A Collection of 220-MHz Yagi Designs: Part 2: Medium-Length Boom Beams: Boom Lengths from 140" to 220" and from 12 to 14 Elements

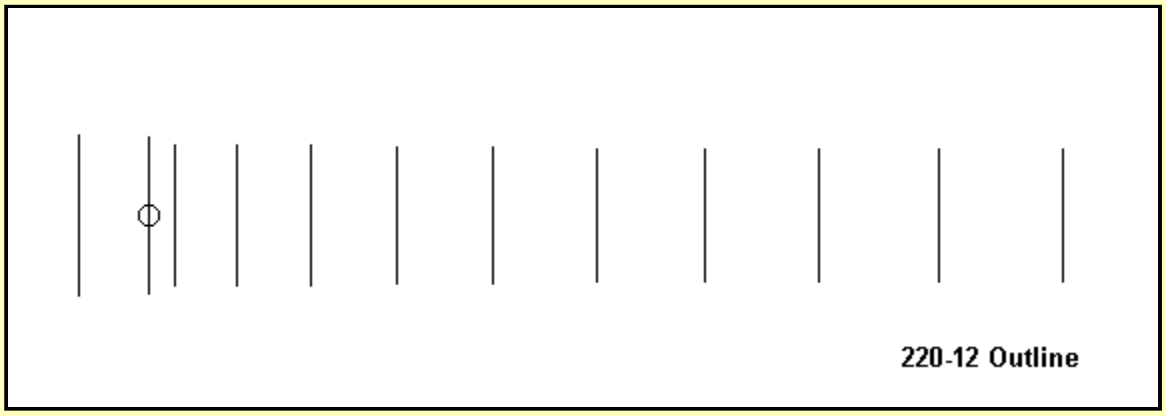
L. B. Cebik, W4RNL (SK)

The second collection of 222-225 MHz Yagis consists of arrays with 12 to 14 elements. The boom lengths vary from 12' to about 18' overall, which is beginning to get into the territory of serious operation on the band. We call them "medium length" booms, because we shall look at a few serious booms in the next section. But for the moment, the medium-size Yagi will be interesting to explore.

As we did in the first collection of utility beams, 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 point to the 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.

220-12: A 12-Element Yagi



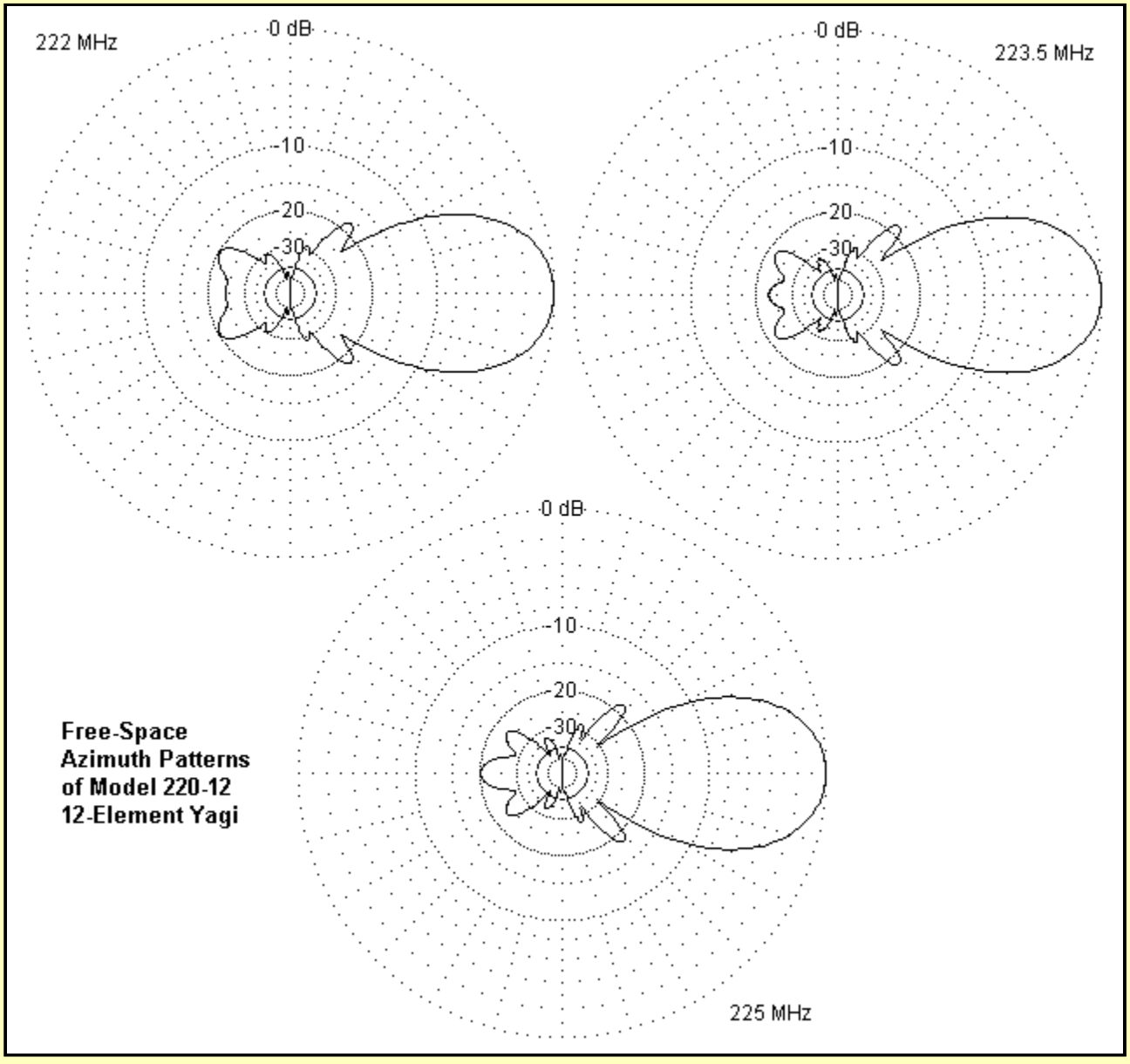
The first Yagi in the new group is the shortest, a 12-element array that fits on a 147.5" boom--just over 12'. It is another derivative from a DL6WU 432-MHz design and uses 1/4" elements. Like all the beams in the Guenter Hoch series, it is broad-banded, which gives the scaler a choice of where in the operating range to place the 223-225 MHz range. Hence, the dimensions are not as constant in the series of beams derived from the 432-MHz design as they would be in the original. Because the beams are broad-band arrays, they do not squeeze out of a given boom length and number of elements all of the gain that is possible. However, they tend to be reliably replicated.

