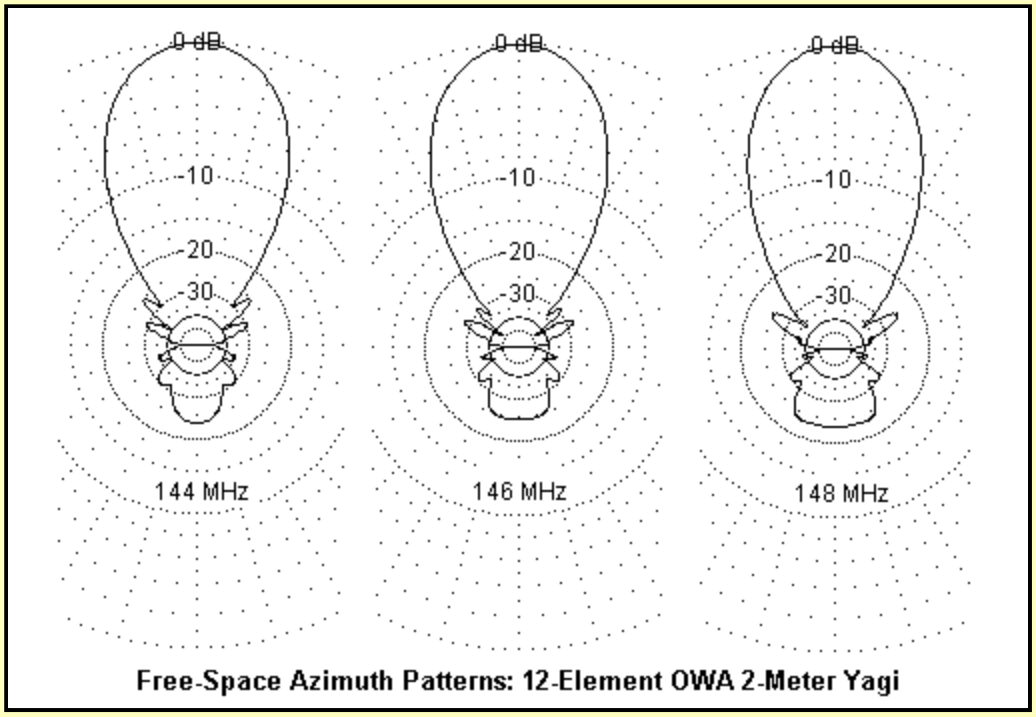
Dimensions (in inches):

Element	Length	Space from Reflector
Reflector	40.90	----
Driver	39.50	8.79
Director 1	37.00	13.47
Director 2	36.33	25.38
Director 3	36.40	40.72
Director 4	36.21	61.38
Director 5	35.20	86.49
Director 6	34.30	116.00
Director 7	33.60	146.00
Director 8	32.90	178.40
Director 9	32.20	210.00
Director 10	31.20	238.00

