The OWA Family Moves to 220

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In the June and July (2002) issues of ***antenneX***, I presented a family of wide-band 2-meter Yagis ranging from 6 to 12 elements. (See "An OWA Family of 2-Meter Yagis From 6 to 12 Elements," Parts 1 and 2.) The arrays had the following basic characteristics:

- Gain commensurate with the boom length and--at the longest length--within 0.3 dB of the best performing arrays on file.
- Direct 50-Ohm feed
- 50-Ohm SWR under 1.25:1 across the 144-148-MHz range
- Significantly reduced forward side lobes--worst case more than 20 dB down, typically more than 25 dB down
- 180-degree and worst-case front-to-back ratio more than 20 dB

The arrays employed 3/16" (0.1875") diameter aluminum elements and were developed via NEC-4 modeling software. All elements are presumed to be insulated and isolated from any conductive boom.

The 220-MHz amateur band has in recent times awakened from previous slumber. The activity results in part from the shrinkage of the band to 222-225 MHz, a blow to amateur pride in the U.S. As well, a number of simple transverters have emerged to permit operation on the band. Finally, a cadre of dedicated operators has gone public, developing interest via local club and hamfest activities.

Therefore, to serve this growing collection of operators, I have adapted the designs of the 2-meter OWA family to the 222-225-MHz range. The process was not as arduous as it might appear at first site. I scaled all dimensions of the arrays from 146 MHz to 222 MHz, the new design frequency. I then adjusted the element diameter to 1/8" (0.125") and made any final necessary adjustments. (The scaled diameter was not too far off the mark, since the frequency ratio is close to 1.5:1 or its inverse for dimensions, 0.6667:1.)

The 220 versions of the OWA family preserve all of the characteristics of their 2-meter cousins. Because the 220-MHz band is smaller as a percentage of the design frequency, the arrays actually cover well over the old 220-225 MHz band limits. The chief advantage is that the greater precision required in building arrays for frequencies approaching UHF is offset somewhat by the slightly wider latitude of acceptable tune-up.

