A Collection of 220-MHz Yagi Designs: Part 3: Very Long Yagis: Boom Lengths from 235" to 596" and from 16 to 33 Elements

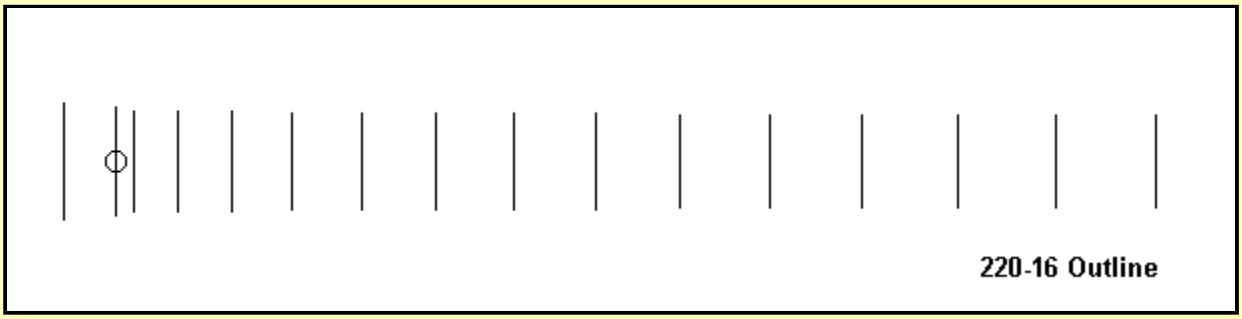
L. B. Cebik, W4RNL (SK)

The third collection of 222-225 MHz Yagis consists of arrays with 16 to 33 elements. The boom lengths vary from 20' to about 50' overall, which is at the high end of the territory of serious operation on the band. These are truly "long-boom" Yagis. Virtually all of them are outside the realm of practical building projects, although there are some HF Yagis with booms of this length. Whatever their practicality, these big Yagis are interesting as designs to study.

As we did in the first and second collections of 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 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.

220-16: A 16-Element Yagi



The first 3 Yagis in out long collection are all DL6WU derivatives. Each one uses 3/8" diameter elements. However, the first one is a variant in its element lengths and spacings. As we have noted, the DL6WU beams are truest in their scaling when the element diameter can be to exact scale with the original. When we change the element diameter to accommodate available materials, the designs are thrown slightly off their ability to be pruned and used without readjustment. The more elements to the array, the truer the design plays despite slight changes in element diameter. However, the shorter versions--like the 20' 16-element design at hand--require the most adjustment. Nevertheless, the array described here shows some very good performance figures--as the chart below the dimensions will attest.

