Designing Multi-Band Parasitic Beams
Part 4: Alternative 15-Meter Moxon, 10-Meter Yagi Design Examples

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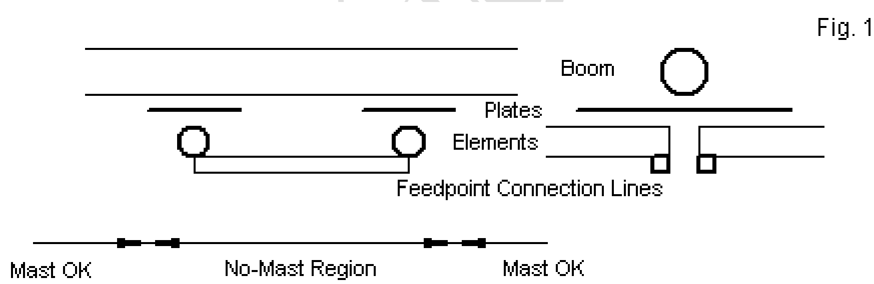
When I initially struck an outline for these notes on multi-band parasitic beam design, I thought that I might need only two episodes. One would, as does Part 1, set forth the general principles and limitations of designing such beams. The second section would illustrate those principles by using two 15-10-meter arrays as examples: a simple beam and a more complex beam. There is nothing like a good example to reveal uncovered details in the expression of the general principles, gaps that require further exploration. Therefore, the relatively small Moxon Yagi combination required a full section, as did the more complex Yagi-Yagi affair. It turns out that we are still not quite done with our work.

We left behind a number of unanswered questions. As well, in the course of developing notes on these subjects, other questions arose. Here is a brief list of what still remains undone.

1. *The Boom-to-Mast Question*: In previous episodes, I have noted that some designs manage to place their driven elements at the boom center. Although the linear center of the boom is not usually the exact center of array mass, it is close enough to give us a guide to the problems involved. Remember that all of our designs make use of a 125-Ω (VF 1.0) transmission line to connect the 10-meter driver to the 15-meter drive that also serves as the connection point for the main feedline. **Fig. 1** illustrates the mechanical problem facing the multi-band beam designer.



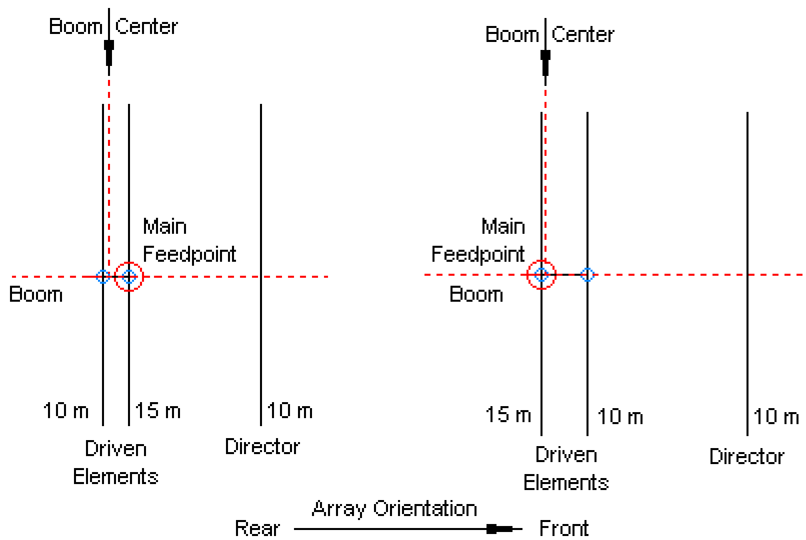
The Mechanical Question: Boom-to-Mast Connection Position

The sketch shows the driver assembly elements from two perspectives. The array side view, looking down the element tubes, is perhaps the more helpful of the two, since it defines a region that I have called the "no-mast" zone. If we hang the elements beneath the boom, as is common upper HF practice, we cannot attach a mast within the region occupied by the elements or the transmission line, as shown on the right. The mast and its plate or other assembly cannot touch either an element or one of the two conductors making up the connecting line. Indeed, a mast needs sufficient spacing to avoid unbalancing the connecting transmission line. The alternative is to find a means to place the mast either ahead of or behind the pair of drivers without (if possible) seriously unbalancing the array or adding deadweight to one or the other end of the boom.