Model 220-12 Dimensions (in inches): Element Diameter 0.25"

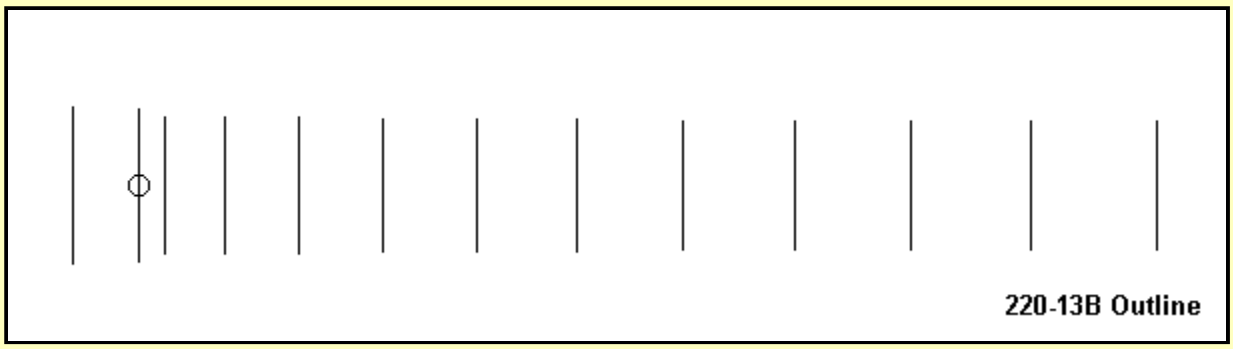
Element	Length	Space from Reflector
Reflector	25.40	----
Driver	24.61	10.35
Director 1	22.49	14.23
Director 2	22.31	23.55
Director 3	22.04	34.67
Director 4	21.79	47.60
Director 5	21.56	62.10
Director 6	21.36	77.62
Director 7	21.19	93.92
Director 8	21.04	111.00
Director 9	20.91	128.85
Director 10	20.79	147.48

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	13.87	14.11	14.32
180-deg F-B	24.05	22.96	20.08
-3dB Beamwidth	38.2	37.2	36.4
Impedance (R+/-jX)	47.4 - j 5.0	51.9 - j 0.7	57.7 + j 1.8
50-Ohm SWR	1.12	1.04	1.16



