A Collection of 220-MHz Yagi Designs: Part 4: Special Designs: Equal-Length Directors, Quagis, and Multiple Reflectors

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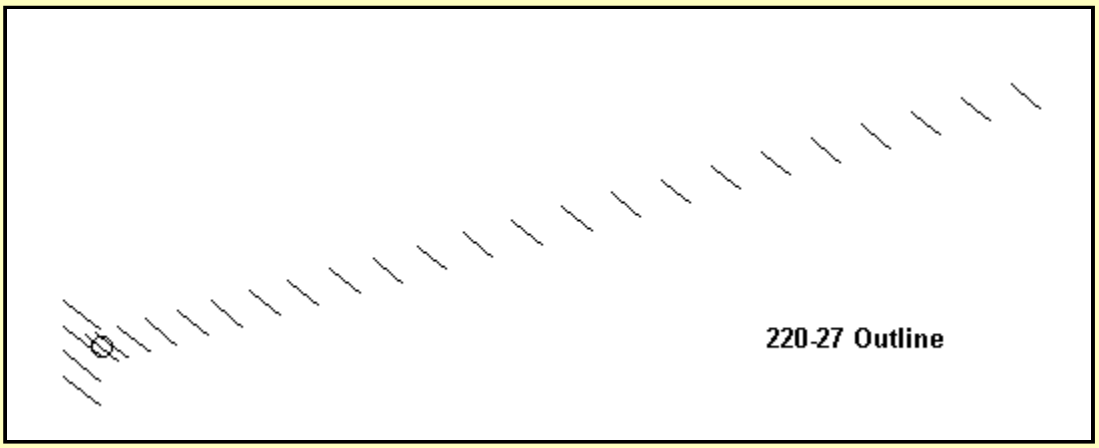
Our final collection of Yagi designs for 222-225 MHz contains some special-interest designs. Since there are almost innumerable aspects of Yagi design and performance in which we might take interest, we can only sample a few possibilities. In fact, the number of possibilities equals the number of remaining designs in my collection of models. Nevertheless, we can look at some special construction methods designed either to improve antenna performance or to make construction and adjustment easier for the newer builder. We can also briefly explore at least one way to improve some performance figures other than gain and front-to-back ratio. From that point forward, you will be on your own.

As we have done throughout this exploration of 220 Yagis, we shall introduce each design with a very short commentary and an outline sketch captured from EZNEC. Then, we shall present a table of dimensions, a table of performance data, and free-space azimuth patterns taken at 222, 223.5, and 225 MHz. Some patterns will be pointed right, others will point straight up. Since these models originate over a long period of time, the conventions of arranging elements on the X and Y axes have varied. However, the pattern shapes are unaffected by their modeled orientation.

Please note the element diameter for each design. It will change from one design to another. Do not use an alternative element diameter without first optimizing the design for the new size. Performance will suffer--often dramatically. As well, note that elements are presumed to be well isolated from the boom. If you wish to use through-mounting for the elements with a metallic boom, consult other sources for applicable correction factors.

220-27: A 27-Element Yagi (22 Directors and 4 Reflectors)



DJ9BV developed a 27-element Yagi design for 432 MHz, from which the design below is adapted. It consisted--as shown in the outline sketch--of 4 reflectors in a plane at right angles to the plane of the driver and 22 directors. Overall, the array is nearly 33.75' long, which places it about in the range of a 24-element DJ6WU design. With 22 directors, that length is for a 24-element Yagi if it had only a single reflector. The elements are 0.25" in diameter in this adaptation. The aim of the array was to improve performance over standard Yagis. In the gain department, the array models

