Designing Multi-Band Parasitic Beams
Part 5: Alternative 15-Meter-10-Meter Yagi Design Examples

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As we experimented with the 10-meter driver placement and the use of an additional director, we found some interesting trends associate with the Moxon-Yagi array. For example, the addition of an extra director appears to broaden the SWR curve, but also to lower the average front-to-back ratio. As well, the gain improvements wrought by an added director appear small and serve mostly to smooth gain performance across a specified passband. In addition, placing the 10-meter driver ahead of the Moxon 15-meter driver resulted in sharper SWR curves. What we cannot tell from using only the Moxon-Yagi dual-band antenna models is whether these are general trends or unique to the combination of Yagi upper-band elements and lower-band Moxon rectangle elements.

Therefore, we need to apply the same general exercise to the more complex Yagi-Yagi array composed of a 3-element wide-band Yagi for 15 meters and a comparable set of Yagi elements for 10 meters. Our initial designs used 4 elements on 10 meters, but the terms of the present work require us to try both 4- and 5-element 10-meter Yagis.

We shall keep in mind the same fundamental questions that we asked at the beginning of Part 4. First, there is the boom-to-mast mounting position question. A design that requires that we place the mast between the two driver elements is generally undesirable, if not completely unacceptable. The potential for contacting or disrupting the 125-Ω transmission line that connects the two drivers is too great. As well, we wish to avoid adjusting the array center of mass by the use of dead weight inserted into one or the other end of the boom.

Second, we wish to know the relative merits, if any, of placing the 10-meter driver behind or ahead of the 15-meter driver, to which we attach the main 50-Ω feedline. The question acquires additional significance in light of the Moxon-Yagi results that yielded sharper SWR curves for the same number of elements with the 10-meter driver in front. Essentially, we do not know if the difference in the SWR curves relative to 10-meter driver placement is a consequence solely of the placement or whether the close proximity of the 10-meter driver ends to the Moxon driver tails had a bearing on the broader SWR curves with the rearward placement scheme.

10-meter driver placement and the addition of an extra director had a major affect on the Moxon-Yagi small array. For example, forward driver placement and an extra director increased the boom length from about 9' to just over 15'. In our initial design work with the Yagi-Yagi combination, we tried to keep the boom length less than 20'. We know in advance that we shall exceed 20' in some designs to come, but the total degree of boom lengthening will be less important. The smallest boom will be about 19' long (plus ends to support the mounting plates), while the longest will be less than 22'. Unless the difference is critical to some construction limitations, the degree of lengthening is almost too small to have any significance.

Finally, we shall again explore—although in a somewhat cursory way—the general situation of using compromise element positions and lengths as these matters affect the more complex structure of the Yagi-Yagi combination. Undoubtedly, we shall uncover seemingly incompatible trends in the performance curves with some adjustment, and the available adjustments will not allow us to peak all performance values simultaneously. Part of what we wish to learn is whether the compromises that we need to make result in acceptable performance curves across the 10-meter band.

The Moxon-Yagi combination and the Yagi-Yagi combination share a significant common trait. Both begin with a wide-band 15-meter element set. The 3-element 15-meter Yagi, described in both Part 1 and Part 3 of this series provides very acceptable performance relative to a monoband version of the antenna and other monoband 15-meter Yagis that we might design. We sacrificed a minimum of gain while still obtaining a wide-band 50-Ohm SWR curve compared to monoband designs that require a matching network on the same boom length. The front-to-back ratio is nearly 20 dB across the 15-meter band. Even more significant for our design work is the fact that the 15-meter Yagi proves to be very stable in the presence of 10-meter elements. As a result, the 15-meter dimensions require either no change across the range of experiments with 10-meter elements or at most a change of only 1" at the ends of the parasitic elements to re-center the operating passband. In addition, the 10-meter elements provide sufficient forward stagger gain to bring the 15-meter performance to a par with the best of monoband 15-meter beams with the same boom length.

The use of a stable 15-meter lower-band array provides us with both an advantage and a limitation relative to these experiments. The advantage is that we shall not need to change any 15-meter element position or length in the course of making adjustments to the 10-meter elements. In terms of the general compromise question, this procedure is also a limitation. We are limited to making the 10-meter elements fit with fixed 15-meter elements. Hence, in the very large picture of compromise settings, we shall not know if giving up a small amount of 15-meter performance might allow us to make a sizable improvement in one or another category of 10-meter performance. Our reasons (or excuses) are two. First, holding the 15-meter array in a fixed condition allows us to see more clearly the trends that we create by adjusting the 10-meter elements. We do not need to face the ambiguity of which adjustment—the one to a 15-meter element or the corresponding one to a 10-meter element—is the source of the performance change. Second, the designs that we shall explore are not finished or final products. Some one or more of them may be suitable for construction, but our goal is mainly an appreciation and understanding of the parameters that surround the design of multi-band upper HF parasitic arrays.

All of the 15-10-meter Yagi combinations in this episode will use the same element taper schedule shown in Parts 1 and 3. This schedule ensures a sturdy beam, should one wish to build one. As well, the use of an unchanging taper schedule allows a direct comparison among all of the Yagi-Yagi designs in this series. Since NEC-4 will be our design vehicle, we shall presume that all elements are well insulated and isolated from any conductive boom material. As a result, the construction methods must be comparable to those shown in Part 1. Connecting any parasitic element directly to a conductive boom will require suitable adjustments to the element's length, although its position on the boom will normally not require change.

We shall use the same plan of attack that we employed with the Moxon-Yagi combination. We shall divide the antenna designs into two groups, those with the 10-meter driver behind the 15-meter driver (designated C) and those with the 10-meter driver forward of the 15-meter driver (designated CC). For each case, we shall begin with a single director ahead of the 15-meter director (designated 1) and then add a second forward director (designated 2). The result is a matrix of 4 compromise designs, although we shall introduce one variation to illustrate the trends and effects of selecting a different compromise among possible element dimensions.

15-Meter 3-Element Yagis Combined with 4- and 5-Element 10-Meter Yagis

The first of our comparative models (C1) uses 4 elements on 10 meters with the 10-meter driver to the rear of the 15-meter driven element. **Fig. 1** outlines the array, while **Table 1** provides the dimensional details. The array is a replication of the one that we discussed in Part 3 of this series. Of the 4 versions under discussion, it requires the shortest boom at just under 19'. The first director is nearly centered between the 15-meter elements, while the forward 10-meter director is quite close to the 15-meter director. The element taper schedule is rated for better than 100 mile-per-hour wind loads without ice on the elements and less depending upon the winter build-up. Note that in this design, the boom center occurs between the two driver elements—just where we would prefer that it not be.