220-13B: A 13-Element Yagi



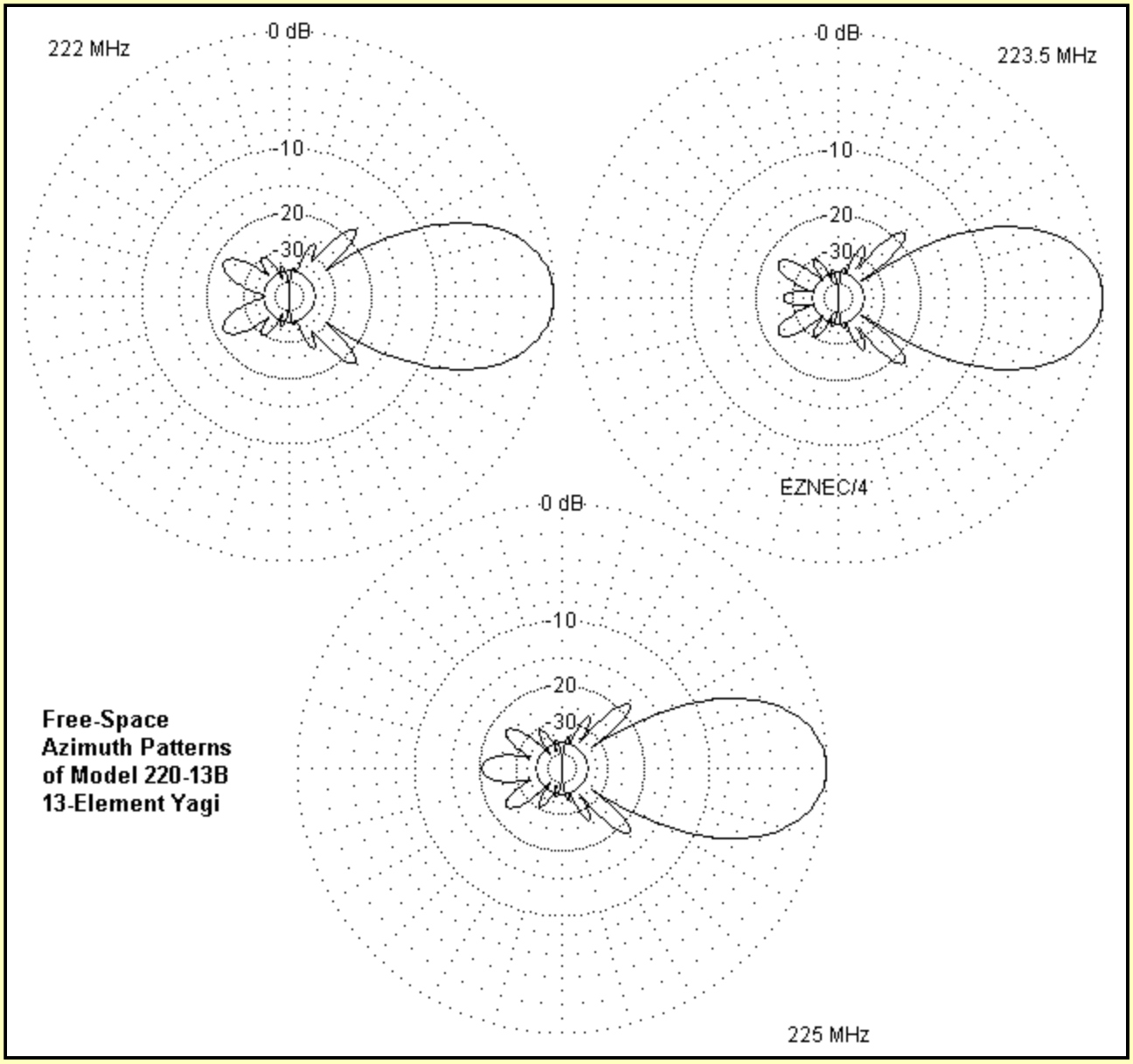
Model 220-13B is also a DL6WU derivative using 1/4" diameter elements. Theoretically, it ought to have the same dimensions except for the additional director. However, as noted, adjustments have been made to the dimensions to align the performance figures. Hence, the dimension chart below will vary a bit from the one for the 12-element version of the array. Of added interest is the fact that as we add more elements, the number of secondary forward and rearward side lobes increases. Although still over 15 dB down from the main forward lobe, they are a noticeable features of almost all long-boom Yagis. The 13th element extends the boom length to nearly 170" but yield about 0.8 dB more gain than the 12-element Yagi.

Model 220-13B Dimensions (in inches): Element Diameter 0.25"

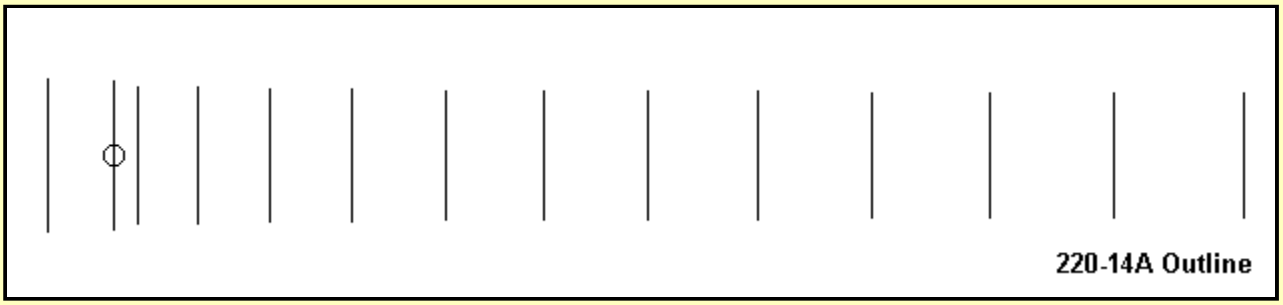
Element	Length	Space from Reflector
Reflector	25.80	----
Driver	25.00	10.52
Director 1	22.85	14.46
Director 2	22.67	23.92
Director 3	22.39	35.23
Director 4	22.14	48.36
Director 5	21.91	63.09
Director 6	21.70	78.86
Director 7	21.53	95.42
Director 8	21.38	112.77
Director 9	21.24	130.91
Director 10	21.12	149.83
Director 11	21.02	169.55

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	14.72	14.95	15.13
180-deg F-B	39.67	27.18	20.59
-3dB Beamwidth	34.8	34.0	33.2
Impedance (R+/-jX)	50.4 + j 1.4	55.7 + j 6.6	63.9 + j 7.8
50-Ohm SWR	1.03	1.18	1.32



220-14A: A 14-Element Yagi



Let's complete this sequence of DL6WU design with a 14-element version of the Yagi on a 191" (nearly 16') boom. The set of patterns will show the beam's lineage, since the side lobes are nearly identically placed for all three of these medium boom-length Yagis. Again, we shall use quarter-inch elements. However, we shall not this time gather an extra 0.8 dB gain. The gain boost is closer to about 0.4 dB over the 13- element array. As well, the dimensions will not coincide with either of the preceding designs due to the need for adjustments in the move from 432 to 223.5 MHz as the design frequency and in the imperfect scaling of 4 mm elements to 1/4" elements.