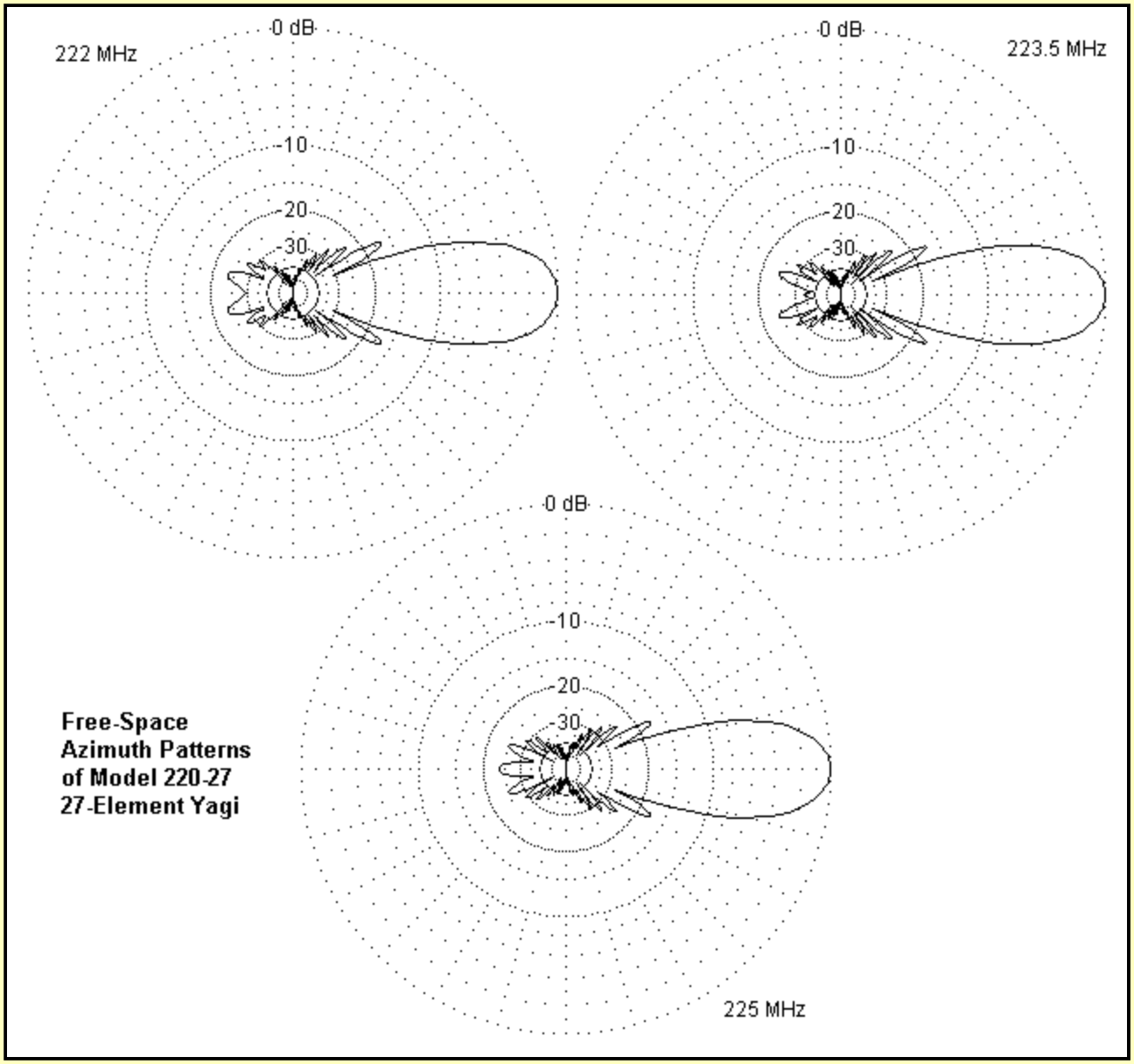
at values one might expect from a DJ6WU 24-element Yagi. However, the DJ9BV excels in two other categories. First, the front-to-back ratio is superior to that of the standard Yagi of the same length and number of elements. Second, the feedpoint impedance is more stable across the entire band than even the DL6WU arrays. Whether these two improvements justify the added mechanical work of installing a 4-reflector system depends largely on the potential user's operating needs.

Model 220-27 Dimensions (in inches): Element Diameter 0.25"

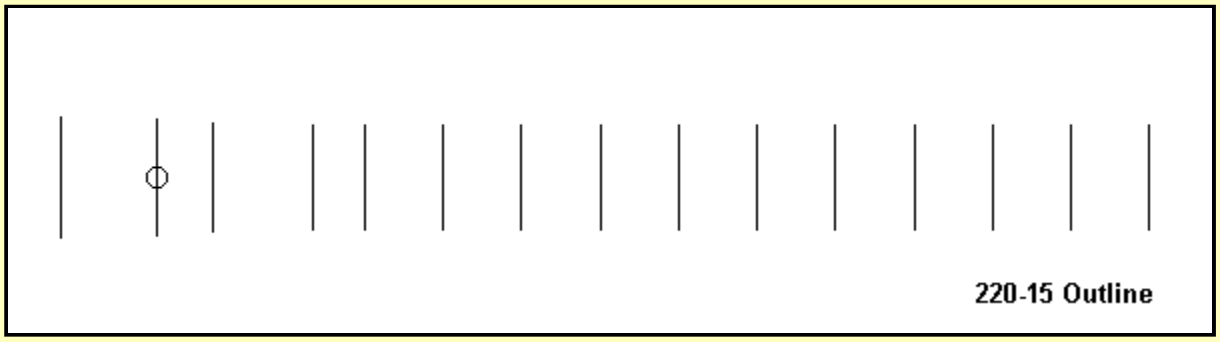
Element	Length/Height	Space from Reflector
Reflector 1	25.99/17.20	----
Reflector 2	25.99/ 5.73	----
Reflector 3	25.99/-5.73	----
Reflector 4	25.99/-17.20	----
Driver	25.00	10.61
Director 1	23.47	14.58
Director 2	23.01	24.14
Director 3	22.63	35.54
Director 4	22.47	48.80
Director 5	22.32	63.66
Director 6	22.09	79.56
Director 7	21.86	96.27
Director 8	21.55	113.78
Director 9	21.55	132.08
Director 10	21.55	151.18
Director 11	21.25	171.06
Director 12	21.25	191.76
Director 13	21.25	212.97
Director 14	21.02	234.19
Director 15	21.02	255.40
Director 16	21.02	276.62
Director 17	20.79	297.84
Director 18	20.79	319.06
Director 19	20.79	340.28
Director 20	20.64	361.50
Director 21	20.64	382.72
Director 22	20.64	403.93