Modeled Performance

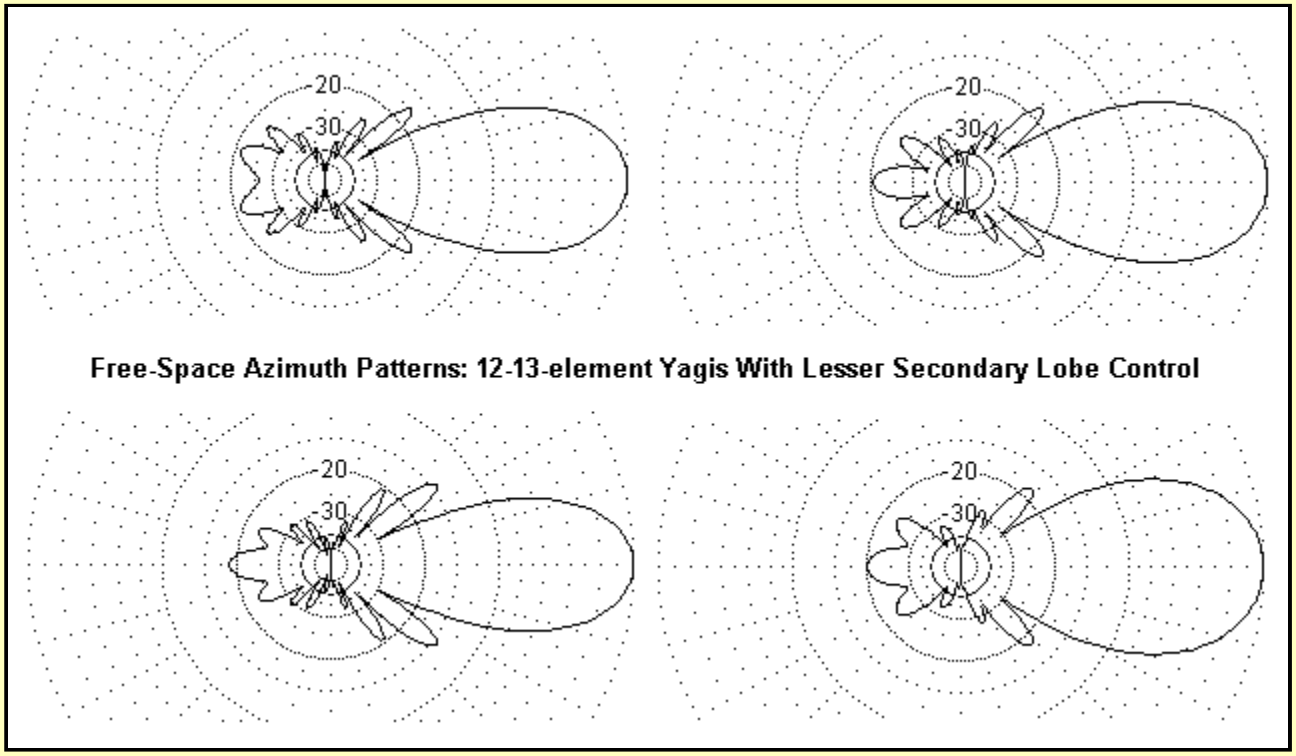
Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	14.07	14.35	14.27
Max. 2ndary Lobe	-25.15	-28.04	-25.04
180-deg F-B	23.22	24.66	23.17
-3dB Beamwidth	38.4	36.8	35.6
Impedance (R+/-jX)	43.1 + j 4.8	47.4 + j 6.1	43.9 - j 3.9
50-Ohm SWR	1.20	1.15	1.17





Free-Space Azimuth Patterns: 12-Element OWA 2-Meter Yagi

The family of Yagis in these notes represent a design exercise that has been based on using a set of specifications somewhat unlike those common to amateur designs. Pattern control was given top priority, even if the end result was not the ideal goal of the elimination of all secondary lobes. However, the following set of free-space azimuth patterns may give some indication of the degree to which pattern control has been improved. Each pattern represents a different VHF Yagi having either 12 or 13 elements. Each pattern also represents a different design and designer, and all show good gain performance with adequate front-to-back ratios throughout. Nevertheless, the -3 dB beamwidths are significantly narrower than the values shown for the 12-element array in our new family. Comparing this collection of azimuth patterns with those for the 12-element OWA Yagi will give some idea of the improvements that are possible for Yagis from 19 to 22 feet in boom length.



Free-Space Azimuth Patterns: 12-13-element Yagis With Lesser Secondary Lobe Control

As almost an incidental specification, the use of OWA techniques also permits a very tight control on the feedpoint impedance of the arrays. All of the Yagis in the collection were designed for 50-

Ohm direct matching to coaxial cable (with the usual common-mode suppression techniques applied).

The achievement of front-to-back ratios that exceeded 20 dB as a worst-case value and the gain levels attained by the arrays at any boom length are an indication that the designer can apply to long-boom Yagi design a more complex set of specifications than most designers have applied in the past.

In the end, however, this has only been a design exercise, not a prelude to construction. Still, it may be serve as a springboard toward even better designs, and so the family portrait may have some utility down the road. We are a long way yet from the development of the ideal Yagi-Uda array for 2 meters.


Return to Index