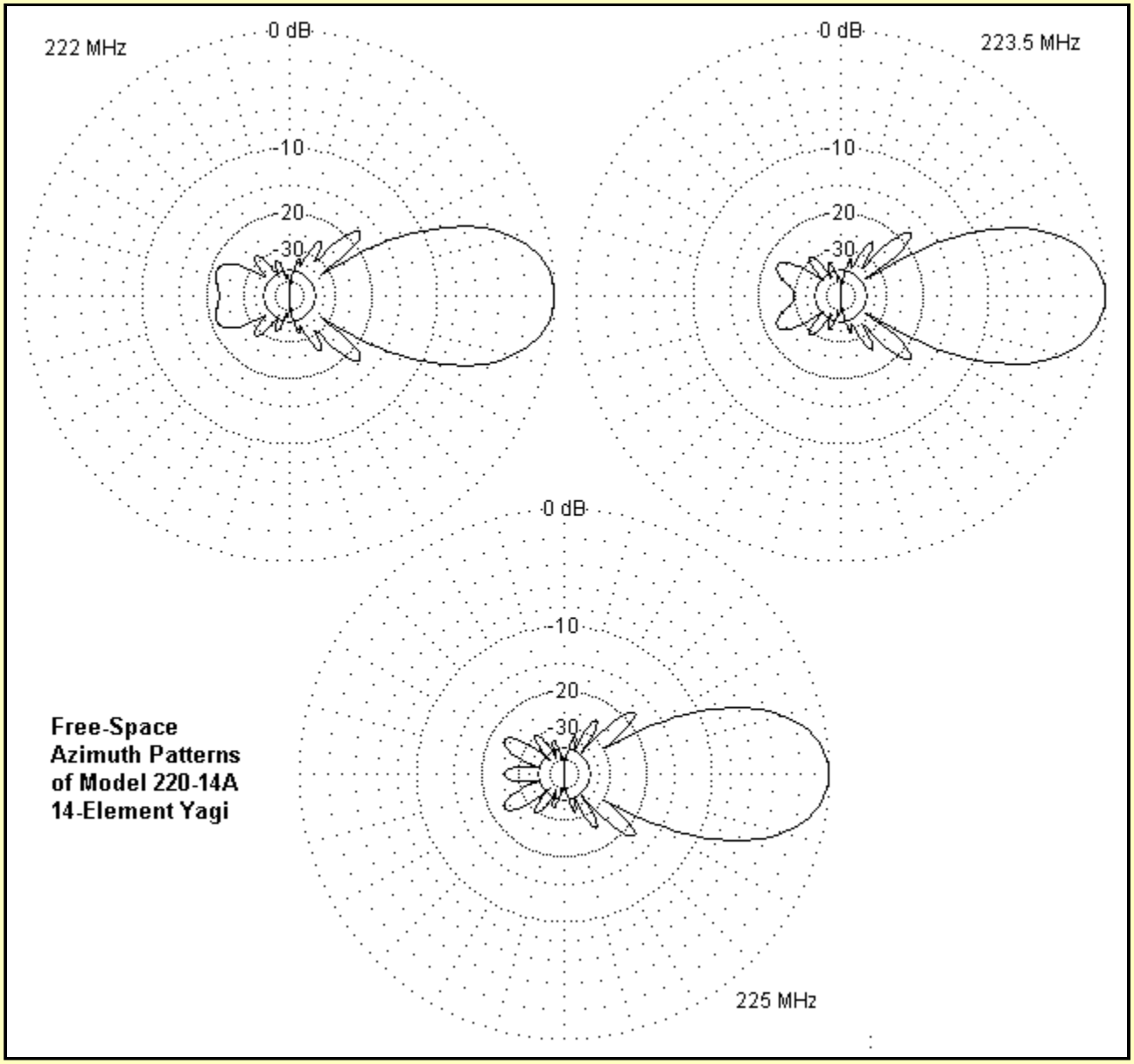
Model 220-14A Dimensions (in inches): Element Diameter 0.25"

Element	Length	Space from Reflector

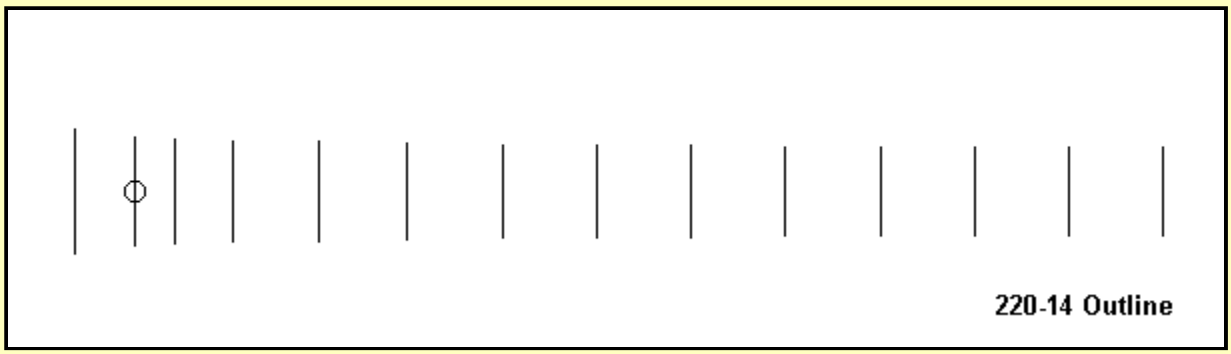
Reflector	25.92	----
Driver	25.11	10.56
Director 1	22.95	14.52
Director 2	22.77	24.03
Director 3	22.49	35.39
Director 4	22.24	48.58
Director 5	22.01	63.37
Director 6	21.79	79.21
Director 7	21.63	95.85
Director 8	21.47	113.28
Director 9	21.34	131.50
Director 10	21.22	150.51
Director 11	21.11	170.31
Director 12	21.00	190.91