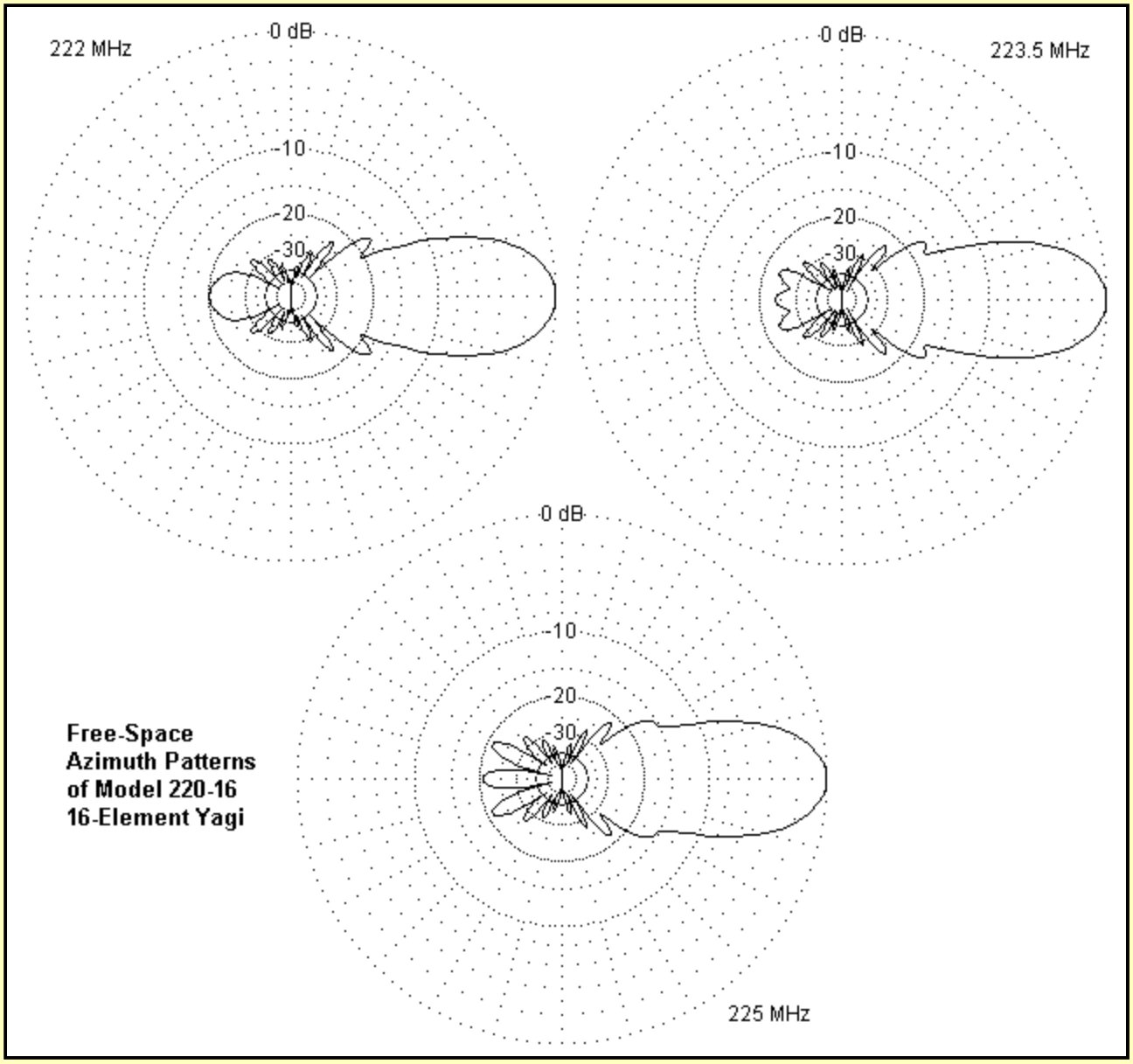
Model 220-16 Dimensions (in inches): Element Diameter 0.375"

Element	Length	Space from Reflector

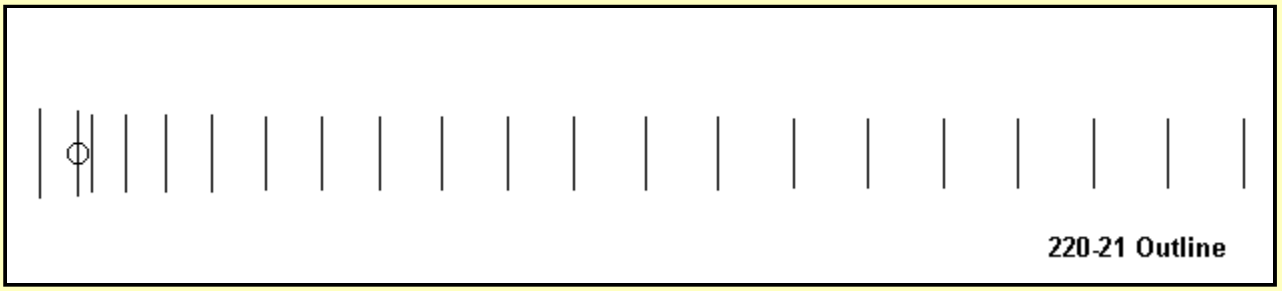
Reflector	26.18	----
Driver	24.97	10.83
Director 1	23.11	14.82
Director 2	22.92	24.39
Director 3	22.65	35.82
Director 4	22.39	49.11
Director 5	22.16	64.00
Director 6	21.94	79.94
Director 7	21.77	96.69
Director 8	21.62	114.24
Director 9	21.48	132.58
Director 10	21.36	151.72
Director 11	21.25	171.65
Director 12	21.14	192.39
Director 13	21.05	213.66
Director 14	20.91	234.92

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	16.52	16.60	16.46
180-deg F-B	20.13	23.70	20.74
-3dB Beamwidth	27.8	27.2	26.6
Impedance (R+/-jX)	41.8 - j 3.0	51.2 + j 8.2	72.6 - j 1.5
50-Ohm SWR	1.21	1.18	1.45