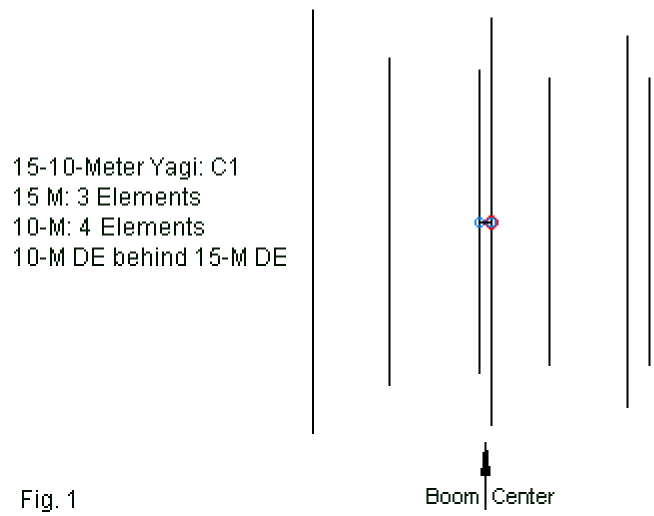


Fig. 1

Table 1. 15Y3-10y4-C1: Dimensions

15-meter Yagi			10-meter Yagi		
Element	Diameter	Length	Element	Diameter	Length
Both	0.875"	30"	Both	0.75"	24"
	0.75	66		0.625	42
	0.625	84	Ref tip	0.5	110
Ref tip	0.5	143	DE tip	0.5	102
DE tip	0.5	137	Dir 1 tip	0.5	96.5
Dir tip	0.5	125	Dir 2 tip	0.5	97

Array Spacing	
15-m ref	0
10-m ref	51.5
10-m DE	112
15-m DE	120
10-m dir 1	160
15-m dir	212
10-m dir 2	227.5

Notes:
1. Length values progressive from element center.
2. Reference dimensions to Fig. 1.
3. Spacing values progressive from rear element.
4. Driver-to-driver TL = 125 Ω, VF 1.0
5. Feedpoint: 15-meter (Moxon) DE

Boom Length: 18.96' plus ends

Table 2 and **Table 3** provide the modeled free-space performance information for the array on 15 meters and on 10 meters, respectively. The 15-meter numbers will be very similar for each band, with a total gain variation among versions of only about 0.2-dB. The gain curves will be smooth with a band-edge-to-band-edge variation in the 0.2 to 0.25 dB range. The SWR curve is very shallow, as indicated by the very modest change in both the source resistance and the source reactance across the band.

Table 2. 15Y3-10y4-C1: 15-M Performance

Frequency	21.0	21.225	21.45	Δ
Free-space Gain dBi	7.82	7.92	8.06	0.24
Front-to-back ratio dB	21.48	21.33	18.04	3.44
Feedpoint Z (R +/- jX Ω)	41.6 – j9.1	42.0 + j0.6	42.2 + j12.0	0.6 + j21.1
50-Ω SWR	1.31	1.19	1.36	

Table 3. 15Y3-10y4-C1: 10-M Performance

Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	7.31	8.20	9.02	1.71
Front-to-back ratio dB	17.82	18.67	15.02	3.65
Feedpoint Z (R +/- jX Ω)	36.6 – j21.5	44.4 + j10.6	58.9 + j34.1	22.3 + j55.6
50-Ω SWR	1.79	1.29	1.89	

The C1 model on 10 meters exhibits a considerable change in gain across the band, the penalty for selecting dimensions that enhance the front-to-back ratio. The settings do not yield the maximum ratios possible, since gain tends to decrease as the front-to-back ratio increases. As well, the settings yield a reasonably well-centered SWR curve. Compare the change in the source resistance and reactance across the band in comparison to values for 15 meters. Even halving the values to compensate for the different width of each band still yields a sharper 10-meter curve, a situation that is usually—but not universally—true of upper-band elements on a multi-band beam. Nevertheless, the gain performance on average exceeds the values for 15 meters, while the front-to-back performance is weaker but normal for upper-band performance.

If we add a second director to model C1, we obtain model C2, as outlined in **Fig. 2**. The second director moves the boom center forward of the 15-meter driver, and the center of mass is not far from the boom center. As shown in **Table 4**, the dimensions for both directors that are forward of the 15-meter director differ considerably from the length of the single forward director in model C1. The required boom is just about 21' long.

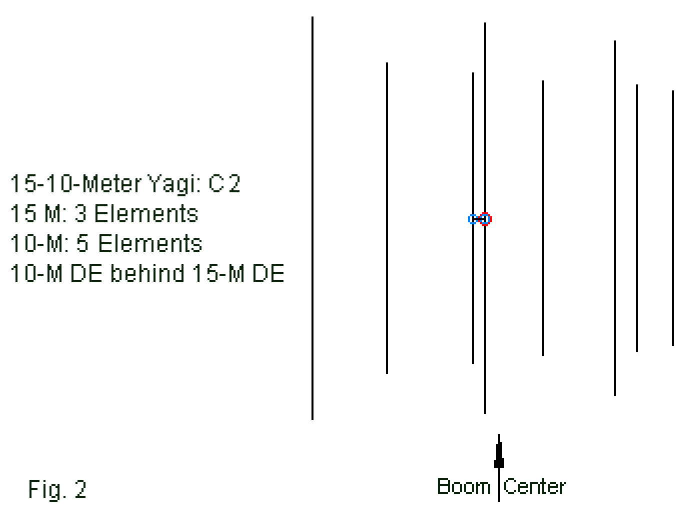


Fig. 2

Table 4. 15Y3-10y5-C2: Dimensions

15-meter Yagi			10-meter Yagi		
Element	Diameter	Length	Element	Diameter	Length
Both	0.875"	30"	Both	0.75"	24"
	0.75	66		0.625	42
	0.625	84	Ref tip	0.5	109
Ref tip	0.5	142	DE tip	0.5	102
DE tip	0.5	137	Dir 1 tip	0.5	96.5
Dir tip	0.5	124	Dir 2 tip	0.5	92.5
			Dir 3 Tip	0.5	89.5

Array Spacing	
15-m ref	0
10-m ref	51.5
10-m DE	112
15-m DE	120
10-m dir 1	161
15-m dir	212
10-m dir 2	227
10-m dir 3	252

Notes:
1. Length values progressive from element center.
2. Reference dimensions to Fig. 2.
3. Spacing values progressive from rear element.
4. Driver-to-driver TL = 125 Ω, VF 1.0
5. Feedpoint: 15-meter (Moxon) DE

Boom Length: 21.00' plus ends

The performance values for the revised array appear in **Table 5** and in **Table 6** for each band. A user could not in operation distinguish the performance report for 15 meters for either model so far.