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	15.16	15.41	15.63
180-deg F-B	22.61	29.71	25.64
-3dB Beamwidth	33.0	32.4	31.4
Impedance (R+/-jX)	48.7 - j 1.6	50.8 + j 6.0	58.1 + j 12.5
50-Ohm SWR	1.04	1.13	1.32



220-14: A 14-Element Yagi



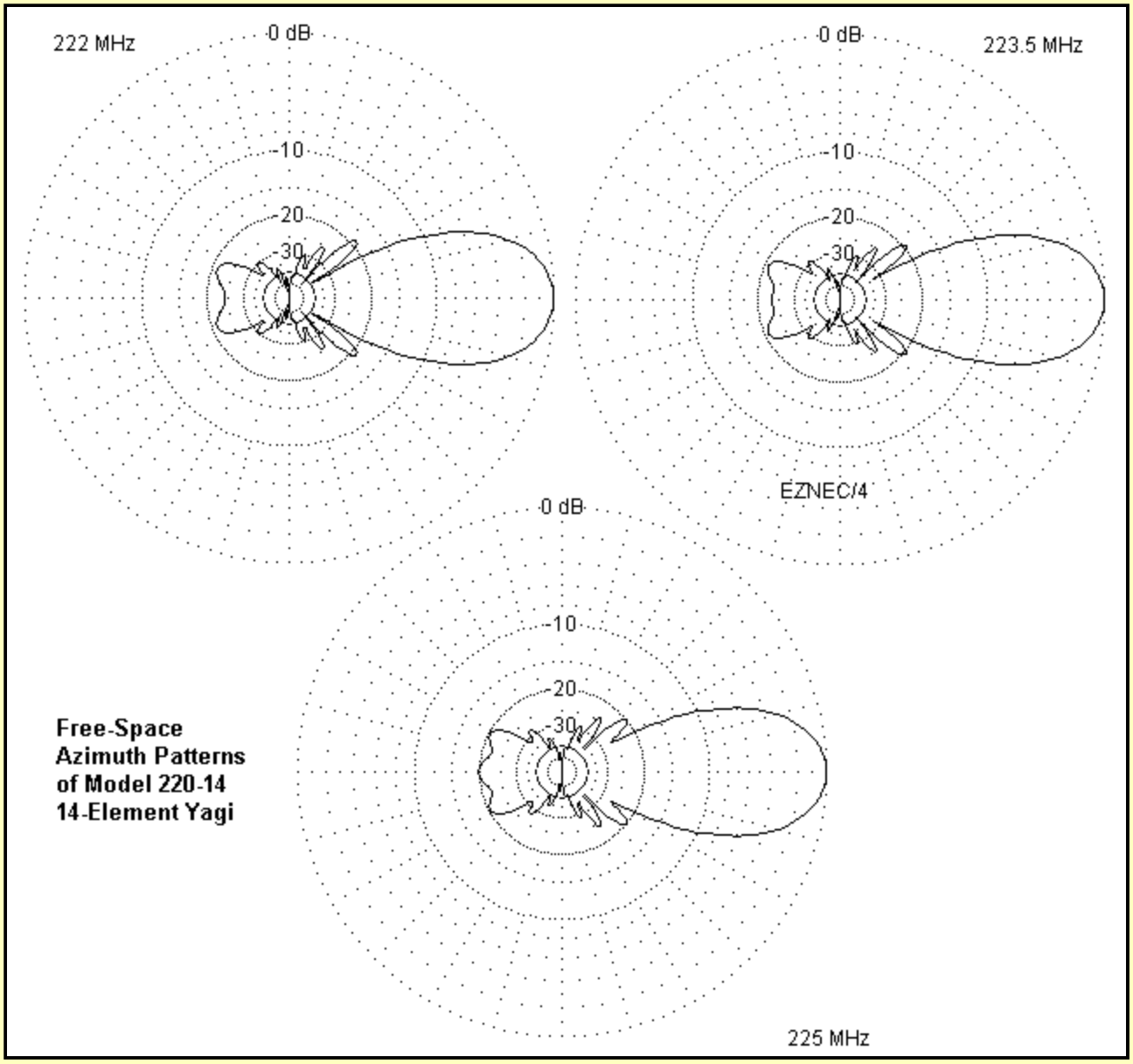
The last of our broad-band scaled Yagis is an interesting, but largely impractical design from some 432-MHz studies. The key question that I was looking at concerned the effects of element diameter on both bandwidth and gain. In scaling the study array for 220, the element diameter increased to a full inch. Increasing the element diameter has-- to a certain point--a positive effect on array gain, but it is easy to reach a point where elements are over-coupled unless we increase their spacing. Therefore, this array uses a 18' boom--and extra 2' of boom to achieve about a half dB gain over the DL6WU-derived 14-element array. A 15-element Dl6WU array using thinner elements would end up with close to the same boom length. Hence, we must consider this design as simply an object of study rather than as a candidate for construction.