220-21: A 21-Element Yagi



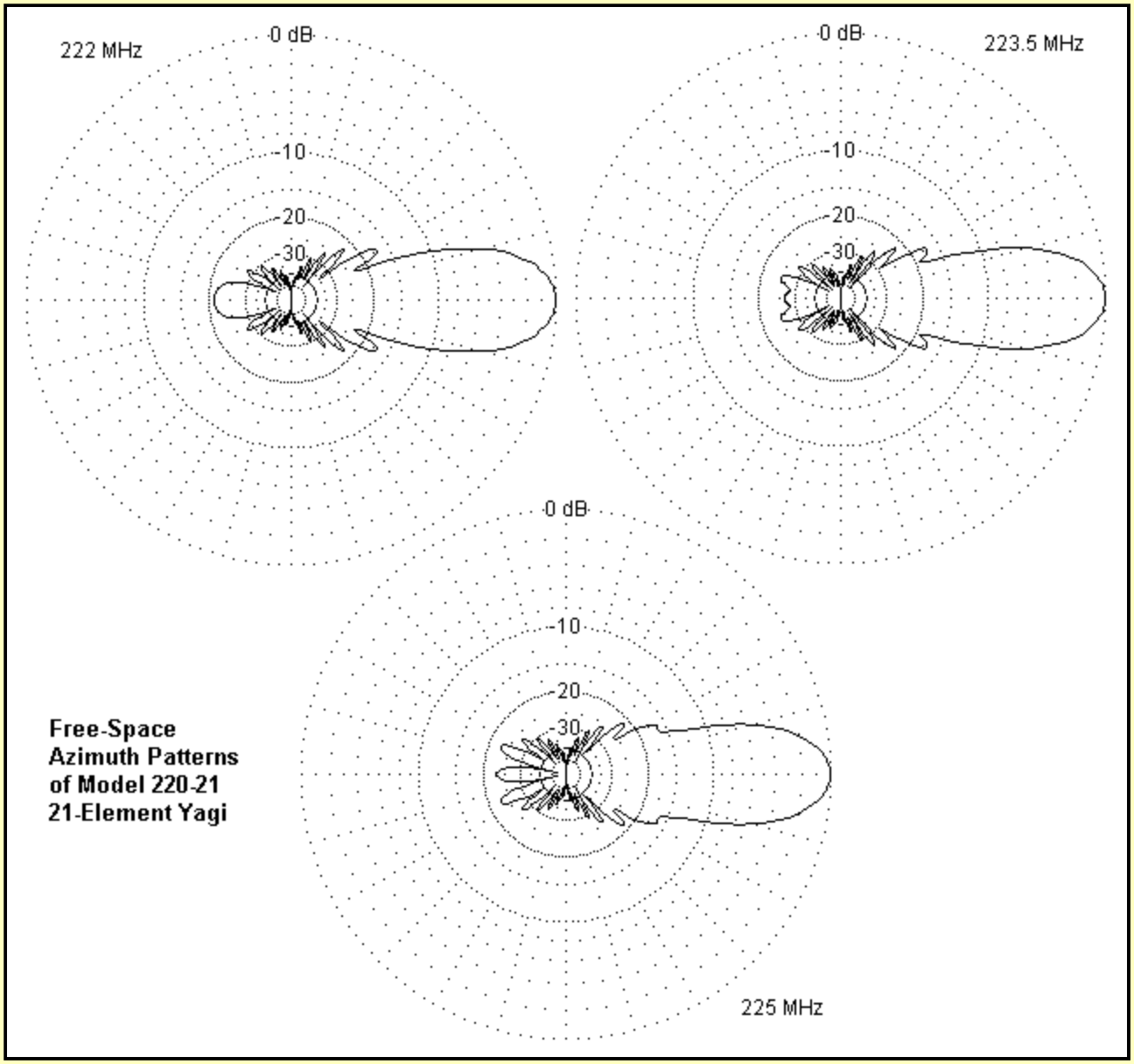
If we add 5 elements to the preceding Yagi design--with a few minor alterations here and there--we can gain nearly 1.5 dB more gain from the resulting array. However, those 5 new elements will occupy about 8 more feet of boom length. A practical 220 EME antenna may require at least 30' of boom. While reviewing this design, it may be worth while to also examine some other progressions--most notably the decrease in beamwidth that accompanies the increases in gain. Consequently, aiming the array moves progressively from the realm of the casual through the area of carefulness and finally into the region of the finicky. A second trend to notice is the strength of the secondary forward lobes. Those lobes, which we called brief attention to in the second section of this collection, continue to increase in strength faster than the main lobe itself. By the time we reach 21 elements, the secondary lobes are down from the main lobe by less than 17 dB.