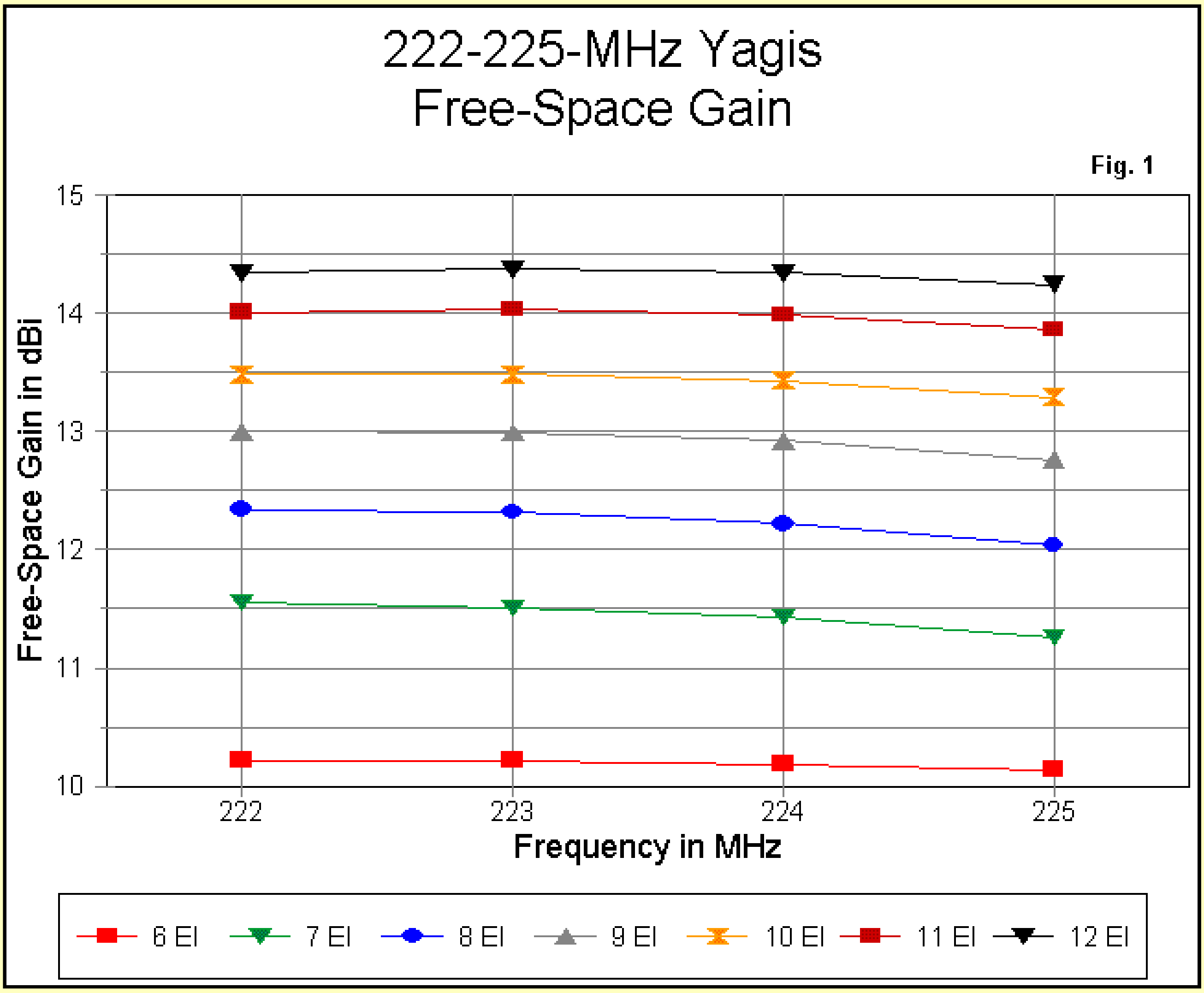


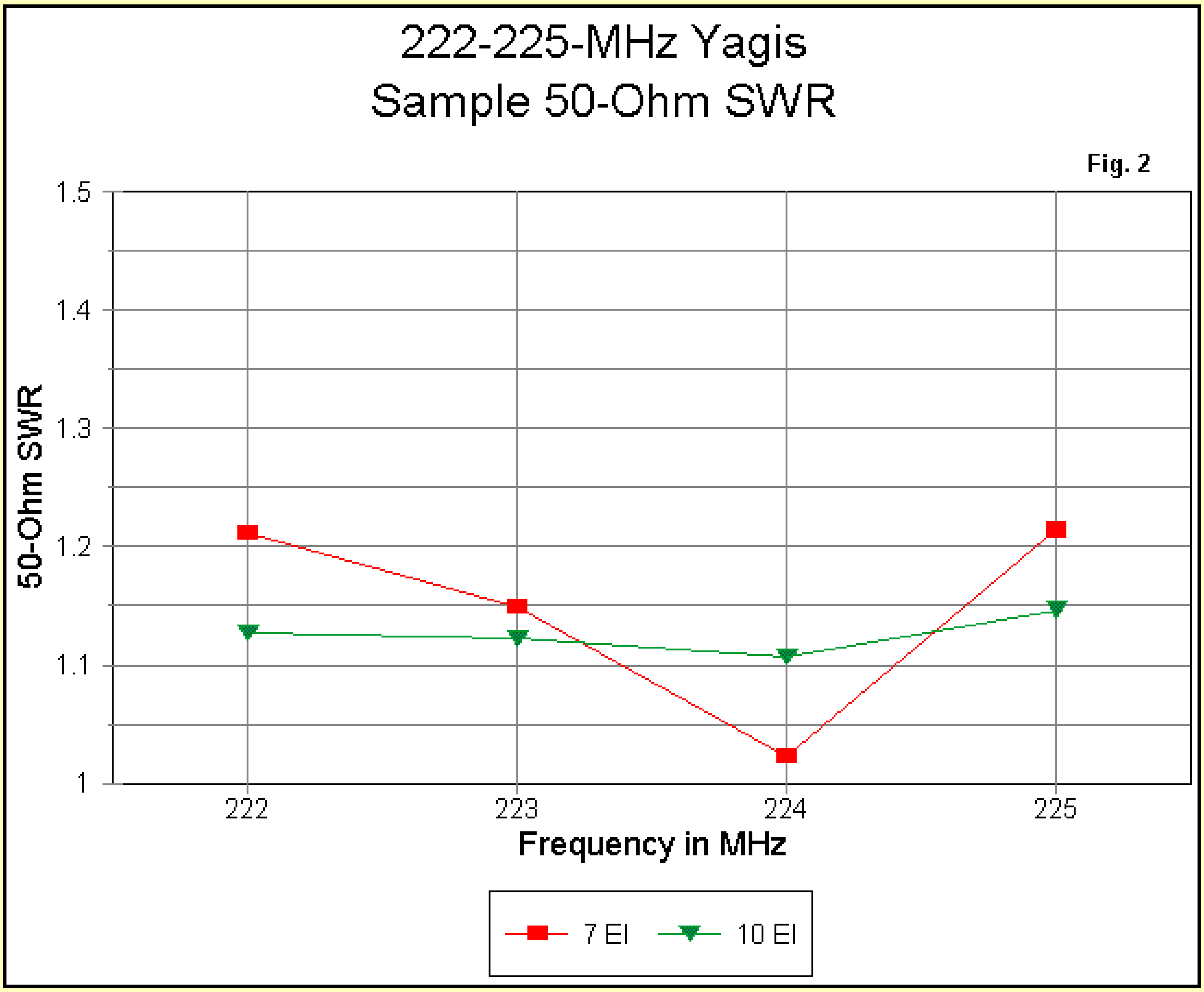
Fig. 1 presents in graphical form the forward gain of the 7 members of the family. Perhaps the foremost feature to note is the relatively small change of gain across the band. I designed the arrays to place the highest gain at or just above 222 MHz. Since the principal use of these arrays would be for point-to-point communications, which occurs at the low end of the available band, highest performance belongs in this region.

As the number of elements increases, the increment of gain advantage decreases. Therefore, the user may enter construction criteria as well as gain into the formula for determining which version to construct. The smallest--6-element--Yagi is under 3' long in this incarnation. The 9-, 10-, and 11-element versions are under 8', 10', and 12' long. These lengths lend themselves to the use of a variety of boom materials and boom-construction techniques.

The widest gain increment occurs between the 6- and 7-element versions of the array. In fact, as later element dimension tables will reveal, the versions from 7 to 12 elements are very closely related so that as we add an element, we change only the length and spacing of the former forward-most director and then optimize the length and spacing of the new forward-most director. This technique simplified the preservation of the 50-Ohm SWR curve and the front-to-back ratio.