Table 5. 15Y3-10y5-C2: 15-M Performance

Frequency	21.0	21.225	21.45	Δ
Free-space Gain dBi	7.92	8.00	8.11	0.19
Front-to-back ratio dB	19.41	20.76	18.68	2.08
Feedpoint Z (R +/- jX Ω)	41.7 – j6.6	43.0 + j2.9	43.9 + j13.8	2.2 + j20.4
50-Ω SWR	1.26	1.18	1.38	

Table 6. 15Y3-10y5-C2: 10-M Performance

Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	7.87	8.49	9.11	1.24
Front-to-back ratio dB	14.33	15.39	17.05	2.72
Feedpoint Z (R +/- jX Ω)	41.7 – j15.9	53.7 + j4.9	46.2 + j22.1	12.0 + j38.0
50-Ω SWR	1.48	1.13	1.59	

On 10 meters, we may note several interesting comparisons between models C1 and C2. First, the gain at the lower end of 10 meters increases, although the high-end gain remains nearly constant. The front-to-back ratio values decrease slightly and show a bias toward the upper end of the band. Like the Moxon-Yagi combinations, the added director appears to improve the SWR curve for the same type of driver positioning. The source resistance and reactance change are only about 2/3 as great as those for the C1 model.

Unlike the Moxon-Yagi combinations that placed the boom center in the "no-mast" zone, adding a director to the Yagi-Yagi assembly not only positions the boom center in a generally good region, but the smoother gain values across the band (or the improvement in low-end gain) and the broader SWR curve may be reason enough to select this version, despite the slightly lower front-to-back values and the longer boom. However, user needs will dictate the final comparative assessment.

Model CC1 moves the 10-meter driver forward of the 15-meter driver, as shown in the **Fig. 3** outline sketch. The initial version of this array uses a single director ahead of the 15-meter director, with the unfortunate result of moving the boom center to the region between drivers. The required boom is just over 20' long, as shown in **Table 7**.

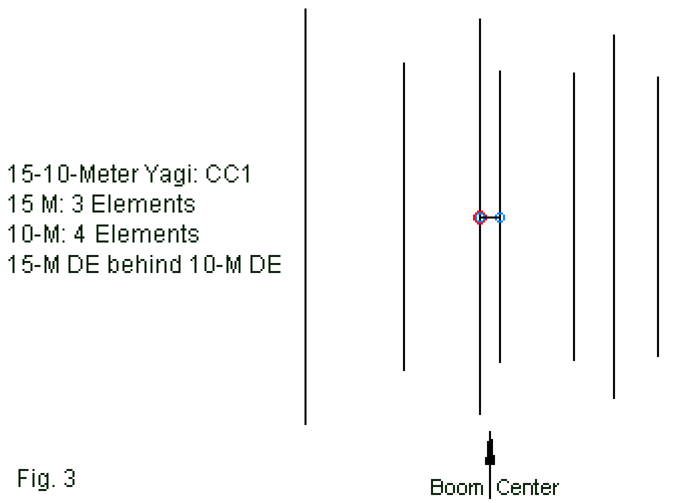


Fig. 3

Table 7. 15Y3-10y4-CC1: Dimensions

15-meter Yagi			10-meter Yagi		
Element	Diameter	Length	Element	Diameter	Length
Both	0.875"	30"	Both	0.75"	24"
	0.75	66		0.625	42
	0.625	84	Ref tip	0.5	106
Ref tip	0.5	143	DE tip	0.5	100.5
DE tip	0.5	137	Dir 1 tip	0.5	98.75
Dir tip	0.5	125	Dir 2 tip	0.5	96.4

Array Spacing	
15-m ref	0
10-m ref	67
150-m DE	120
105-m DE	134
10-m dir 1	184
15-m dir	212
10-m dir 2	242

Notes:
1. Length values progressive from element center.
2. Reference dimensions to Fig. 3.
3. Spacing values progressive from rear element.
4. Driver-to-driver TL = 125 Ω, VF 1.0
5. Feedpoint: 15-meter (Moxon) DE

Boom Length: 20.17' plus ends

The movement in the 10-meter driver position also results in a revision of the spacing between 10-meter elements and in their lengths, compared to the elements in model C1 with the rearward 10-meter driver. However, the revised 10-meter driver position requires no change to the 15-meter elements. The modeled performance values appear in **Table 8** and in **Table 9**. The 15-meter performance numbers remain virtually unchanged from those derived from models C1 and C2. Because the 10-meter elements forward of the driver yield slightly higher forward stagger consequences, we find a slight increase in 15-meter gain as we compare C1 and CC1. However, the amount is only about 0.1-dB.

Table 8. 15Y3-10y4-CC1: 15-M Performance

Frequency	21.0	21.225	21.45	Δ
Free-space Gain dBi	7.92	8.03	8.18	0.26
Front-to-back ratio dB	21.27	20.30	17.11	4.16
Feedpoint Z (R +/- jX Ω)	40.2 – j8.8	41.3 + j1.4	42.5 + j13.7	2.3 + j22.5
50-Ω SWR	1.34	1.21	1.40	

Table 9. 15Y3-10y4-CC1: 10-M Performance

Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	8.39	8.97	9.12	0.73
Front-to-back ratio dB	17.76	15.93	15.49	2.27
Feedpoint Z (R +/- jX Ω)	44.5 – j3.7	49.4 + j17.7	36.0 + j24.5	13.4 + j28.2
50-Ω SWR	1.14	1.43	1.92	

Moving the 10-meter driver to a forward position allows us to find dimensions that enhance the gain at the low end of the band. The gain change across 10 meters is less than half the value for model C1 and only 2/3 the value of model C2. However, some of the improvement derives from the selection of dimensions from the ones that are possibly usable. The evidence for this fact shows up in the front-to-back values, which favor the low end of the band. The SWR curve also favors the low end of the band, with a somewhat marginal value at 29 MHz. However, with the forward 10-meter driver position, the change in reactance across the band is lower than for either model using a rearward 10-meter driver position.