Model 220-21 Dimensions (in inches): Element Diameter 0.375"

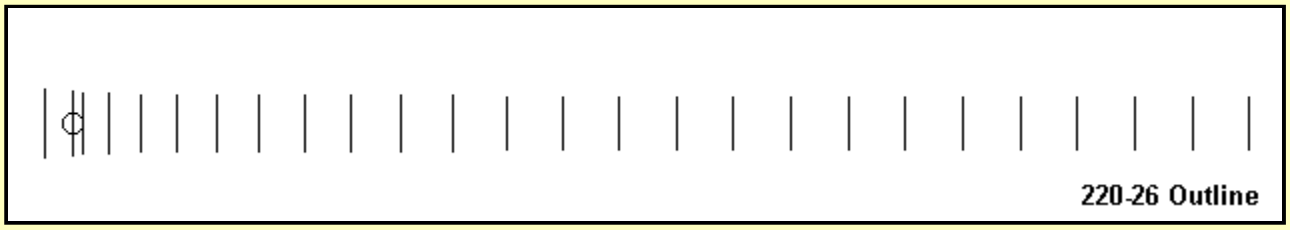
Element	Length	Space from Reflector
Reflector	26.03	----
Driver	25.22	10.61
Director 1	23.05	14.58
Director 2	22.87	24.14
Director 3	22.59	35.54
Director 4	22.33	48.80
Director 5	22.11	63.66
Director 6	21.89	79.56
Director 7	21.72	96.27
Director 8	21.57	113.78
Director 9	21.43	132.08
Director 10	21.31	151.18
Director 11	21.20	171.06
Director 12	21.10	191.76
Director 13	21.00	212.97
Director 14	20.93	234.19
Director 15	20.85	255.40
Director 16	20.78	276.62
Director 17	20.70	297.84
Director 18	20.64	319.06
Director 19	20.58	340.28

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	17.87	17.99	17.90
180-deg F-B	21.17	26.38	22.91
-3dB Beamwidth	24.2	23.6	23.0
Impedance (R+/-jX)	46.5 + j 2.5	56.0 + j 11.7	70.6 - j 1.0
50-Ohm SWR	1.09	1.28	1.41



220-26: A 26-Element Yagi



The next longer array uses a boom length of just over 37' and 26 elements. The design is the last in our sequence of those derived from the work of DL6WU. Like the 21-element Yagi, this design uses 3/8" diameter elements. In fact, the number of elements is now sufficiently large that no adjustments are required between the two arrays to arrive at satisfactory performance across the 223-225 MHz spread. (In fact, the 26-element 432 array was the original DL6WU design and smaller versions were pruned from it.) The extra 9' of boom nets us about 1 dB of further gain, with front-to-back ratio and feedpoint impedance remaining stable.

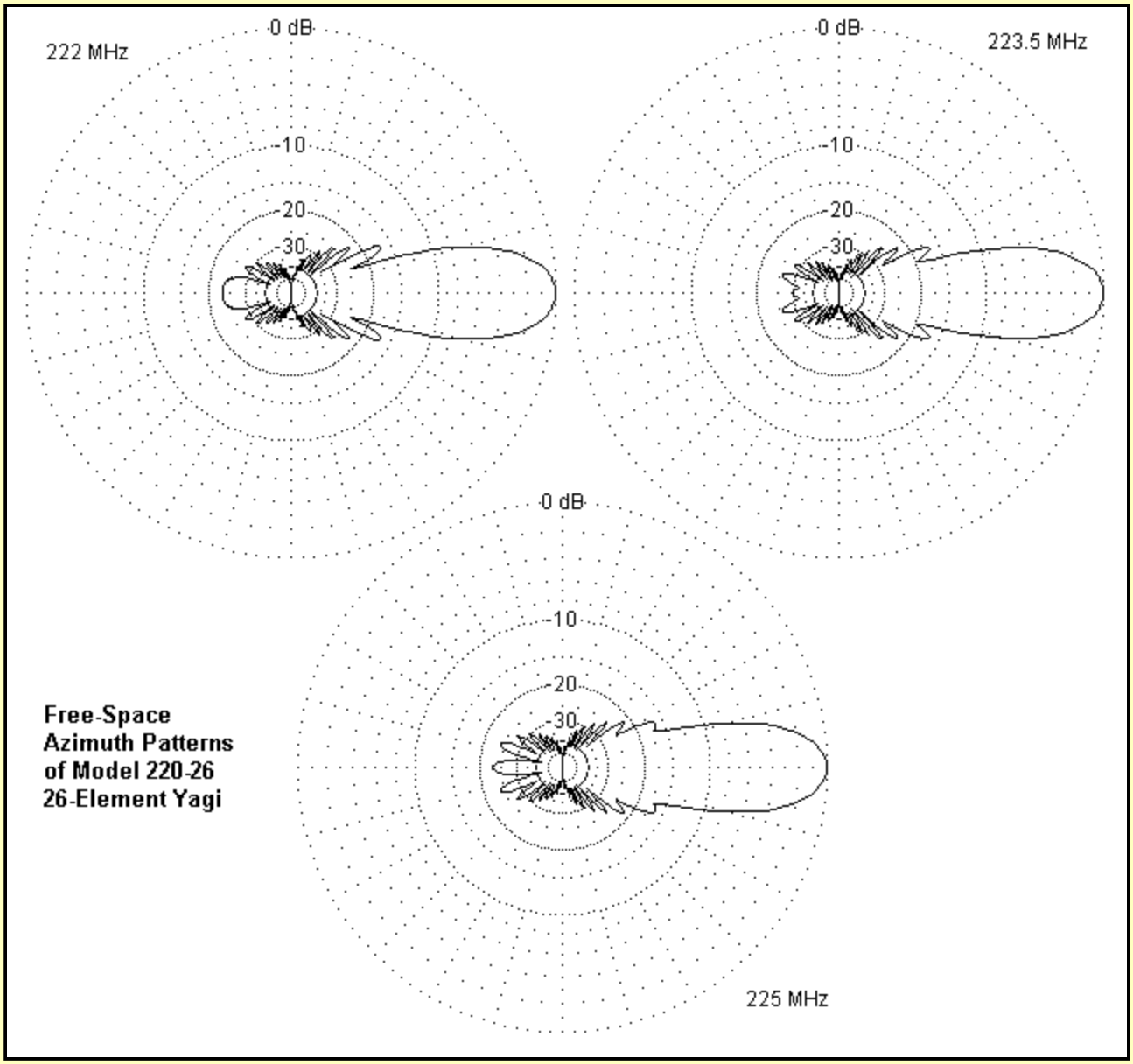
Model 220-26 Dimensions (in inches): Element Diameter 0.375"