However, the 6-element array is a cousin, designed on the same basic principles, but using an independent set of dimensions to achieve its performance within a certain boom length--under 5' on 2 meters and under 3' at 220. The gain graph shows that the design is slightly better at preserving gain across the entire band, although the front-to-back ratio will show more variation--ranging from a low of 21 dB to a high of 35 dB. In contrast, the other members of the family aimed for slightly higher gain for the boom length, so long as the front-to-back ratio remained above 20 dB. The result is a set of front-to-back figures ranging from 21 to 25 dB and a noticeable but not very significant peak in gain.

Since the SWR curves of the arrays would form a morass of tightly packed lines on a graph, I shall present instead two contrasting cases. See **Fig. 2**.



The OWA SWR curve, when extended to its limits, shows 2 low points. The first is a shallow dip near the lower frequency limit of designed operation. The second is a deep dip near the upper operating limit. Below the lower dip, the SWR increases relatively slowing, while above the upper dip, SWR increases rather sharply as the feedpoint impedance drops precipitously. The 220-MHz versions of the OWA family are designed for operation closer to the upper frequency dip to ensure a worst-case SWR of 1.25:1 for the most carefully constructed array. (Construction variables are likely to raise the entire set of SWR values as leads between the feedline and the element introduce some reactance into the impedance seen by the feedline proper.)