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	18.12	18.39	18.62
180-deg F-B	29.28	34.05	23.78
-3dB Beamwidth	24.2	23.6	23.0
Impedance (R+/-jX)	47.4 - j 2.6	51.0 - j 4.6	45.8 - j 7.8
50-Ohm SWR	1.08	1.10	1.20



220-15: A 15-Element Yagi



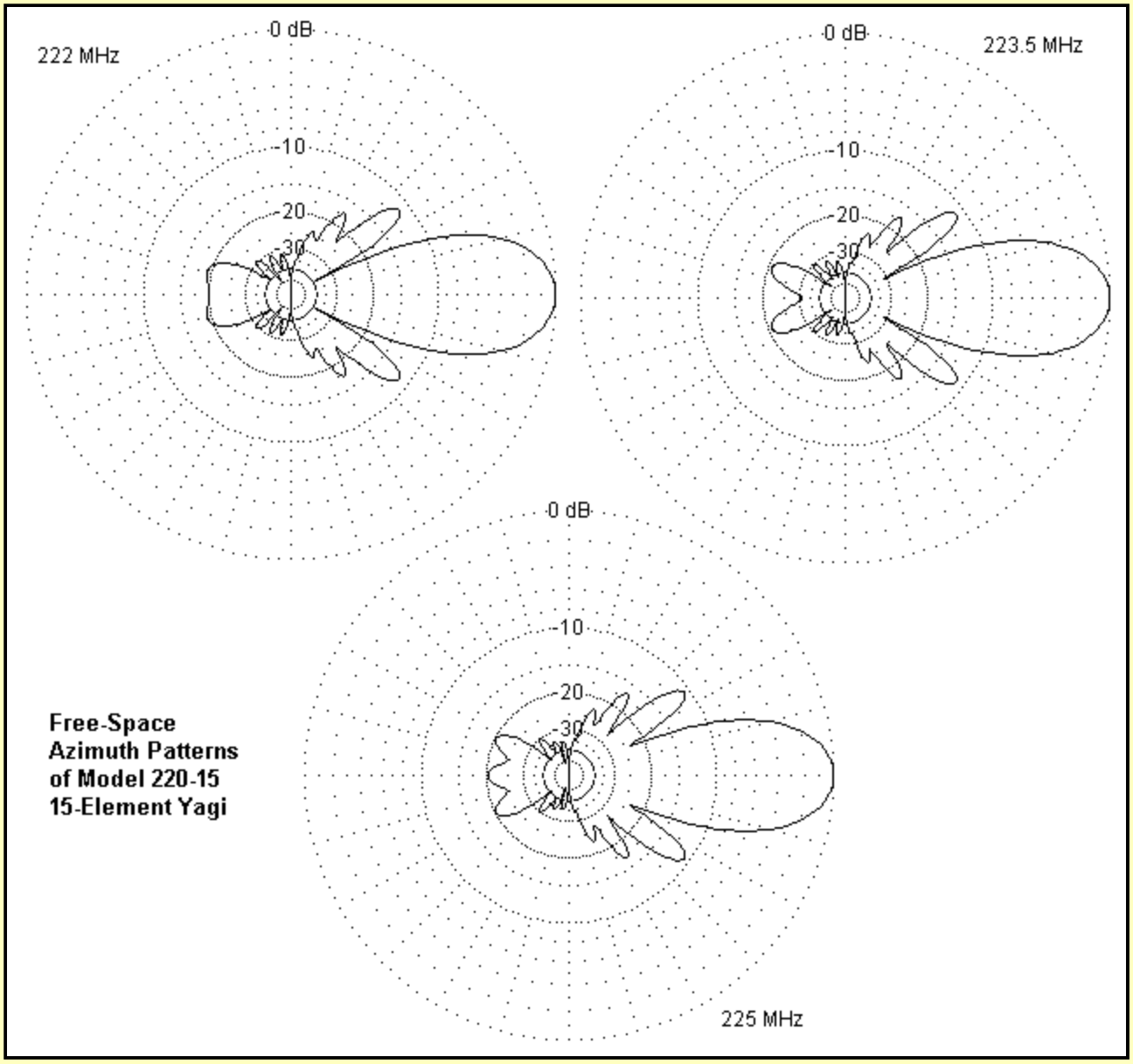
The following 15-element Yagi design is only for comparative purposes with the array to follow. It places 15 3/16" elements on a boom nearly 18' long. The key design property being tested is the use of directors of equal lengths from the second director forward to the last. The reflector, driver, and first director have been set for a 50-Ohm match at the feedpoint across the band. The result of this experiment is a beam with gain slightly below that of the DL6WU 14-element Yagi explored in Part 2, even though the boom is 20" longer for the present design. The purpose in using uniform-length directors for almost all of them is to simplify construction for the newer builder. If that goal is worthy in any given situation, then the 1/4 dB loss in gain may be acceptable.