Element	Length	Space from Reflector
Reflector	26.03	----
Driver	25.22	10.61

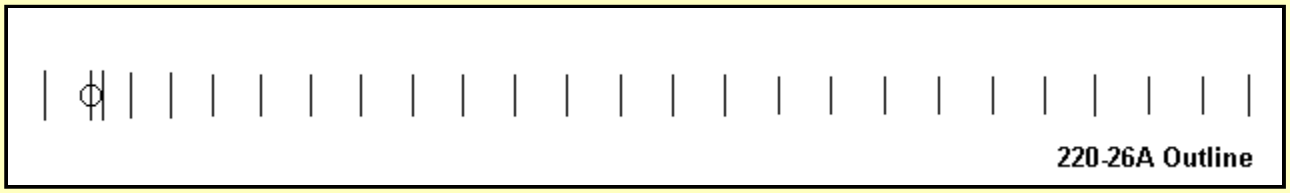
Director 1	23.05	14.58
Director 2	22.87	24.14
Director 3	22.59	35.54
Director 4	22.33	48.80
Director 5	22.11	63.66
Director 6	21.89	79.56
Director 7	21.72	96.27
Director 8	21.57	113.78
Director 9	21.43	132.08
Director 10	21.31	151.18
Director 11	21.20	171.06
Director 12	21.10	191.76
Director 13	21.00	212.97
Director 14	20.93	234.19
Director 15	20.85	255.40
Director 16	20.78	276.62
Director 17	20.70	297.84
Director 18	20.64	319.06
Director 19	20.58	340.28
Director 20	20.52	361.50
Director 21	20.45	382.72
Director 22	20.41	403.93
Director 23	20.35	425.15
Director 24	20.30	446.36

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	18.88	19.01	18.93
180-deg F-B	23.01	29.84	22.98
-3dB Beamwidth	21.8	21.2	20.6
Impedance (R+/-jX)	48.5 + j 3.0	59.3 + j 8.5	63.7 - j 6.5
50-Ohm SWR	1.07	1.26	1.31