The final model in our sequence is CC2, which uses the forward 10-meter driver position and an extra director. With a 21.6' (plus end allowance) boom, it is the longest of the designs. The boom center is just forward of the 10-meter driver, which would allow a safe boom-to-mast connection. As well, with 4 elements on each side of the indicated position, the center of mass is likely to be reasonably close. Like model C2, model CC2 uses the added director effectively to yield a less challenging mounting situation. **Table 10** provides the full details of the arrays dimensions. Note especially the progression of 10-meter directors with respect to both length and inter-element spacing

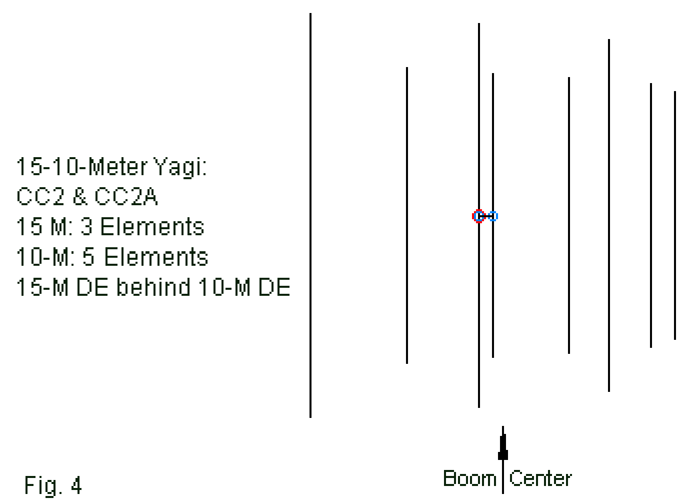


Fig. 4

Table 10. 15Y3-10y5-CC2: Dimensions

15-meter Yagi			10-meter Yagi		
Element	Diameter	Length	Element	Diameter	Length
Both	0.875”	30”	Both	0.75”	24”
	0.75	66		0.625	42
	0.625	84	Ref tip	0.5	105.5
Ref tip	0.5	143	DE tip	0.5	100.5
DE tip	0.5	137	Dir 1 tip	0.5	98.3
Dir tip	0.5	125	Dir 2 tip	0.5	94
			Dir 3 Tip	0.5	87.5

Array Spacing	
15-m ref	0
10-m ref	68
15-m DE	120
10-m DE	130
10-m dir 1	184
15-m dir	212
10-m dir 2	242
10-m dir 3	259

Notes:
1. Length values progressive from element center.
2. Reference dimensions to Fig. 4.
3. Spacing values progressive from rear element.
4. Driver-to-driver TL = 125 Ω, VF 1.0
5. Feedpoint: 15-meter (Moxon) DE

Boom Length: 21.58’ plus ends

The performance values derived from the array model appear in **Table 11** and in **Table 12**. The 15-meter values show their anticipated stability. The added director increases the average gain by about 0.1-dB, while the forward 10-meter driver position also increases gain by about 0.1-dB. Hence, with respect to our initial model (C1), the gain is up about 0.2 dB at the center of 15 meters. However, without some slight adjustment to the 15-meter reflector and director, the beam shows a front-to-back ratio bias in favor of the low end of the band. Trimming about 1” from the ends of each parasitic element would bring the array back into a well-centered condition without affect the 10-meter performance.

Table 11. 15Y3-10y5-CC2: 15-M Performance

Frequency	21.0	21.225	21.45	Δ
Free-space Gain dBi	8.03	8.14	8.27	0.24
Front-to-back ratio dB	20.62	19.24	16.35	4.27
Feedpoint Z (R +/- jX Ω)	39.9 – j6.2	41.0 + j4.2	41.9 + j16.5	2.0 + j22.7
50-Ω SWR	1.30	1.25	1.49	

Table 12. 15Y3-10y5-CC2: 10-M Performance

Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	8.72	9.09	9.28	0.56
Front-to-back ratio dB	15.36	14.75	16.31	1.56
Feedpoint Z (R +/- jX Ω)	37.9 – j19.2	51.7 + j3.5	35.5 + j15.6	16.2 + j34.8
50-Ω SWR	1.67	1.08	1.65	

The added director of model CC2 does the same general work as it did for model C2 relative to its shorter version. It allows a smoother gain curve with only about a half-dB difference between the band-edge values. As well, it allows a well-center SWR curve that is comparable to the one for model C2, but with a very low mid-band value. Indeed, this model shows the highest gain at 28 MHz of any of the four models that we are examining. Although the front-to-back ratio values are about 5-dB down from the amateur standard for monoband Yagis, the differential in the value across the band is very low.

Model CC2 has enough plus-side merits that it deserves use to illustrate how small changes in the element dimensions can alter the performance in significant ways. Model CC2A has the same outline, but makes changes that are indicated in the dimension set in **Table 13**.

Table 13. 15Y3-10y5-CC2A: (Alternative to CC2) Dimensions

15-meter Yagi			10-meter Yagi		
Element	Diameter	Length	Element	Diameter	Length
Both	0.875"	30"	Both	0.75"	24"
	0.75	66		0.625	42
	0.625	84	Ref tip	0.5	105.5
Ref tip	0.5	143	DE tip	0.5	100.5
DE tip	0.5	137	Dir 1 tip	0.5	98.3
Dir tip	0.5	125	Dir 2 tip	0.5	94
			Dir 3 Tip	0.5	*86.25*

Array Spacing	
15-m ref	0
10-m ref	68
15-m DE	120
10-m DE	130
10-m dir 1	184
15-m dir	212
10-m dir 2	242
10-m dir 3	*256*

Notes:
1. Length values progressive from element center.
2. Reference dimensions to Fig. 2.
3. Spacing values progressive from rear element.
4. Driver-to-driver TL = 125 Ω, VF 1.0
5. Feedpoint: 15-meter (Moxon) DE

Boom Length: *21.33'* plus ends

By altering only the position and length of the most forward 10-meter director, we can modify the performance curves. The changes are small. The variation moves the most forward director back by 3" and shortens its length by 1.25" on each end. The performance results appear in **Table 14** and **Table 15**.

Table 14. 15Y3-10y5-CC2A: 15-M Performance

Frequency	21.0	21.225	21.45	Δ
Free-space Gain dBi	8.01	8.12	8.25	0.24
Front-to-back ratio dB	20.77	19.44	16.50	4.27
Feedpoint Z (R +/- jX Ω)	40.0 – j6.6	41.8 + j3.9	41.8 + j16.1	1.8 + j22.7
50-Ω SWR	1.31	1.24	1.48	

Table 15. 15Y3-10y5-CC2A: 10-M Performance

Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	8.58	8.99	9.23	0.65
Front-to-back ratio dB	16.11	15.66	16.49	0.83
Feedpoint Z (R +/- jX Ω)	37.4 – j21.4	47.6 + j3.4	36.4 + j19.8	11.2 + j41.2
50-Ω SWR	1.76	1.09	1.74	

As we would expect, the 15-meter numbers change only by enough to prove that they are not simple copies of the last set. The closer position and shorter length of the most forward driver is enough to reduce the 10-meter gain by a numerically more noticeable amount, but an amount that would be operationally undetectable. The maneuver also raises the minimum SWR value at the band center and sharpens the curve relative to the initial settings for CC2. What we gain for these small costs is an even smoother front-to-back ratio curve with a nearly constant value across the wide span of 10 meters. Again, which performance categories receive precedence depends mostly on the requirements that we bring to the design exercise. However, the variation between models CC2 and CC2A demonstrates once more that with certain fixed design elements, such as the 15-meter elements, many adjustment trends will oppose each other. The designer has to select the most acceptable ones for a given set of communications and construction goals.