Model 220-15 Dimensions (in inches): Element Diameter 0.1875"

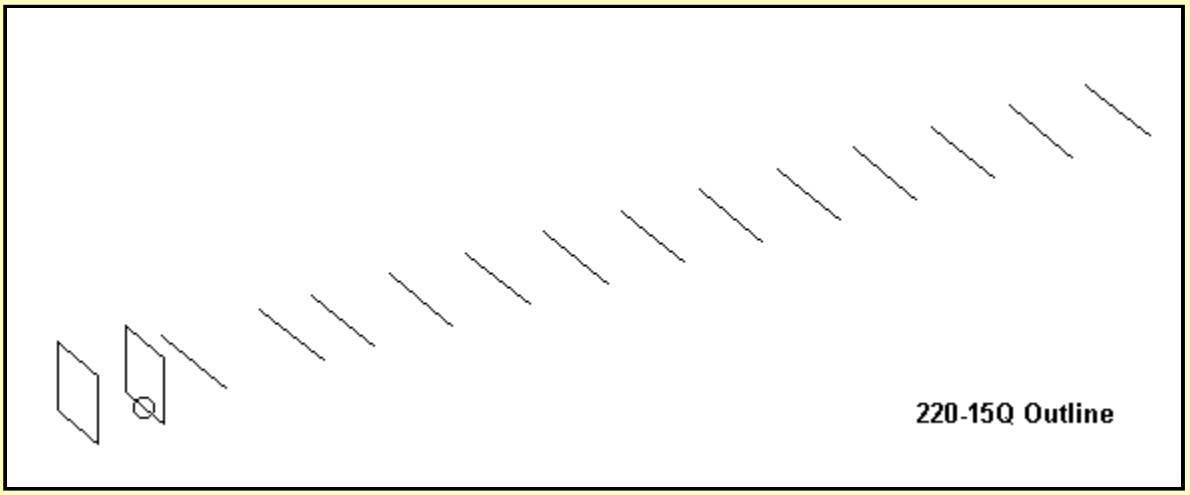
Element	Length	Space from Reflector
Reflector	26.00	----
Driver	24.44	19.33
Director 1	22.80	30.74
Director 2	22.11	50.75
Director 3	22.11	61.32
Director 4	22.11	77.07
Director 5	22.11	92.87
Director 6	22.11	108.87
Director 7	22.11	124.73
Director 8	22.11	140.38
Director 9	22.11	156.17
Director 10	22.11	171.97
Director 11	22.11	187.77
Director 12	22.11	203.62
Director 13	22.11	219.36

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	14.47	14.76	14.90
180-deg F-B	20.17	30.76	20.37
-3dB Beamwidth	28.6	27.4	26.2
Impedance (R+/-jX)	45.7 - j 13.2	41.2 - j 5.8	37.2 + j 5.9
50-Ohm SWR	1.34	1.26	1.39



220-15Q: A 15-Element Quagi



Bill Buchanan, WB4WEN, sent me the design of the array from which the above Yagi was derived. It is a design expressly for 220: a 15 element quagi, as shown in the outline sketch. It has all of the features of the Yagi that I generated for purposes of comparison, except that the driver and the reflector are quad elements. In many cases, quagis show no better performance than comparable Yagis, but in this special case, it does. Remember that directors 2 through 13 are all the same

length for construction simplicity. The design shows better than 1 dB gain over the Yagi of the same design, with a few inches saved on the boom, since the quagi reflector and driver can be closer spaced for the 50-Ohm feedpoint match. The gain of the array falls directly between the values for the 14-element and the 16-element DL6WU designs, and the boom length is also between the two. What the uniform elements may give up in maximum gain is restored by the use of quad elements for the driver and reflector.