We may approach the upper frequency dip in two ways, illustrated most vividly by the 7- and 10-element arrays. The 7-element version of the antenna shows the lowest ultimate SWR, but the cost of achieving it is a higher SWR at the band edges: about 1.22:1. The 10-element array has a much shallower dip, but the SWR (without consideration of construction-induced additions) never exceeds 1.15:1.

In thinking about the differences between the two curves and the low overall design SWR, line loss is not the principle consideration. The differences in line loss between a 1.1:1 and a 1.25:1 are insignificant. However, the lower the design SWR, the less critical the final construction, since there is greater room for the introduction of otherwise unwanted reactances.

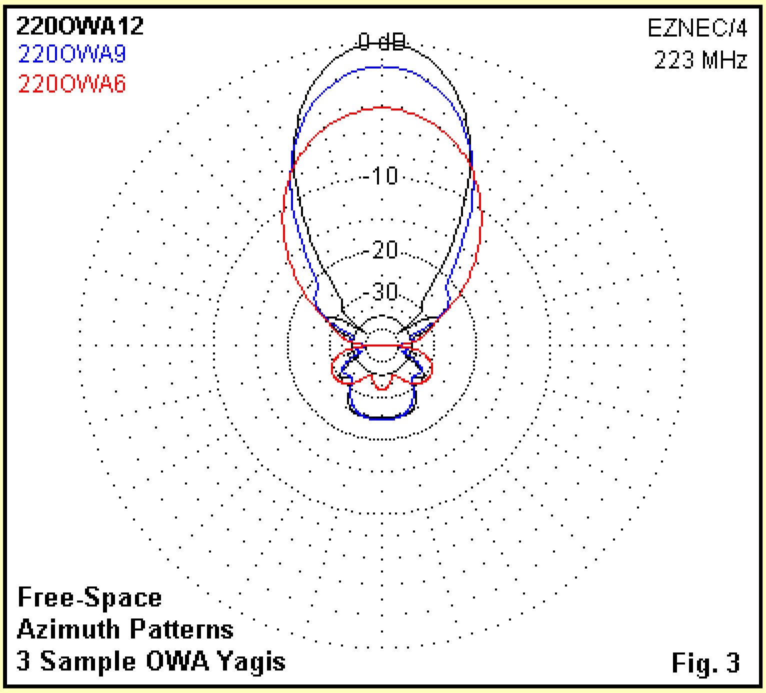


Fig. 3 samples the patterns of the 6-, 9-, and 12-elements versions of the array. The shortest beam shows the cleanest pattern. The forward lobe is smooth, with no visible secondary forward lobes. The beamwidth of the pattern is wide enough that any tendencies toward the development of secondary forward lobes are encompassed by the overall forward pattern.

As we increase gain, we decrease the beamwidth, permitting secondary forward lobes to reveal themselves. The 9-element array shows them as slight bulges. The 12-element array not only shows identifiable secondary lobes, but tertiary bulges as well. One aim in the design of these arrays was to minimize these secondary lobes, and the patterns show the degree of success.

The rear lobes are equally susceptible to multiple lobes. Indeed, the 6-element beam shows a clear triple-lobe structure. The more closely knit family from 7 to 12 elements all show the type of structure of the overlapping 9- and 12-element versions in **Fig. 3**. A central rear lobe has two small side lobes. Although these arrays have more energy to the rear than the 6-element version, they should prove entirely serviceable in terms of operation or even a G/T (gain vs. thermal temperature) analysis.

The simplest way to present the individual family members is in a systematic presentation of dimensions and performance. Therefore, most of what follows will be tabular in format, with some free-space azimuth patterns to illustrate the performance expectations from the arrays.