220-26A: A Longer 26-Element Yagi



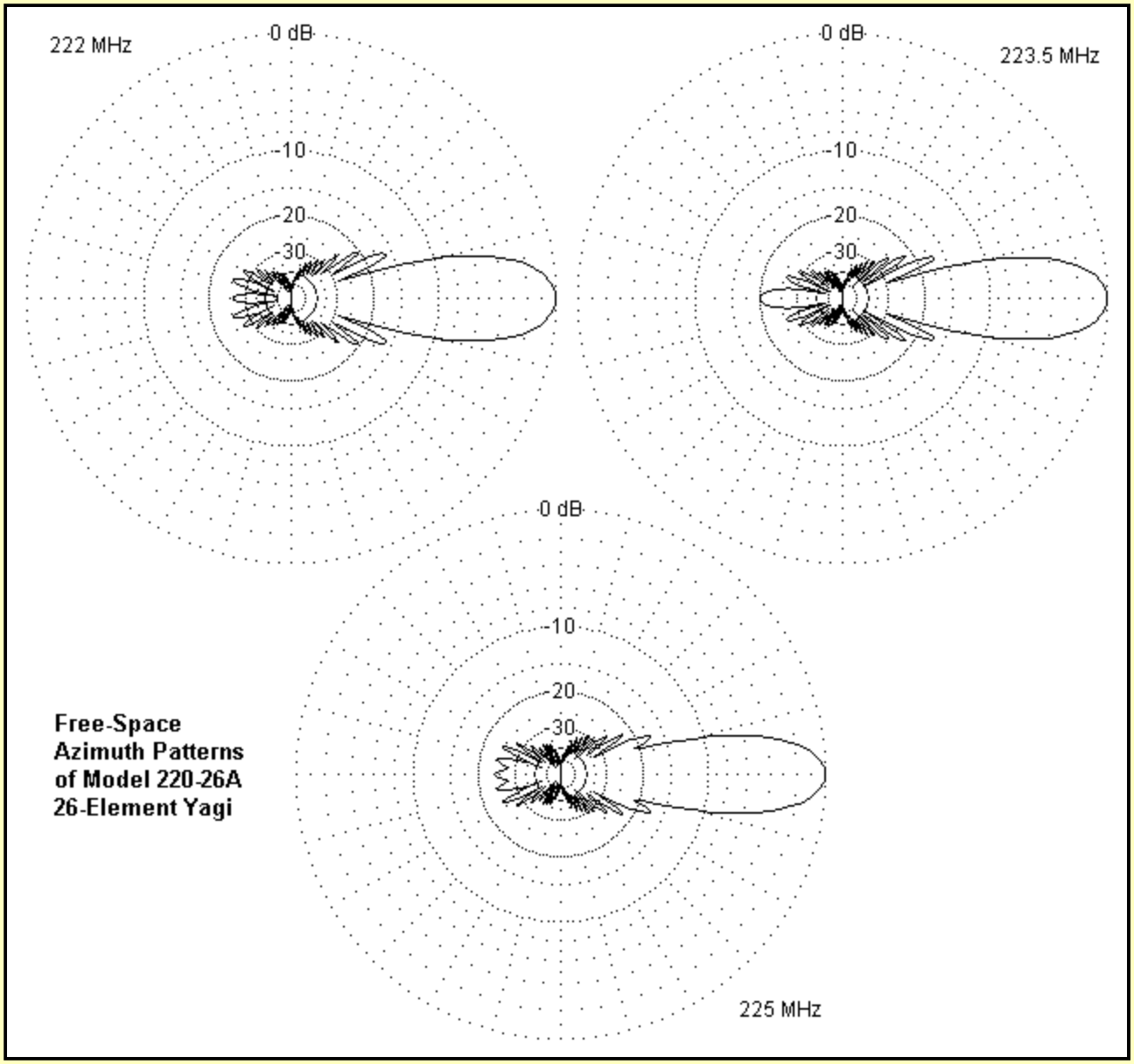
In the medium-length-boom collection, we looked at a "study design" using 1" elements. The use of such large elements at VHF and UHF frequencies seems odd to many. However, some very effective designs are possible. SM5BSZ developed a fairly narrow-band design for 432 MHz using 10-mm (0.394") elements. The design scales to 220 with 0.75" elements, about 0.004" below optimal, with a loss of only a little of the gain. The design shows a very sharp peak gain value, but that evaluation is somewhat relative to the 20 dBi free-space gain of the array: the peak is about 0.5 dB above the band-edge values. In the 220 version, the peak gain is about 20.33 dBi and occurs just below the upper end of the band. With judicious adjustment, a designer can move it to any place in the band. For this extra dB above the preceding 26-element design, we need another 10' of boom length--about 47.5' total. SM5BSZ designs do not rely on a constant element-length taper. Therefore, in the dimension chart below, you will note some forward directors that are longer than the ones immediately to their rear.