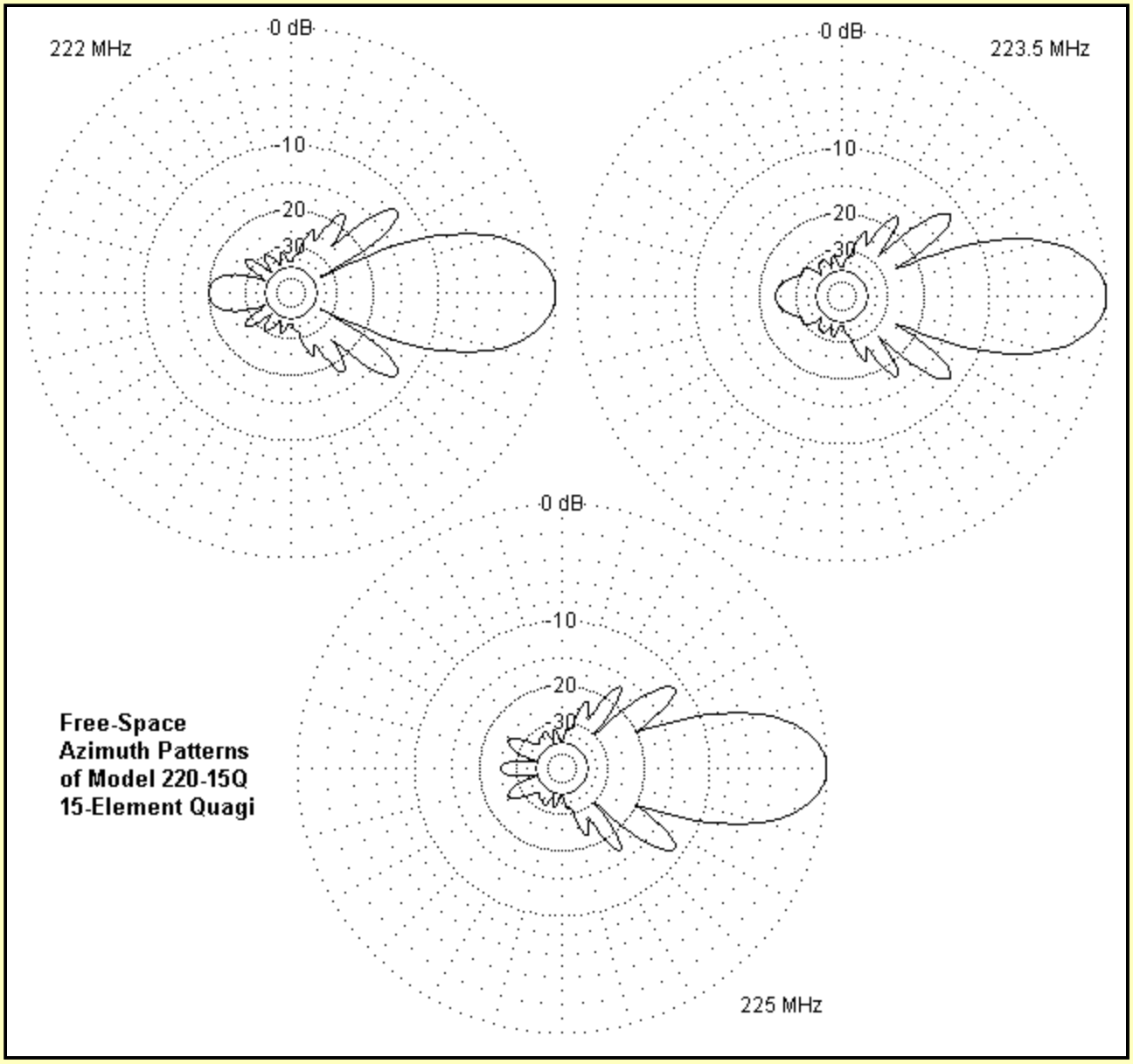
Model 220-15Q Dimensions (in inches): Element Diameter 0.1875"

Note: Reflector and Driver dual numbers represent the length of a quad element side and the circumference of the element.