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6 Elements: 1/8" (0.125") diameter aluminum

Element	**Length (")**	**Distance from Reflector (")**
Reflector	**26.45**	**-----**
Driver	**26.28**	**6.66**
Director 1	**24.58**	**9.42**
Director 2	**23.88**	**17.05**
Director 3	**23.88**	**24.52**
Director 4	**22.99**	**35.66 (2.97'--0.67 wl)**

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Performance Expectations: See Fig. 4.

Frequency	**Free-Space**	**Front-Back**	**Feedpoint Z**	**50-Ohm**

MHz	Gain dBi	Ratio dB	R +/- jX Ohms	SWR
222	10.22	35.09	50.0 + j 9.4	1.21
223	10.22	28.86	51.1 + j 7.0	1.15
224	10.19	24.70	49.5 + j 2.5	1.05
225	10.14	22.10	43.4 - j 1.9	1.16

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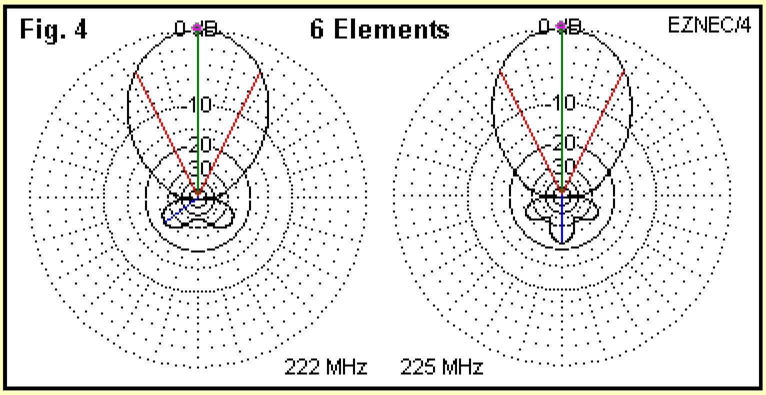

Fig. 4 6 Elements

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7 Elements: 1/8" (0.125") diameter aluminum

Element	Length (")	Distance from Reflector (")
Reflector	26.90	-----
Driver	25.98	5.78
Director 1	24.33	8.86
Director 2	23.89	16.69
Director 3	23.94	26.78
Director 4	23.81	40.37
Director 5	22.72	55.02 (4.59'--1.03 wl)

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Performance Expectations: See fig. 5.

Frequency MHz	Free-Space Gain dBi	Front-Back Ratio dB	Feedpoint Z R +/- jX Ohms	50-Ohm SWR
222	11.55	29.59	46.4 + j 8.5	1.21
223	11.51	26.76	49.7 + j 6.9	1.15
224	11.43	23.18	50.6 + j 1.0	1.02
225	11.26	20.60	43.6 - j 6.4	1.21

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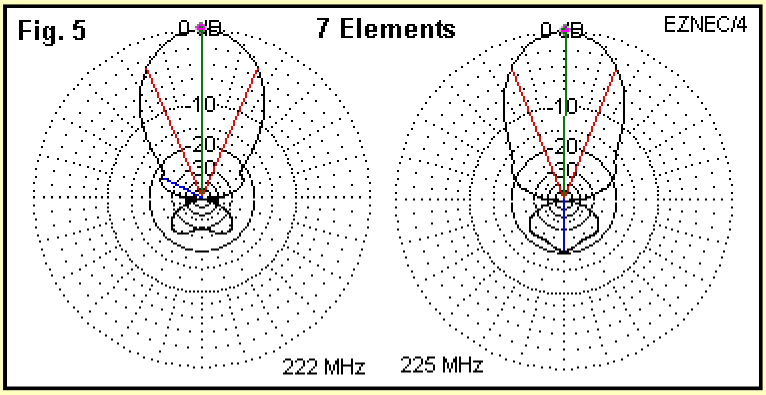

Fig. 5 7 Elements

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8 Elements: 1/8" (0.125") diameter aluminum

Element	Length (")	Distance from Reflector (")
Reflector	26.90	-----
Driver	25.98	5.78

Director 1	24.33	8.86	
Director 2	23.89	16.69	
Director 3	23.94	26.78	
Director 4	23.81	40.37	
Director 5	23.15	56.88	
Director 6	21.83	74.32	(6.19'--1.40 wl)

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Performance Expectations: See Fig. 6.