We may best compare some of the properties that we have noted, along with others, by exploring some relevant frequency sweep graphs of relevant performance values. As a review, the 15-meter 3-element values for gain and front-to-back ratio appear **Fig. 5**. The graph uses model C1, but the values for the other models are too close to require multiple lines.

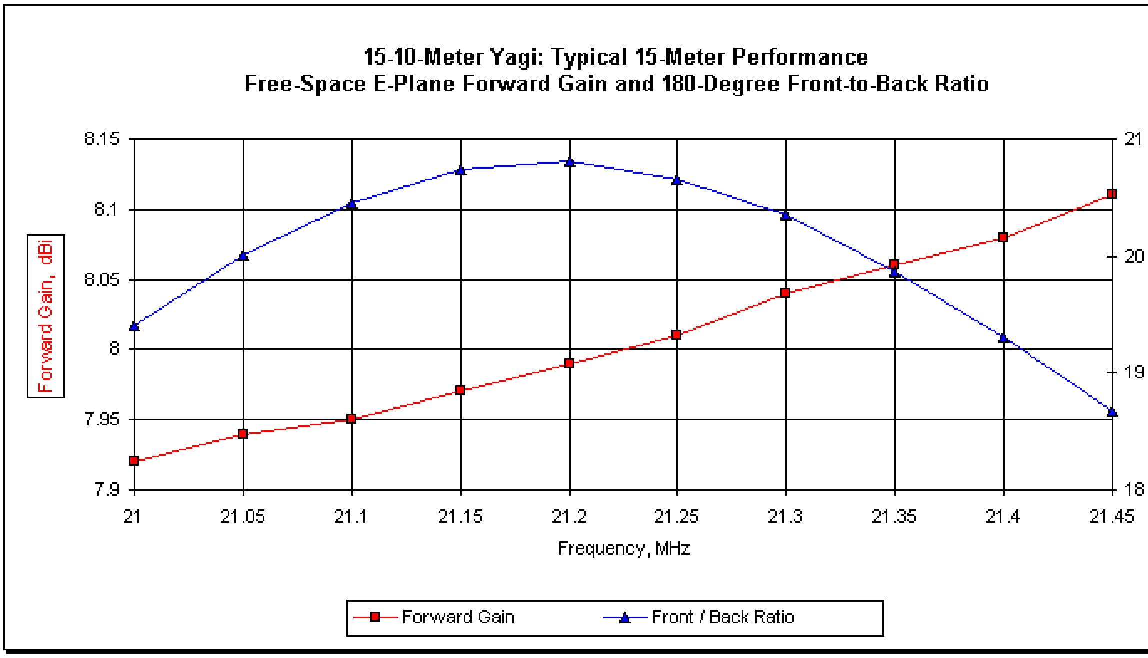


Fig. 5

The free-space forward gain curve has the expect rise in value with increases in the operating frequency within the passband. (At a point above the upper end of the passband, the forward gain will rapidly fall, pass through zero, and show up as gain in the reverse direction. At this point, the former reflector is too long to play almost any role in determining performance, and the former director will be long enough to function as a reflector for a 2-element Yagi.)

The curve for the front-to-back ratio shows a slight downward drift in the peak frequency relative to the same antenna used as a monoband Yagi. To re-center the curve and produce almost equal front-to-back values at both band edges, one may trim the parasitic elements by a small amount. For C1, the trimming will be less than an inch per element end. Since the sample numerical values in the tables suggest further drift for the most complex versions of the array, an additional half-inch trim may be necessary. In terms of deriving satisfactory operational performance from the 15-meter elements in any version of the beam, the trimming is optional.

Fig. 6 provides data on the resistance, reactance, and 50-Ω SWR at the feedpoint on 15 meters. Note that the SWR minimum value is lower than the mid-band frequency and that the driver reactance is inductive for at least 2/3 of the band. It is possible to trim the 15-meter driver, but you should take this step only after setting the parasitic elements for the best sweep curves. In many instances, the parasitic trimming will yield small changes in the driver impedance sweep so that you will not need to trim the driver at all.

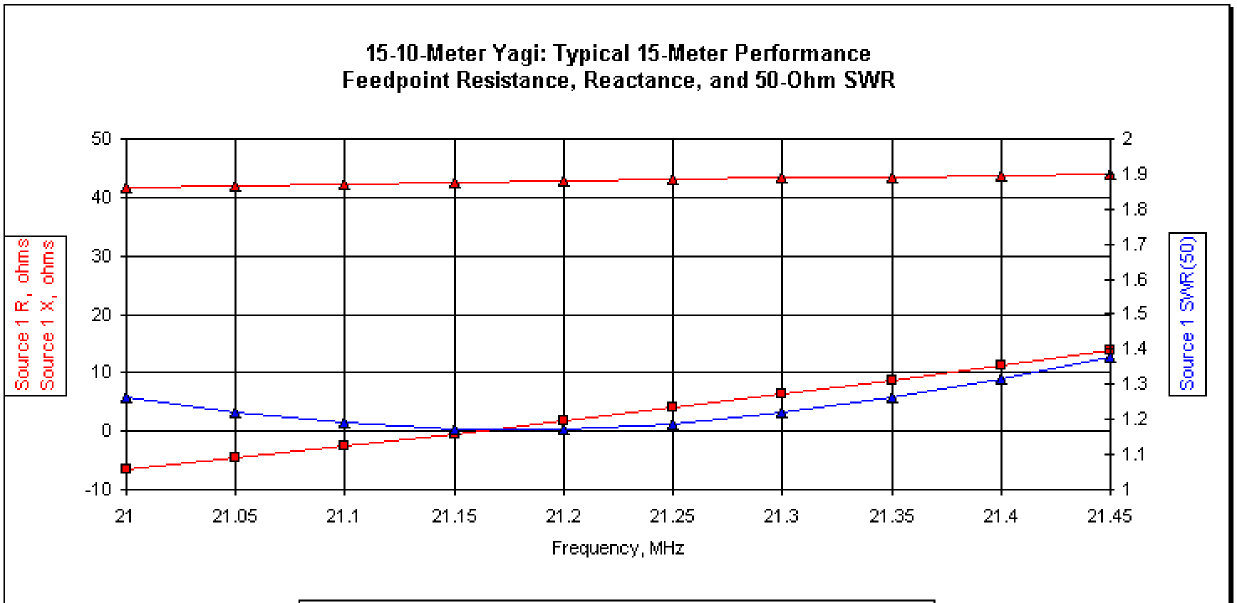


Fig. 6

The greatest differences appear in comparative graphs of performance values for the 10-meter section of the array. **Fig. 7** provides the free-space forward gain curves for all of the variations that we have discussed, including both CC2 and CC2A. Unlike the 10-meter Yagi elements associated with the Moxon rectangle, the Yagi-Yagi combination produces a small but distinct improvement in forward gain when we add the new director to the array using either 10-meter driven element position.