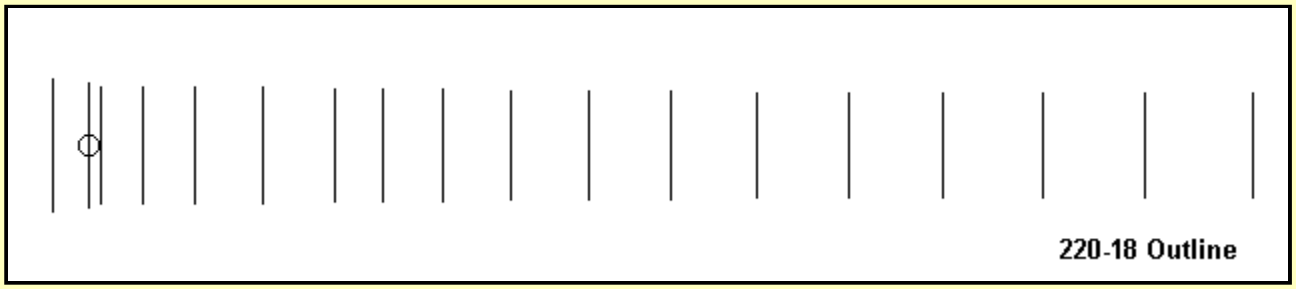
Element	Length	Space from Reflector
Reflector	14.53/58.14	----
Driver	14.00/55.99	13.63
Director 1	22.79	23.60
Director 2	22.11	43.60
Director 3	22.11	54.18
Director 4	22.11	69.93
Director 5	22.11	85.72
Director 6	22.11	101.58
Director 7	22.11	117.37
Director 8	22.11	133.28
Director 9	22.11	149.02
Director 10	22.11	164.82
Director 11	22.11	180.61
Director 12	22.11	196.46
Director 13	22.11	212.20

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	15.82	15.99	16.05
180-deg F-B	20.01	23.63	24.93
-3dB Beamwidth	28.2	27.2	26.2
Impedance (R+/-jX)	61.7 - j 20.1	53.9 - j 9.0	43.6 + j 9.8
50-Ohm SWR	1.51	1.21	1.28



220-18: 18-Element Yagis With 0.1875" and 0.25" Diameter Elements



If you examine the arrays in Parts 2 and 3 (and in this part so far), you will discover that there are secondary forward lobes of considerable proportions. They range in strength from 11 to 17 dB below the level of the main lobe, depending upon Yagi design. In general, the higher the overall gain, the larger the secondary lobes relative to the main lobe. As well, various design variants may suffer higher strength secondary forward lobes as the cost of working toward other goals. The 15-element quagi (and the comparative Yagi) are cases in point. In addition, in many designs, the feedpoint impedance drifts from optimal for a 50-Ohm feed cable as the challenge of gain yields beams with narrow operating bandwidths. The design that we shall present here is the result of a study in striving toward two goals at the expense of gain. One technique of obtaining a wide operating bandwidth is to employ OWA principles around the driver end of the array. A technique of reducing the strength of the secondary lobes is to use enough elements for a given boom length.