Model 220-14 Dimensions (in inches): Element Diameter 1.0"

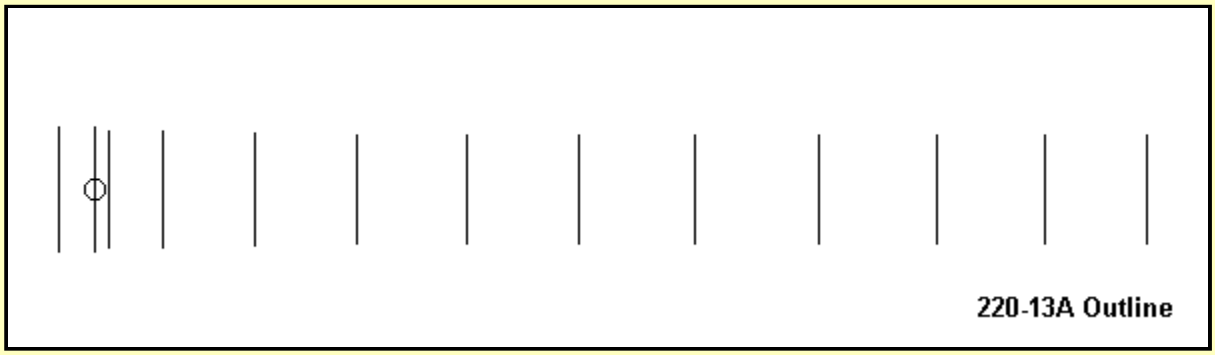
Element	Length	Space from Reflector
Reflector	26.00	----
Driver	23.00	12.18
Director 1	22.12	19.90
Director 2	21.23	31.63
Director 3	21.23	48.86
Director 4	20.34	66.53
Director 5	19.75	85.39
Director 6	19.50	104.25
Director 7	19.26	123.10
Director 8	19.07	141.96
Director 9	18.95	160.82
Director 10	18.77	179.69
Director 11	18.53	198.54
Director 12	18.38	217.39

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	15.80	15.92	15.97
180-deg F-B	24.28	23.31	19.86
-3dB Beamwidth	31.6	30.8	30.2
Impedance (R+/-jX)	44.4 - j 3.7	37.1 + j 2.0	43.6 + j 7.0
50-Ohm SWR	1.47	1.35	1.23



220-13A: A 13-Element Yagi



Very often, when designing for a narrower operating bandwidth, one can arrive at a gain value with either a shorter boom or with fewer elements than when designing for broad-band operation. SM5BSZ developed an interesting array that I have scaled to 220 in two stages. This first stage uses 1/8" elements on a 212" boom. The boom length is close to that of the 14-element array we just visited, but there is one fewer element. Yet performance is about the same for the two arrays. Note the last 3 forward directors: they actually increase in length rather than adhering to the constant taper of the array we have looked at so far. Check the element length list for other unexpected changes in the directors. That the array is designed for narrower-band use than some of the other arrays that we have examined is shown in the rate of change of gain, front-to-back,

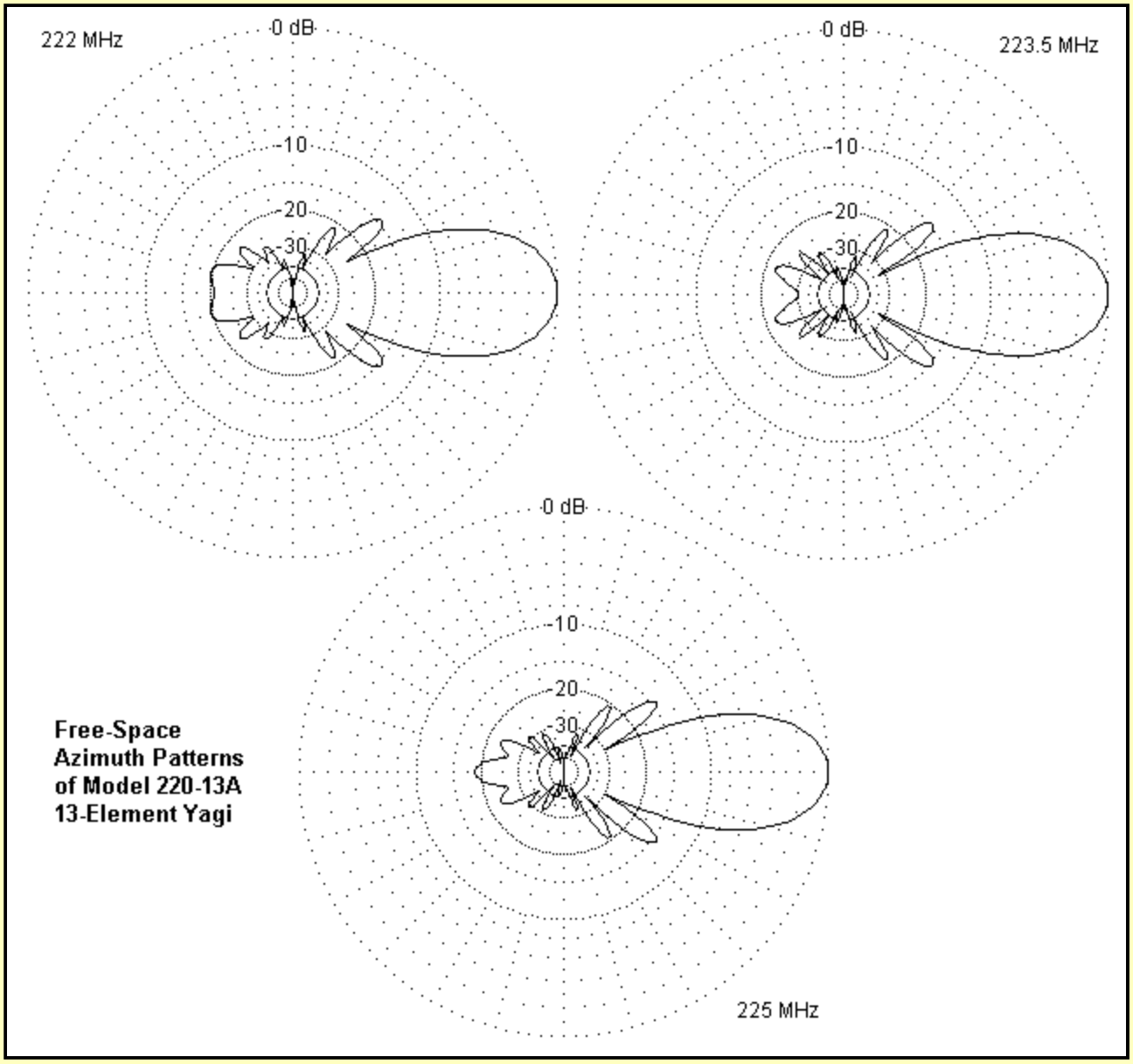
and feedpoint impedance in the chart below. If all we wish to do is save weight relative to the 14-element array above, then this design will do the job. However, as a preview of things to come, we shall take a second look at the design.