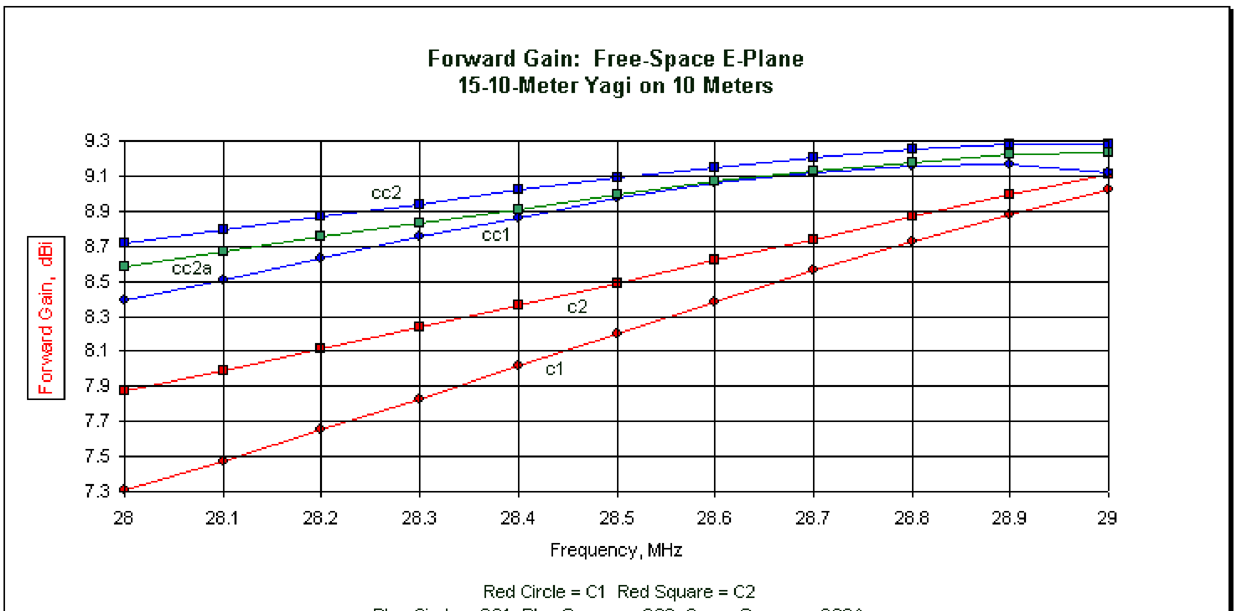


Fig. 7

The comparable graph of Moxon-Yagi options suggested that we would obtain no significant gain improvements using either a rearward or a forward 10-meter driver position. This trend does not hold for the Yagi-Yagi combination that we have been exploring. C1 and C2, the two arrays with a rearward 10-meter driver position, show significantly lower gain potential than even the shorter of the arrays with a forward driver position. From the perspective of forward gain, a forward position for the 10-meter driver is desirable. The forward position for the 10-meter driver also shows another desirable trait: the beams reach their peak gain value within (just barely) the 10-meter passband.

The gain curves also establish a likeness between the simpler array and the present design collection. One useful function of the added director is to raise the gain at the lower end of the band to yield more even performance across the wide 10-meter passband. The director cannot eliminate the upward gain curve, but it can reduce its slope.

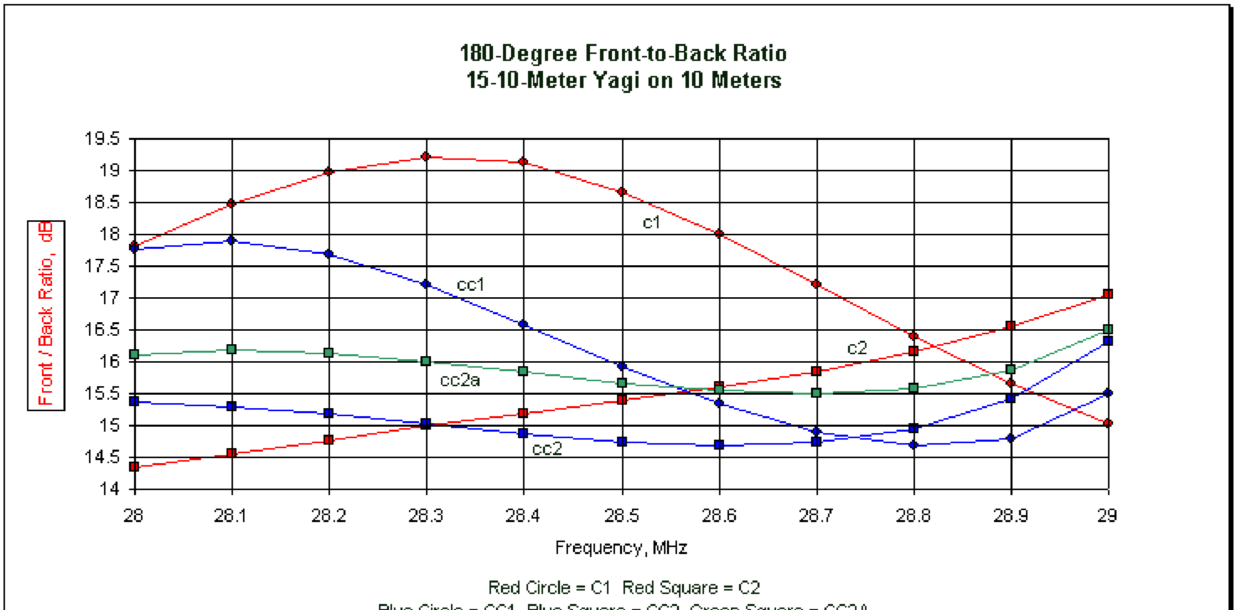


Fig. 8

When we turn to the 180° front-to-back curves in **Fig. 8**, we discover an exercise in abstract art amid the flow of the lines. The differentials among designs do not rest on the relatively simple parameters that we found for the less complex Moxon-Yagi combinations. Model C1, with a rearward 10-meter driver and only one forward director shows the highest peak front-to-back value, but at the upper end of the band, the value rapidly decreases to arrive at the lowest value on the graph. Model C2, with an extra forward director, centers the SWR curve, but at the expense of shifting the front-to-back curve to peak beyond the upper limit of the passband.