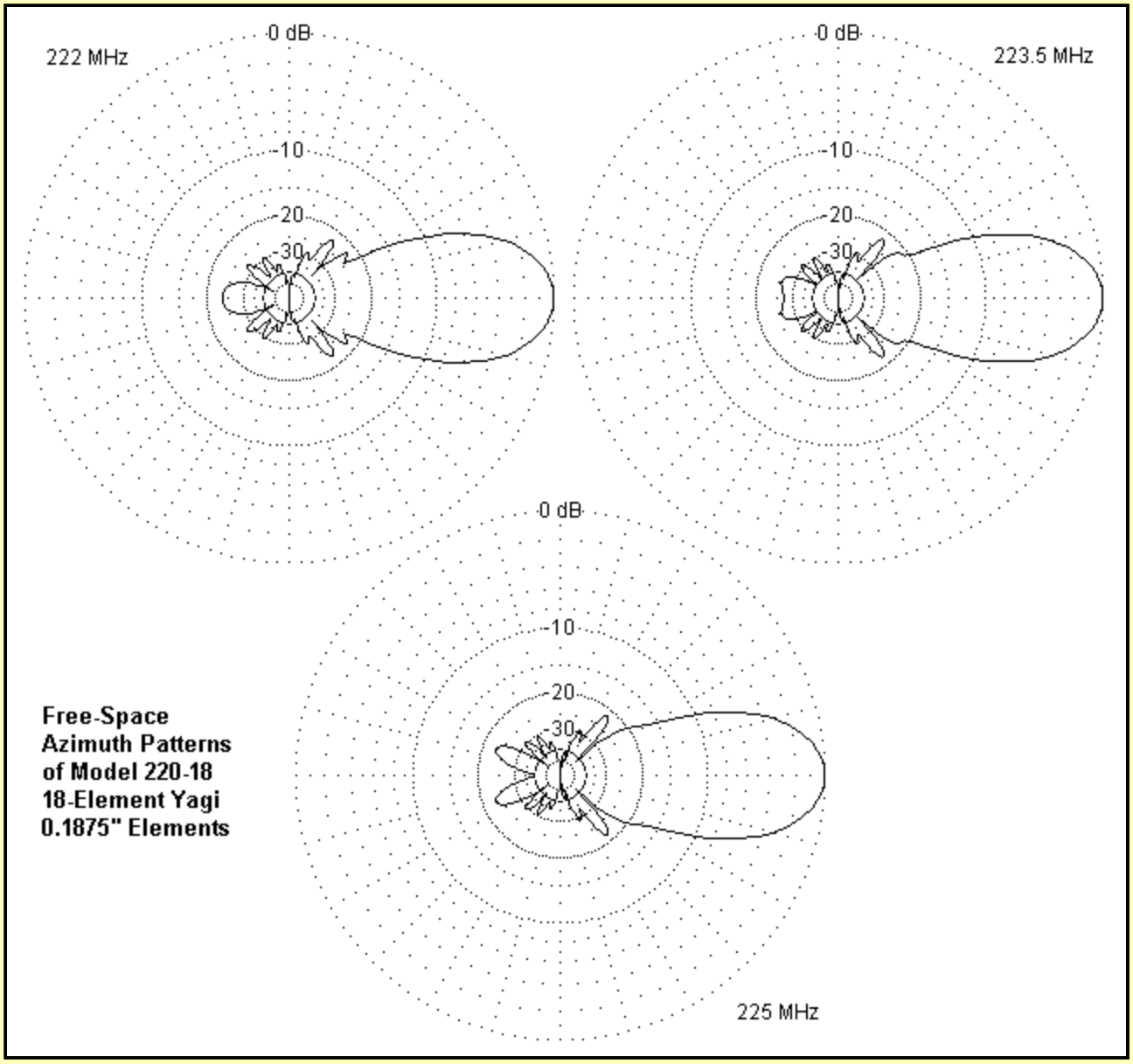
The following 2 Yagis differ only in their element size (3/16" and 1/4"), but that occasions small changes in element length and spacing. Nonetheless, they both use 18 elements on a 19' boom. Their performance is comparable, with the larger-diameter elements producing a modicum more gain. However, in both cases, the 50-Ohm SWR is less than 1.2:1 across the band. As well, the secondary forward lobes are always more than 21 dB below the main forward lobe. The suppression of secondary lobes also shows up in the beamwidth of the main lobe. Note that the main lobe is wider than the main lobe of the 15-element quagi and Yagi, despite their comparable gains and boom lengths. The two 18-element designs achieve in gain almost what one might expect from the a 15-element DL6WU Yagi on a boom of similar length to these arrays. Thus, the cost of better control is not so much gain as it is the need for 3 extra elements. The performance charts and the pattern displays--when compared to those for other arrays in this collection--are sufficient demonstration of the control obtained by the 18-element OWA Yagis.

Model 220-18 Dimensions (in inches): Element Diameter 0.1875"

Element	Length	Space from Reflector
Reflector	26.67	----
Driver	25.30	6.58
Director 1	23.79	9.19
Director 2	23.34	16.70
Director 3	23.34	26.83
Director 4	23.21	40.11
Director 5	22.82	53.61
Director 6	22.64	63.06
Director 7	22.36	74.35
Director 8	22.11	87.47
Director 9	21.88	102.18
Director 10	21.67	117.92
Director 11	21.50	134.46
Director 12	21.35	151.79
Director 13	21.21	169.90
Director 14	21.09	188.80
Director 15	20.99	208.48
Director 16	20.89	228.96

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	15.98	16.04	16.00
180-deg F-B	23.47	26.94	39.63
-3dB Beamwidth	30.4	29.8	29.4
Impedance (R+/-jX)	42.7 - j 4.2	45.9 + j 1.9	58.6 + j 4.7
50-Ohm SWR	1.20	1.10	1.20