Frequency MHz	Free-Space Gain dBi	Front-Back Ratio dB	Feedpoint Z R +/- jX Ohms	50-Ohm SWR
222	12.34	23.52	46.6 + j 8.0	1.20
223	12.32	23.98	49.5 + j 7.4	1.16
224	12.22	23.04	51.7 + j 2.5	1.06
225	12.04	21.15	46.7 - j 6.6	1.17

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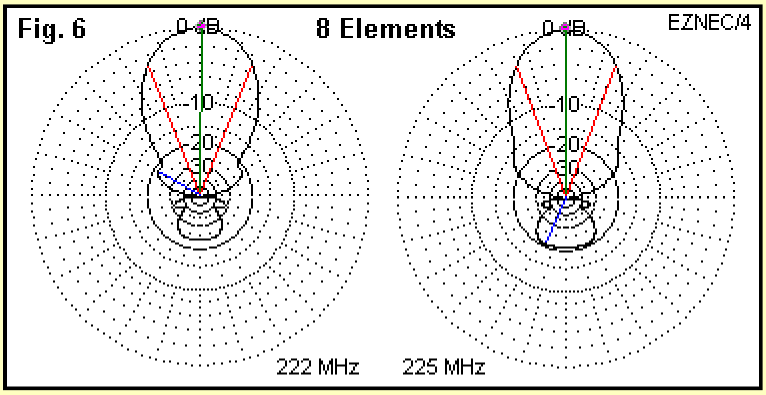
Fig. 6



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9 Elements: 1/8" (0.125") diameter aluminum

Element	Length (")	Distance from Reflector (")	
Reflector	26.90	-----	
Driver	25.98	5.78	
Director 1	24.33	8.86	
Director 2	23.89	16.69	
Director 3	23.94	26.78	
Director 4	23.81	40.37	
Director 5	23.15	56.88	
Director 6	22.56	76.29	
Director 7	21.18	94.70	(7.89'--1.78 wl)

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Performance Expectations: See Fig. 7.

Frequency MHz	Free-Space Gain dBi	Front-Back Ratio dB	Feedpoint Z R +/- jX Ohms	50-Ohm SWR
222	13.00	21.92	45.2 + j 5.5	1.17
223	12.99	22.56	46.0 + j 6.1	1.16
224	12.92	23.00	47.5 + j 4.7	1.02
225	12.76	22.60	46.4 - j 1.2	1.08

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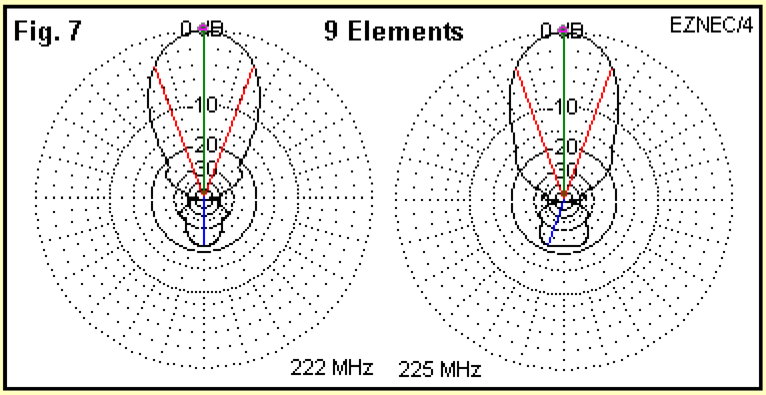
Fig. 7 9 Elements

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10 Elements: 1/8" (0.125") diameter aluminum

Element	Length (")	Distance from Reflector (")
Reflector	26.90	-----
Driver	25.98	5.78
Director 1	24.33	8.86
Director 2	23.89	16.69
Director 3	23.94	26.78
Director 4	23.81	40.37
Director 5	23.15	56.88
Director 6	22.56	76.29
Director 7	22.10	96.41
Director 8	20.26	114.43 (9.54'--2.15 wl)

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Performance Expectations: See Fig. 8.