Model CC1, with a single forward director and a forward 10-meter driver, has a somewhat skewed impedance curve that favors the low end of the band. That curve places the peak front-to-back value near the low end of 10 meters. The curve also passes through a minimum value and begins to rise again before reaching the upper limit of the passband. Models CC2 and CC2A show relatively level and parallel curves. Although the average values seem modest, they manage to exceed the values of the other models over at least a small portion of the band. At this point, we may compare the gain and the front-to-back curves for models CC2 and CC2A.

The latter improves the front-to-back ratio over the former by a more significant amount than we find in its decreased forward gain values.

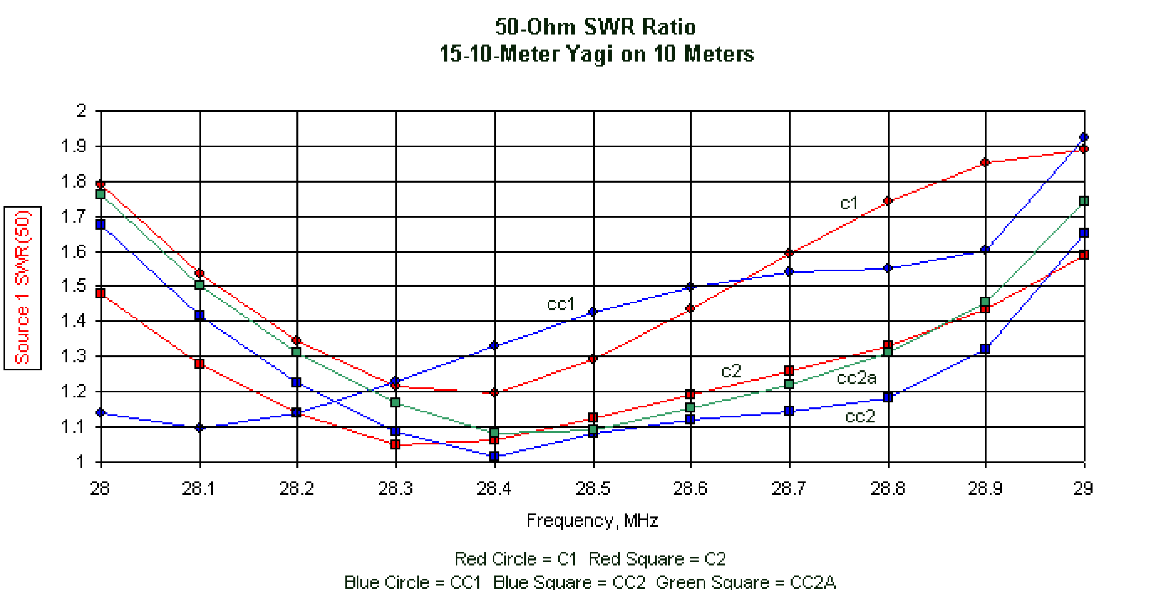


Fig. 9

The 50-Ω SWR curves in **Fig. 9** all meet the standard maximum value limit of 2:1. C2 has perhaps the broadest curve, although CC2 and CC2A show well-formed curves with only moderate peak values at the band edges. The two models with only a single director forward of the 15-meter director provide the most aberrant curves, indicating lesser control over the feedpoint impedance than we obtain by adding a further director. In contrast to the Moxon-Yagi arrays, the forward position for the 10-meter driver does not show a distinct sharpening of the SWR curves in the Yagi-Yagi combinations. It is therefore likely that the difference that we saw in Part 4 resulted from the presence or absence of coupling between the 10-meter driver ends and the 15-meter driver tails.

Unlike the Moxon-Yagi combinations, the Yagi-Yagi arrays show distinct advantages to using a forward position for the 10-meter driver. The forward position yields adequate impedance characteristics. With an added director ahead of the 15-meter director, the front-to-back ratio is more even across the band, even though the average value may be less due to the absence of distinct peaks. In addition, the forward driver position yields higher and more level forward gain values across the 10-meter passband. In the final decision-making process, one is likely to debate the differences between models CC2 and CC2A. Both models appear to allow a boom-to-mast mounting position just forward of the 10-meter driver. The difference lies mostly in whether we prefer the most perfect SWR curve possible or the slightly better front-to-back ratio performance.

Some of the Moxon-Yagi trends reappeared in the Yagi-Yagi exercise, while others did not. Because the Yagi-Yagi combinations use additional elements, including added 15-meter and 10-meter directors, we would be hasty in ascribing all differences to the Moxon rectangle geometry. Nevertheless, the differences and similarities of the trends are instructive and become part of the accumulated experience that makes up the art, craft, and science of designing multi-band parasitic arrays.

Concluding Notes

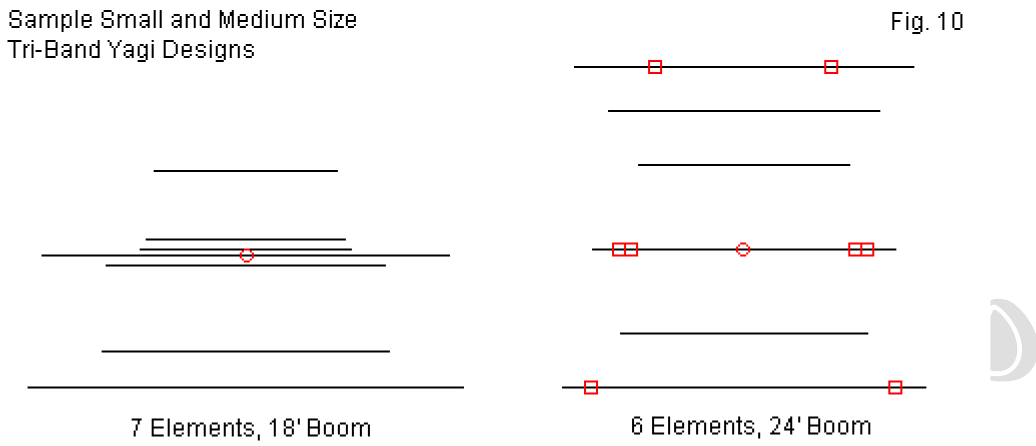
This small series of notes has aimed to develop an appreciation and—to whatever degree possible—an understanding of some of the elements that go into the design of multi-band parasitic beams. In Part 1, we developed in a broad way the general principles (including pitfalls) involved in both the mechanical; and electrical aspects of the design process. Perhaps the two most significant points involve stability and the most forward element. The lower-frequency element set will be the most stable and undergo the least modification as the overall multi-band design emerges. The stability, including broadband behavior, is much lower on an upper band, where we find a compression of the gain and impedance curves relative to monoband beams of similar arrangement. Upper-band elements are far more sensitive to small changes in position and length than are lower-band elements. Unfortunately, the top band for most upper-HF multi-band arrays coincides with the widest band covered. Moreover, lower band elements normally show greater activity on upper bands than upper-band elements show when one uses a lower band.