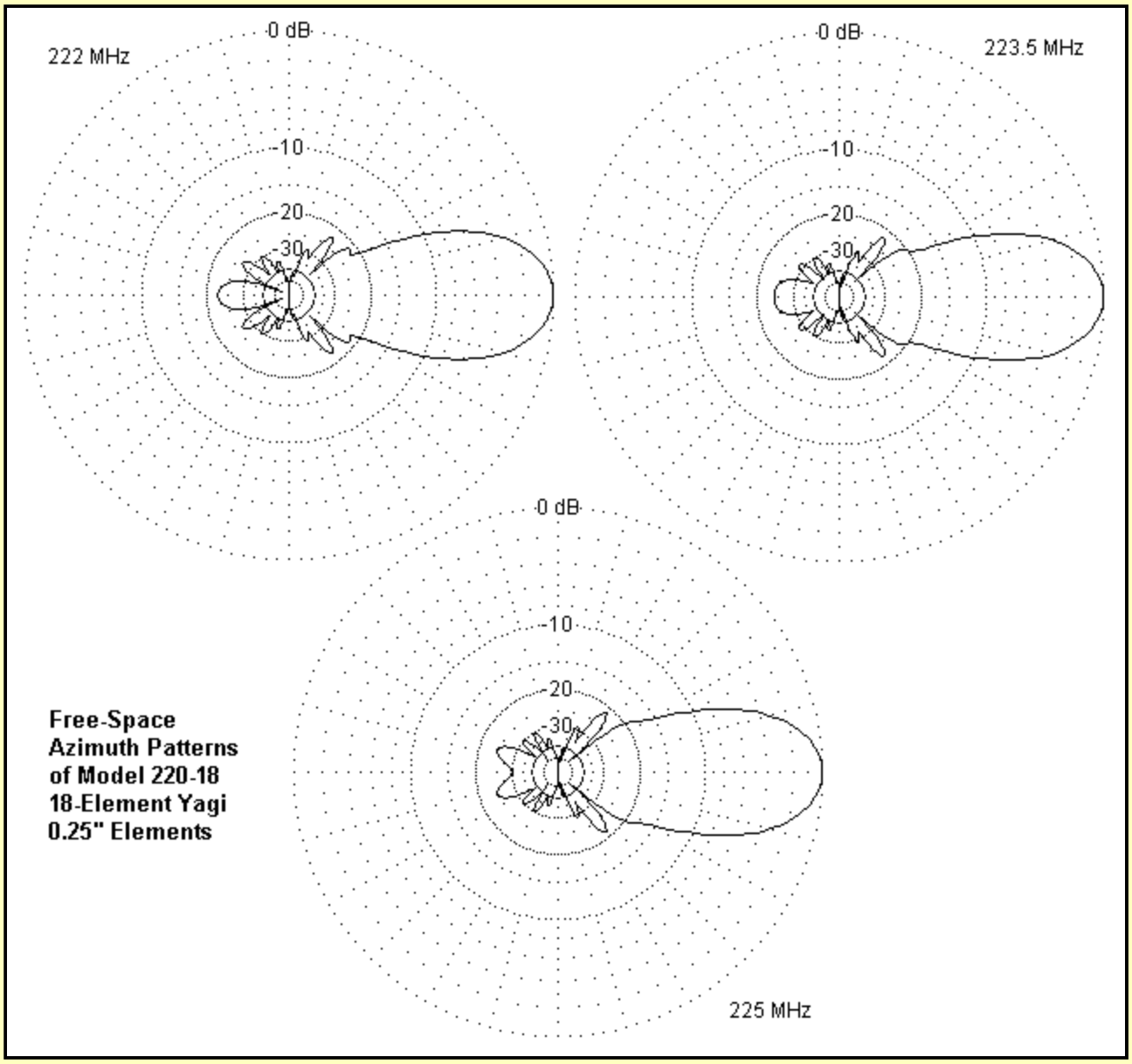
Model 220-18 Dimensions (in inches): Element Diameter 0.25"

Element	Length	Space from Reflector
Reflector	26.40	----
Driver	25.23	6.52
Director 1	23.56	9.10
Director 2	23.11	16.80
Director 3	23.11	26.57
Director 4	22.98	39.72
Director 5	22.59	53.08
Director 6	22.41	62.45
Director 7	22.14	73.62
Director 8	21.89	86.61
Director 9	21.66	101.18
Director 10	21.46	116.77
Director 11	21.29	133.14
Director 12	21.14	150.31
Director 13	21.01	168.24
Director 14	20.89	186.95
Director 15	20.78	206.45
Director 16	20.69	226.72

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	16.04	16.08	16.03
180-deg F-B	22.47	23.87	29.85

-3dB Beamwidth	30.0	29.6	29.2
Impedance (R+/-jX)	42.1 - j 2.6	43.6 + j 2.8	53.5 + j 8.6
50-Ohm SWR	1.20	1.16	1.20



These two versions of the 18-element Yagi give you a chance to choose your favored element material: 3/16" rod or perhaps lighter 1/4" tubing. However, they should not be considered to be the most fully optimized designs possible either in their boom length category or in the degree of pattern and impedance control. Improvements are always possible.

Similar comments apply to all of the Yagis in this collection. The survey of designs is mostly an idea base. More design possibilities exist in various publications and books devoted to VHF and UHF operation. Indeed, ARRL's brand new publication, *Yagi Antenna Classics*, has a beam for 220 that I will someday check out.

In the meantime, I hope that this collection of designs for the 223-225 MHz region provides enough data to satisfy one's curiosity about the sorts of things that are possible. Then you can invent some new possibilities.

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