Model 220-13A Dimensions (in inches): Element Diameter 0.125"

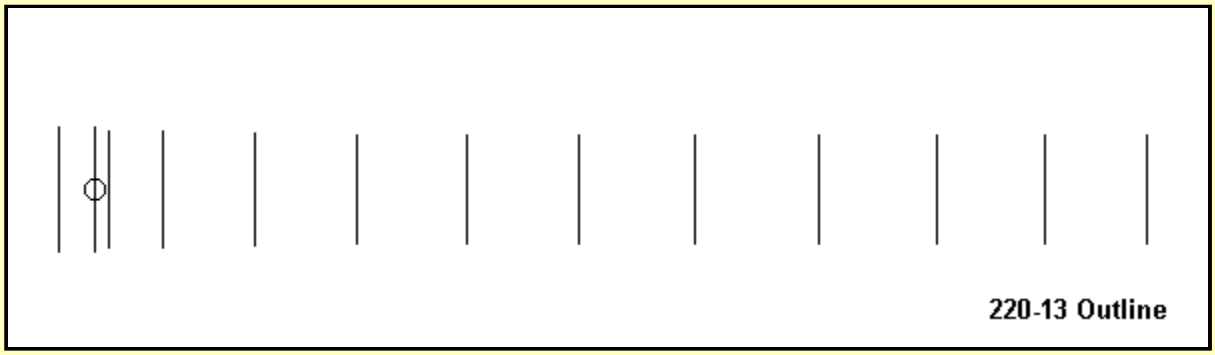
Element	Length	Space from Reflector
Reflector	25.60	----
Driver	25.40	7.29
Director 1	24.00	9.82
Director 2	23.63	20.41
Director 3	22.91	38.18
Director 4	22.46	58.28
Director 5	22.71	79.45
Director 6	22.50	101.40
Director 7	22.23	124.01
Director 8	22.10	147.92
Director 9	22.21	171.06
Director 10	22.46	192.22
Director 11	22.50	212.01

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	15.44	15.92	16.27
180-deg F-B	20.79	30.26	18.69
-3dB Beamwidth	30.2	28.8	27.4
Impedance (R+/-jX)	39.7 + j 3.9	49.0 + j 9.6	63.8 + j 0.1
50-Ohm SWR	1.28	1.22	1.28



220-13: A 13-Element Yagi



The Yagi with which we shall finish this medium-boom-length collection may seem to be identical to the one that we just finished. However, there is a significant set of changes. The driver and the first 4 directors have been increased in diameter--in this scaling, to 0.25". Only one element length has been changed--the driver--in order to bring the impedance curve back into good order. However, the overall performance of the array has improved by about 0.4 dB--a good increase in gain for the small change made in the design. In effect, the wholesale increase of element diameter may not be completely necessary to improve array performance. With the right element lengths, increasing the diameter of only certain key elements can achieve the same goal without requiring that we increase the boom length by the amount we saw required in the Yagi with 1" elements. Moreover,