To some degree, the activity of lower-band elements at higher frequencies is usable to enhance at least some aspects of performance, such as forward gain. However, in most cases, a forward lower-band element will act as a reflector to reduce upper-band performance unless the upper band has a director at the front of the overall array. The forward-most upper-band director generally acts less to enhance basic performance than it does to restore control of the upper-band elements over the performance properties in terms of gain, front-to-back ratio, and to some degree impedance bandwidth. As our final two episodes showed, the addition of a second forward director can sometimes enhance performance, if only to smooth out the upper-band performance across its passband. Nevertheless, design revisions showed us that with some elements fixed—such as those for the lower band—revisions that improve performance in one category may result in degraded performance in others.

The smaller and larger sample designs that we showed served to illustrate some of these basic principles in action. For clarity, we used only two bands for the designs. As well, we used direct feeder interconnection via a 125-Ω transmission line between the drivers, with the lower-band driver as the main feedpoint location. As noted, other schemes are not only possible, but in some cases preferable.

The motivation behind the series was my personal appreciation of both the art and craft of creating multi-band beams, a set of knowledge-based skills exhibited both by individual designers and by design teams associated with commercial antenna makers. In fact, their task is considerably more difficult than the efforts needed for our sample designs, since they typically create tri-band antennas. It may be useful to briefly survey a few types of designs as a way of closing this tribute. **Fig. 10** will get us started by showing the general outline of 2 long-standing designs.

In the relatively small category, we find a 7-element Yagi on an 18' boom with essentially 2-element performance on 20 and on 15 meters and close to 3-element performance on 10 meters. The beam uses open-sleeve coupling and therefore has no interconnecting lines from the 20-meter driver to the slaved drivers for 15 and 10 meters. The 15-meter elements (a reflector and a driver) lie behind the 20-meter driver and make use of activity in the highest-band elements as a means of preventing the 20-meter driver from reducing the 15-meter gain. In contrast, all of the identifiable 10-meter elements lie forward of the main feedpoint, with a driver and two directors. The second director not only improves forward gain, but also aids in establishing the 10-meter operating bandwidth. The 15-meter elements serve as a minimal reflector.



The medium-length beam is a more traditional type, pioneered in the 1960s. It uses a combination of trapped and simple elements to create 3 elements on 20 meters and on 15 meters, with 4 elements on 10 meters. The driver uses 10- and 15-meter traps to establish operation on all three bands. The rear-most element uses traps to establish reflectors for 15 and 20 meters. The forward-most element uses traps to set up a director for 20 and for 10 meters. The use of traps, especially in the director, avoids the need for 10-meter control directors. Traps have recently received relatively harsh verbal treatment, especially by makers of non-trap beams. However, they show the highest losses to overall performance when used in the driven element, although the trapped driver simplified driver connections. Trapped drivers also tend to show a tendency toward reduced operating bandwidth on upper bands. However, the design shown is still in successful use at many stations today, although somewhat more complex designs—still with traps—have supplanted it.

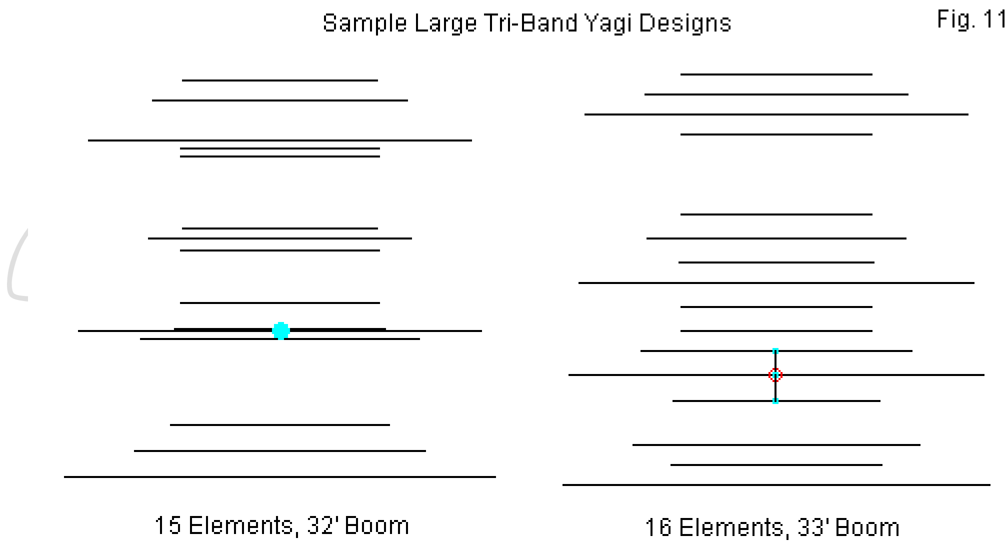


Fig. 11 outlines two larger beam designs of comparable performance. On 20 meters, the wider spacing among the 20-meter elements plus forward-stagger effects tends to roughly

equalize performance with the 4 20-meter elements in the 16-element design. On 15 meters, both designs use 4 elements. Interestingly, the elements appear at very comparable positions along the boom, although the surrounding elements dictate different activity levels, especially on other bands. On 10-meters, both beams use a 10-meter director as the front element, ahead of a 15-meter director. As well, both designs make extensive use of control directors that bracket lower-band elements to allow the 10-meter elements to achieve an acceptable performance level. (In fact, both beams have enough elements on 10 meters along the boom to achieve higher performance on that band than on any other.)

The two beam designs differ in their final arrangement of elements, and the method of feeding the elements dictates that placement to a significant degree. The beam on the left uses open-sleeve coupling, which accounts for the very close spacing of an element for each band. In contrast, the beam on the right uses a 50-Ω direct connection system. Both beam designs place the main feedline connection on the 20-meter driver element.

Since my personal collection models in no way represents the final commercial designs of these antennas, which are subject to manufacturer improvements over time, I shall not provide any performance numbers. As well, I shall not try to give an element-by-element account of the functions of the array pieces across the operating spectrum. It suffices to note that these representatives of both older ad newer design techniques have produced successful multi-band beams using many of the understandings that we have tried to develop in this small series of notes.

The series may not inspire any building efforts on anyone's part. However, if they engender an appreciation for the art and craft of multi-band beam design, the notes will have done their work well enough.