One way to manage the array balance might be to add another 10-meter director. By adding the new element, we violate or original intention of keeping the beams as short as feasible. Still, the additional element and boom length might shift the center point enough to allow a clean mast-to-boom junction without resorting to Tee fittings and other non-standard mounting systems.

2. *The Driven-Element Placement Question*: In our quest for short boom lengths, we automatically placed the secondary 10-meter driver behind the 15-meter driven element. However, without the boom-length restriction, we might as easily have chosen the place the 10-meter driver forward of the 15-meter driven element and still have used the lower-band driver as the connecting point for the main feedline. **Fig. 2** illustrates our alternatives.

Fig. 2



The Driver-Position Question: 15-10 or 10-15?

The sketches of hypothetical structures are not far off the boom centers that we shall encounter. The option on the right does not resolve the mechanical problem, but it does inform us that we shall automatically require longer booms—as much as 3' to 4' longer—than the option on the left. In return, the upper-band-forward position is suggestive of an additional opportunity to make use of forward stagger by placing two 15-meter elements behind the rearmost 10-meter elements. The design question then becomes whether we gain anything significant enough to warrant the forward position for the 10-meter driver.

3. *The General Compromise Question*: Every multi-band beam is a mass of compromises required by limitations that we impose—sometimes just by wanting a beam to cover more than one band with a single feedline and boom. Our initial boom-length restriction was about 10' for the smaller array and 20' for the larger. We have already seen that some of our new options will require longer booms. A second restriction emerges from tying together the feedpoints of the driven elements for both bands. This limitation would occur whether we used traps, direct connections, or open-sleeve coupling. The required proximity of the drivers and the need for an acceptable 50-Ω SWR limits the potential positions available to the drivers. This factor interacts with the positions of the elements for each band. As a consequence, we face a new set of limitations. The element positions and lengths required for the best impedance curve do not coincide with those for the best front-to-back ratio curve, and neither set coincides with the positions and lengths needed to maximize gain. As we begin to remove some limitations, such

as the length of the boom, we enter less certain ground in terms of reaching a decision about what set of dimensions is "best." For example, we need to obtain full passband coverage with less than 2:1 50-Ohm SWR in most amateur arrays. In some cases, but not all, we can obtain excellent SWR curves, but at the cost of other performance categories. If we peak one or another performance category, such as the front-to-back ratio, the SWR curve may narrow, skew, or simply rise too high.

The result is that every design set to paper (and into a prototype) is not the only set of array dimensions that will yield performance that is acceptable to someone. The designs that we shall review in this final set of notes will all show signs of compromise. However, it will be much harder to specify just why I chose the compromises used in the designs. Nonetheless, the effort to articulate those reasons may give insight into both the process of design and the potential range of variation that one may expect from personal adjustments to the listed designs.

In working with these questions, we need a rough plan. Therefore, we shall work first with the Moxon-Yagi combination and later with the Yagi-Yagi combination. Each basic array will have 4 versions, all of which use the same direction-connection feed system with its 125-Ω transmission line. We shall look at two designs with the 10-meter driver behind the 15-meter driver and two with the 10-meter driver ahead of the 15-meter driven element. The differentiation between designs for each driver placement will be in the addition of an extra director to determine if it provides assistance with the mechanical question and with overall upper-band performance.

For both exercises, we shall use set 15-meter element groupings that will not vary. This restriction allows us to see more clearly the nature of the compromises involved in the design process. Still, it does restrict our flexibility below the level that a serious beam designer might have in adjusting element positions. On the other hand, the 10-meter elements will have so little affect on the 15-meter elements that the performance on the lower-band is relatively immune to whatever we do to the upper-band elements.

For each variation on the design themes, we shall initially provide tabular results of the NEC-4 modeling. As in past episodes, there will be tables of dimensions, and all beams will use the same element taper schedules used in earlier sections. As well, each beam variation will have free-space performance tables for both 10 and 15 meters. In general, we shall reserve most of our comments for follow-up summaries using a number of frequency-sweep curves on both bands. Let's begin with the smaller Moxon-Yagi combinations.