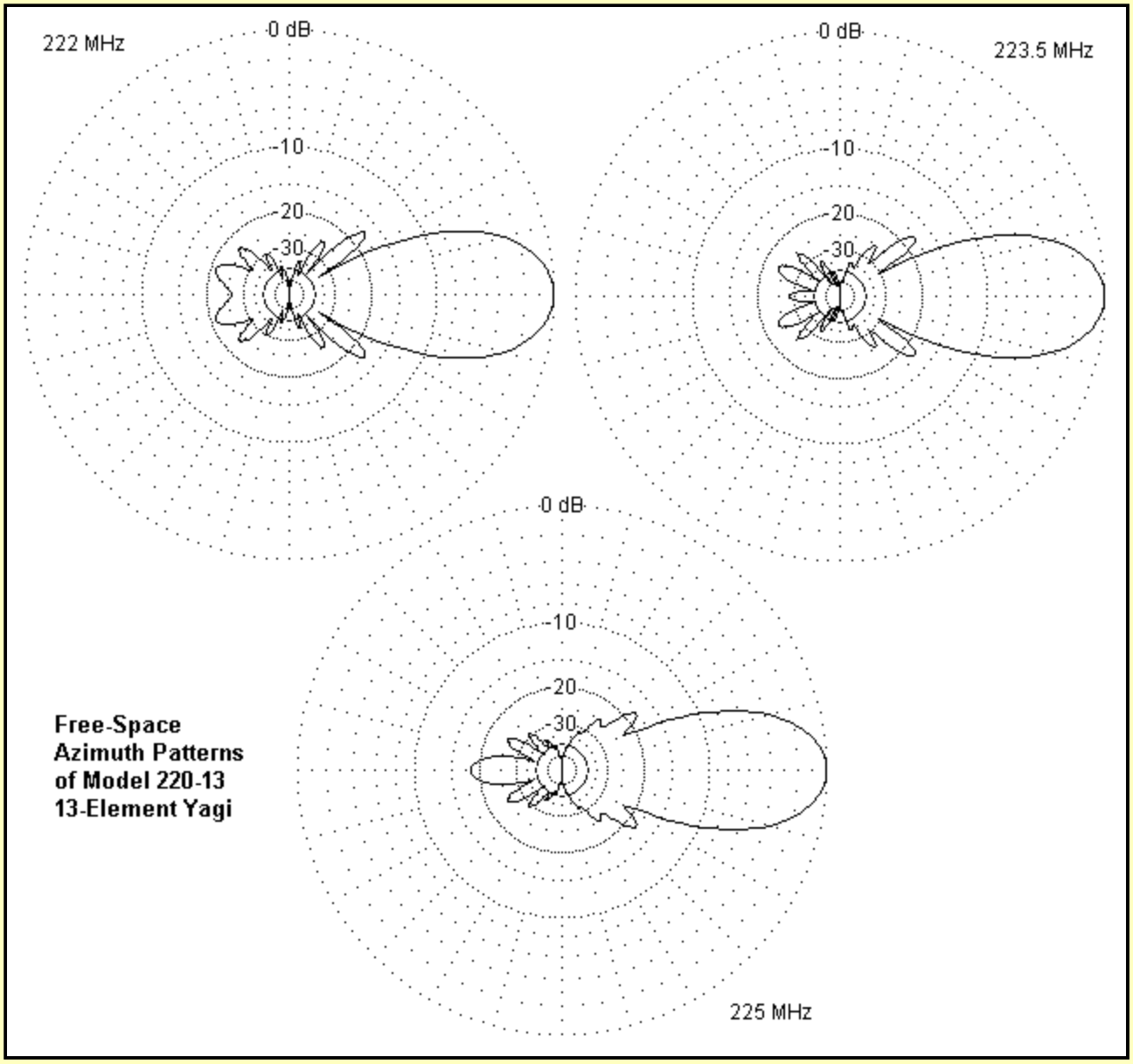
the side lobes in the version using only 0.125" elements are considerably stronger than those in the design version that employs 0.25" elements in key places. Thus, the SM5BSZ design--as scaled and adjusted for 220--holds more than construction interest in the evolution of Yagi design work. (Indeed, SM5BSZ has developed a challenging set of papers on the foundations of Yagi calculations.)

Model 220-13 Dimensions (in inches): Element Diameter 0.125" (* = 0.25")

Element	Length	Space from Reflector
Reflector	25.60	----
Driver	24.79	7.29 *
Director 1	24.00	9.82 *
Director 2	23.63	20.41 *
Director 3	22.91	38.18 *
Director 4	22.46	58.28 *
Director 5	22.71	79.45
Director 6	22.50	101.40
Director 7	22.23	124.01
Director 8	22.10	147.92
Director 9	22.21	171.06
Director 10	22.46	192.22
Director 11	22.50	212.01

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	15.96	16.36	16.55
180-deg F-B	25.98	28.62	18.38
-3dB Beamwidth	30.0	28.8	27.6
Impedance (R+/-jX)	31.6 - j 2.4	46.9 + j 5.7	69.4 - j 0.7
50-Ohm SWR	1.59	1.14	1.39



The SM5BSZ-derived 13-element Yagi completes my collection of medium-boom arrays between 12 and 14 elements on booms from 12' to 18' long. Other designs certainly exist, although they do not happen to be at hand. However, the ones we have examined give a reasonably fair picture of what is possible within the range of boom lengths and element numbers that define the collection. Remember that you can, by judicious optimizing, move the point of maximum gain or any other operating parameter to any point within the 223-225 MHz band to meet special operating needs.

In addition, we have seen a few of the limitations and a few added possibilities beyond those we ordinarily think about when designing Yagis. There are a few more radical possibilities for this range of arrays, but we shall defer them until Part 4 of the collection. In between here and there, namely, in Part 3, we shall take an abbreviated look at some truly long-boom Yagis--up to 60' in boom length. However impractical they may seem, they are worth a look.

Go to Amateur Radio Page