Frequency MHz	Free-Space Gain dBi	Front-Back Ratio dB	Feedpoint Z R +/- jX Ohms	50-Ohm SWR
222	13.48	22.40	46.4 + j 4.6	1.13
223	13.48	22.37	46.3 + j 4.2	1.12
224	13.43	22.32	46.0 + j 2.8	1.10
225	13.29	21.98	43.7 - j 1.0	1.15

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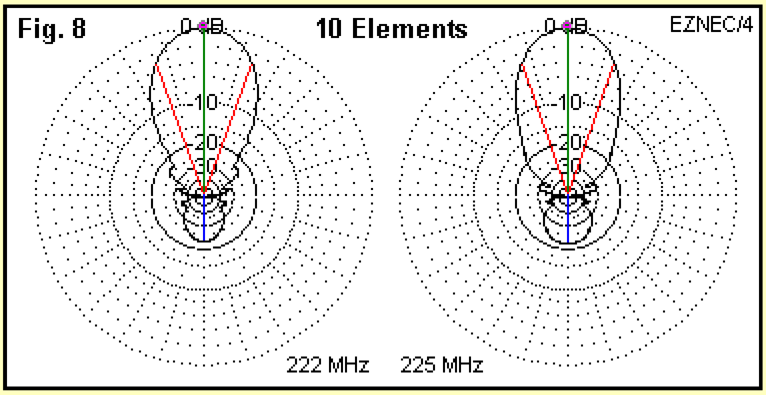
Fig. 8 10 Elements

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11 Elements: 1/8" (0.125") diameter aluminum

Element	Length (")	Distance from Reflector (")
Reflector	26.90	-----
Driver	25.98	5.78
Director 1	24.33	8.86
Director 2	23.89	16.69
Director 3	23.94	26.78
Director 4	23.81	40.37
Director 5	23.15	56.88

Director 6	22.56	76.29
Director 7	22.10	96.41
Director 8	21.64	117.33
Director 9	21.05	134.82 (11.24'--2.54)

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Performance Expectations: See fig. 9.

Frequency MHz	Free-Space Gain dBi	Front-Back Ratio dB	Feedpoint Z R +/- jX Ohms	50-Ohm SWR
222	14.01	25.70	47.2 + j 6.3	1.15
223	14.03	25.23	48.6 + j 5.1	1.11
224	13.99	23.91	48.5 + j 1.5	1.04
225	13.86	22.25	43.8 - j 4.0	1.17

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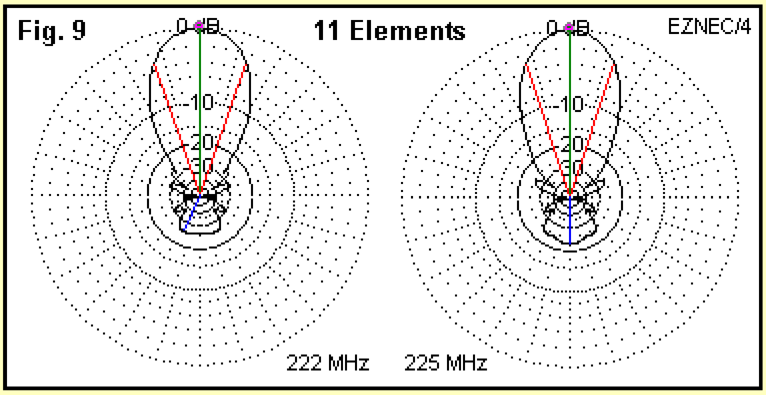

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12 Elements: 1/8" (0.125") diameter aluminum

Element	Length (")	Distance from Reflector (")
Reflector	26.90	-----
Driver	25.98	5.78
Director 1	24.33	8.86
Director 2	23.89	16.69
Director 3	23.94	26.78
Director 4	23.81	40.37
Director 5	23.15	56.88
Director 6	22.56	76.29
Director 7	22.10	96.41
Director 8	21.64	117.33
Director 9	21.18	138.11
Director 10	20.52	156.52 (12.79'--2.94 wl)

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Performance Expectations: See Fig. 10.