Model 220-26A Dimensions (in inches): Element Diameter 0.75"

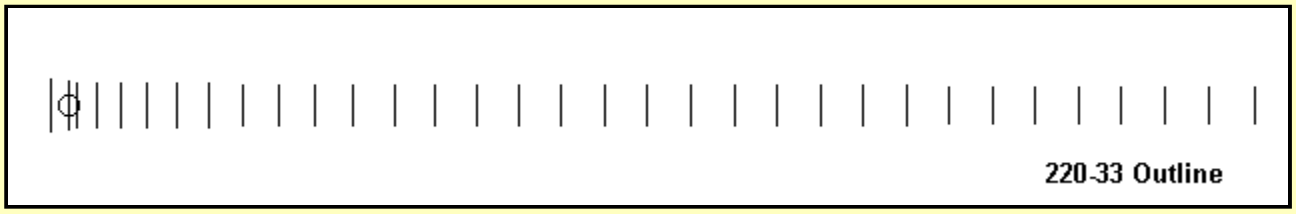
Element	Length	Space from Reflector
Reflector	24.44	----
Driver	24.80	21.79
Director 1	23.18	27.31
Director 2	22.02	41.22
Director 3	21.48	59.34
Director 4	20.95	79.38
Director 5	20.51	102.17
Director 6	20.25	125.78
Director 7	20.06	149.33
Director 8	19.89	173.44
Director 9	19.75	197.56
Director 10	19.59	221.89
Director 11	19.44	246.62
Director 12	19.32	271.44
Director 13	19.23	296.28
Director 14	19.14	321.14
Director 15	19.03	346.04
Director 16	18.88	371.21
Director 17	18.74	396.56
Director 18	18.67	421.84
Director 19	18.66	447.24
Director 20	18.78	471.91
Director 21	19.06	495.67
Director 22	18.78	521.11
Director 23	18.65	545.90
Director 24	19.84	568.25

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	19.55	20.01	20.32
180-deg F-B	26.12	20.04	22.82
-3dB Beamwidth	20.4	19.2	18.0
Impedance (R+/-jX)	33.3 - j 4.7	31.9 - j 2.9	48.7 + j 12.2
50-Ohm SWR	1.53	1.58	1.28



220-33: A 33-Element Yagi



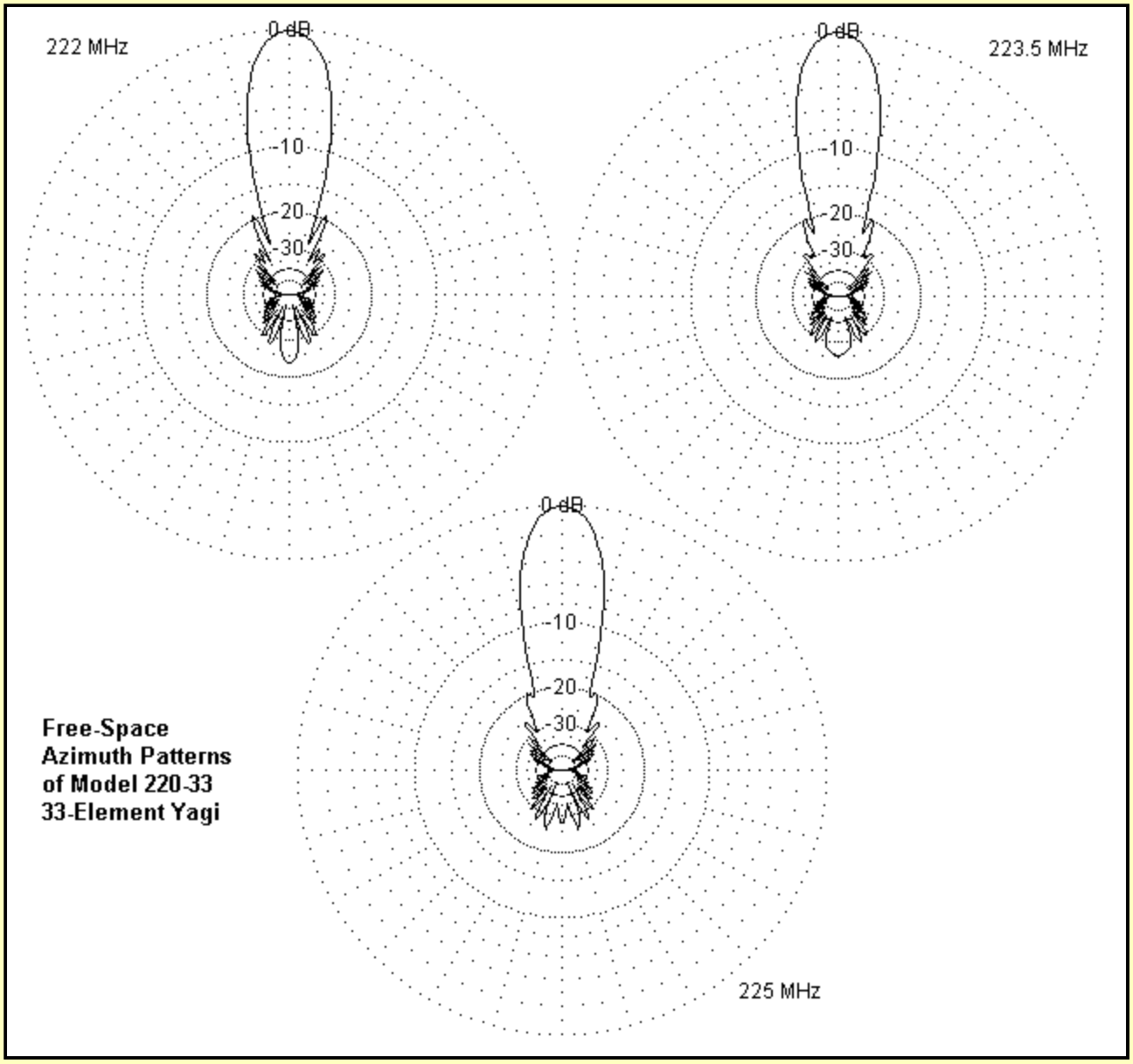
The final array in our collection of super-boom Yagis derives from a HyGain design, the original for which came from Joe Reisert, W1JR. It is an older design relative to some of the others and shares some properties in common with both the DL6WU and the SM5BSZ designs. Like the Guenter Hoch designs, it can be pruned to almost any desired length and yield a quite usable and competent Yagi of the new shorter length. However, in common with the designs of Leif Asbrink, it does not rely upon a constant taper to the director lengths. In the dimension chart, you will find many succeeding directors using the same length as the preceding one. Using 3/8" diameter elements, the array achieves about the same gain as the 26-element SM5BSZ design, but has much more broad-band characteristics. In the performance table, note the smaller range of gain change and beamwidth change across the band. The cost of broad-banding the performance is 7 elements and 2.3' of extra boom length. We have now hit the 50' mark in booms. As with all these derivative designs, additional tweaking is certainly possible. For example, the low SWR value can be spread across the 220 band without material harm to the other performance figures.