15-Meter 2-Element Moxons Rectangles Combined with 3- and 4-Element 10-Meter Yagis

The 15-meter tapered-element Moxon rectangle that we introduced in Part 2 remains the stable core of all of the variations in this portion of our work. Whatever, the 10-meter driver placement or the number of new 10-meter directors, the performance of this portion of the array remains almost constant. Among all of the beams that we shall analyze, the Moxon forward gain varies by under 0.2-dB, with an average front-to-back variation across the band of only about 2 dB. (The front-to-back average is skewed by the fact that its value rises to a very high peak value near but not on the mid-band frequency.) Equally tame are the SWR curves with a maximum variation of less than 0.2 across the 15-meter band. Although one might wish to tweak the design slightly to place resonance at the band center in any final design, this move is wholly unnecessary to obtain excellent Moxon performance across the band with all variations.

Version C1 of the array—where C simply means compromise—places the 10-meter driver behind the 15-meter driver. As well it uses a single 10-meter director forward of the Moxon rectangle for 15. **Fig. 3** outlines the design and also shows the approximate position of the boom center. It is likely that one might be able to connect the boom to a support mast slightly behind the center point an avoid interactions with the driver while still providing a strong support.

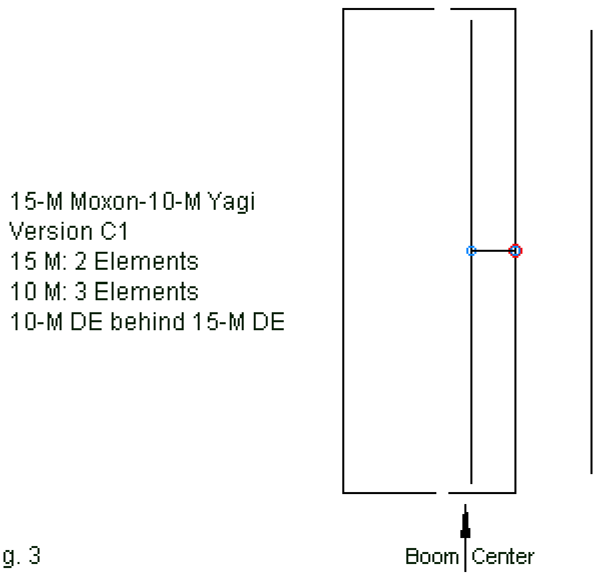


Fig. 3

The dimensions and performance values for this array appear in **Tables 1**, **2**, and **3**. The values are very similar to those appearing in Part 2 of this series.

Table 1. 15-meter Moxon—10-meter Yagi C1 dimensions

15-meter Moxon Rectangle			10-meter Yagi		
Element	Diameter	Length	Element	Diameter	Length
Both	0.865”	30”	Both	0.75”	24”
	0.75	66		0.625	48
	0.625	84		0.5	72
	0.5	100	DE tip	0.375	101
	0.375	105	Dir tip	0.375	96
Ref tail	0.375	39.5			
DE tail	0.375	28.5			
Gap		6			
Total width		74	Boom length: 8.92’ plus ends		

Array Spacing	
15-m ref	0”
10-m DE	55
15-m DE	74
10-m Dir	107

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

This version of the simple 2-band beam is the smallest in terms of boom length. A 10’ length of tubing would provide more than enough room for the elements and any mounting plates used, with a bit of room for end caps to keep the boom from whistling in the wind. See Parts 1 and 2 of this series for additional construction ideas.

Table 2. Moxon-Yagi C1: 15-meter performance

Frequency	21.0	21.225	21.45
Free-space Gain dBi	6.47	6.20	5.96
Front-to-back ratio dB	19.48	31.13	23.04
Feedpoint Z (R +/- jX Ω)	46.4 – j11.6	59.3 – j8.3	70.7 – j7.3
50-Ω SWR	1.29	1.26	1.44

Table 3. Moxon-Yagi C1: 10-meter performance

Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	6.07	6.52	7.05	0.98
Front-to-back ratio dB	12.72	15.25	14.88	2.53
Feedpoint Z (R +/- jX Ω)	41.3 – j8.2	40.2 + j3.7	35.6 + j19.9	5.7 + j28.1
50-Ω SWR	1.30	1.26	1.77	

The 15-meter performance data is typical of Moxon rectangles, and the 15-meter patterns shown in Part 2 are adequate to portray the azimuth patterns that we can expect. The 10-meter data is more interesting because it reveals an SWR curve that seems to be shifted to favor the lower end of the band. At the same time, the front-to-back ratio data appears to favor the upper end of the band. The contrast in the data lines reveals one of those conflicts calling for a compromise set of element positions and lengths. If we had set the dimensions for the best SWR curve, we would have obtained the data in **Table 3a**.