Frequency MHz	Free-Space Gain dBi	Front-Back Ratio dB	Feedpoint Z R +/- jX Ohms	50-Ohm SWR
222	14.34	24.65	47.5 + j 6.1	1.14
223	14.37	24.77	48.7 + j 4.8	1.11
224	14.34	24.23	48.4 + j 1.1	1.04
225	14.24	23.08	43.6 - j 4.2	1.18

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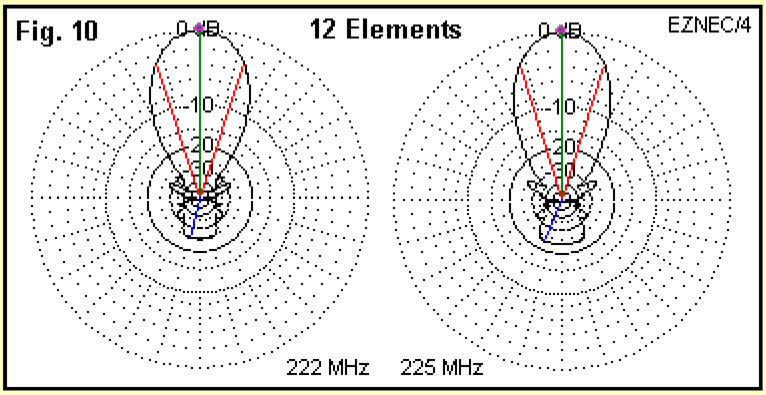

Construction of Yagi arrays requires increased attention to detail as we increase frequency. HF is very forgiving of relatively sloppy construction methods. However, even by 6 meters, the effects of loose leads, casual measurement, and unwise choices of materials become all too apparent.

The arrays presented here call for great care in three areas of effort, all of which together re-affirm the construction principle of going slowly and getting it right. First, obtain the right materials. Do not alter the element diameters without redesigning the entire array. A change in diameter of the elements will throw off the inter-element coupling and thus the entire operation of the array. Beware of boom materials susceptible to UV degradation or other adverse weathering affects. The longer the model you may choose to build, the more critical material selection becomes.

Second, measure element lengths and spacing very carefully, and cut precisely. Cutting a 16th long and sanding the element ends to precision is wise if you lack a precision shop. If you use any through mounting of elements, use a drill press--even a small fixture that accepts a hand drill will do. The object is precise alignment of all of the elements. Keeping everything on a single plane is likely more of an aesthetic ideal than an electrical necessity. However, keeping the elements as exactly parallel to each other as possible is a necessity.

Third, plan carefully the mounting of the driven element and the attachment of the feedline or a connector to this element. If at all possible, keep the driver in line with the other elements, since even a 1" displacement will slightly change the H-plane pattern of the array. Over ground, this slight change may wash out as ground reflections add and subtract from direct radiation, but the gain may suffer slightly. Equally or perhaps more important, use extreme care with driver leads to the feed cable stub or connector.

The only element in the array which may be altered without significant changes in the performance of the array is the driver. Use of a fatter driver will call for element shortening, but will otherwise not adversely affect performance--or improve it. However, this available latitude does give the builder options for construction that may be useful in view of available materials.

1/8" aluminum rod is often obtainable from local home centers, but may be purchased from outlets like Texas Towers at very reasonable prices. I shall leave boom construction and element mounting systems to the many handbooks on the market. The most promising methods will vary from one size array to the next.

None of these array approach the size needed for moon-bounce work, although a quad array of the longest ones might approach the threshold for such operations. Nevertheless, the arrays do promise more effective point-to-point communications in the 222-225-MHz region. That is enough of a service to keep any family busy.

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