Model 220-33 Dimensions (in inches): Element Diameter 0.375"

Element	Length	Space from Reflector
Reflector	26.34	----
Driver	26.00	9.66
Director 1	23.93	13.54
Director 2	23.44	23.21
Director 3	22.95	34.55
Director 4	22.71	47.87
Director 5	22.48	62.55
Director 6	22.11	78.53
Director 7	21.81	95.20
Director 8	21.81	112.63
Director 9	21.57	130.96
Director 10	21.32	150.07
Director 11	21.20	169.85
Director 12	21.14	189.94
Director 13	21.02	210.49
Director 14	20.90	231.49
Director 15	20.90	252.72
Director 16	20.77	273.95
Director 17	20.77	295.26
Director 18	20.65	316.49
Director 19	20.65	337.80
Director 20	20.24	359.03
Director 21	20.12	380.26
Director 22	20.12	401.57
Director 23	20.12	422.80
Director 24	19.88	444.11
Director 25	19.94	465.34
Director 26	19.94	486.57
Director 27	19.82	507.88
Director 28	19.82	529.11
Director 29	19.82	550.42
Director 30	19.82	572.50
Director 31	19.82	595.52

Modeled Performance

Parameter	222 MHz	223.5 MHz	225 MHz
Gain dBi	19.92	29.99	19.91
180-deg F-B	23.27	25.63	27.69
-3dB Beamwidth	20.2	19.8	19.5
Impedance (R+/-jX)	41.2 + j 4.4	47.7 + j 4.2	32.2 - j 6.1
50-Ohm SWR	1.24	1.10	1.59



In terms of boom length, we have reached the end of the collection. In general, we achieve higher gain with longer boom arrays. As we strive for more gain, the higher that we go, the more added boom length is needed for each extra dB of gain. However, we must make allowances for variations in that general rule of thumb. First, the selection of element diameter will have a bearing on just how long a boom needs to be in order to achieve a given gain level, with the possibility that we may reach a point where the element diameter increases the boom length faster than it increases gain. Second, there will be variations in boom length for a given gain that relate to the performance bandwidth characteristics of the array, with broader bandwidth Yagis generally needing more boom length for a given gain level than narrow-band models.

Despite these general trends, we have not yet reached the limits of our overall collection of designs. There are some design and construction facets of 220 Yagi design that we have not encountered. We may try some construction variations because they offer performance improvements. Or, to reverse the coin, we may sacrifice performance in order to simplify construction and adjustment. Finally, we might take an interest in some performance factors other than gain and front-to-back ratio. We shall sample these variations on the Yagi theme in our final episode.

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