Table 3a. Moxon-Yagi C1: 10-meter performance: best SWR curve

Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	5.47	5.84	6.31	0.84
Front-to-back ratio dB	10.58	13.24	17.99	7.41
Feedpoint Z (R +/- jX Ω)	50.4 – j6.7	49.0 – j1.5	43.6 + j7.6	6.8 + j14.3
50-Ω SWR	1.14	1.04	1.24	

The 50-Ω SWR curve for the alternative dimensions is outstanding—and does not affect the 15-meter performance of the Moxon. To obtain this excellent SWR performance, we lost two other facets of the compromise performance values. First, the forward gain level dropped considerably—by more than 0.6-dB. In addition, the front-to-back curve shows an extreme amount of variation, rising from a very poor level at the low end of the passband to a very good value that occurs only at the upper end of the passband.

In contrast, we might also design the array for better overall front-to-back values. We can improve the average value by about a full dB relative to the values in **Table 3**, but in the process the SWR curve drifts even further off center and reaches a value of 2:1 at the upper end of the passband. Although we might present such a design, we must always allow for construction variables and leave room for variations between the computer design and a prototype. Pressing a design to the limit on paper is one very good way of ensuring that a prototype will pass over the limit.

Version C2 of the array retains the 10-meter driver position behind the Moxon driver. But it adds an additional director ahead of the existing director. In fact, both directors require custom positions and lengths to reach the relevant compromise performance. **Fig. 4** provides the outline of the revised array. Although the new director lengthens the boom, it does not resolve the mechanical problem of the mast connection point. In fact, one might judge that the new director only makes matters worse.

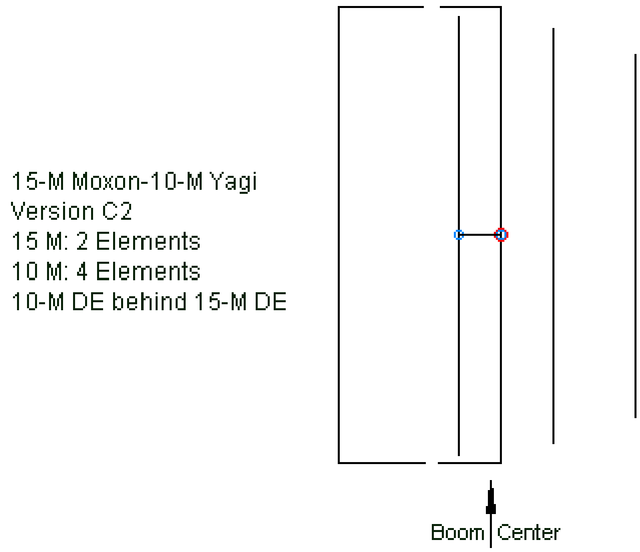


Fig. 4

The dimensions for the revised array appear in **Table 4**. Note the changes in the position and length of the first director relative to version C1. The revised design would require a 12' boom to handle the elements and their mounting assemblies to keep them well insulated and isolated from the boom.

Table 4. 15-meter Moxon—10-meter Yagi C2 dimensions

15-meter Moxon Rectangle			10-meter Yagi		
Element	Diameter	Length	Element	Diameter	Length
Both	0.865"	30"	Both	0.75"	24"
	0.75	66		0.625	48
	0.625	84		0.5	72
	0.5	100	DE tip	0.375	101
	0.375	105	Dir 1 tip	0.375	95.5
Ref tail	0.375	39.5	Dir 2 tip	0.375	83.5
DE tail	0.375	28.5			
Gap		6			
Total width		74	Boom length: 11.33' plus ends		

Array Spacing	
15-m ref	0"
10-m DE	55
15-m DE	74
10-m Dir 1	98
10-m Dir 2	136

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

Despite the extensive changes to the 10-meter elements, the net result for 15-meter operation is a set of tiny changes that we could not operationally detect. **Table 5** shows the performance in free-space terms. The patterns of Part 2 remain valid for this implementation of the Moxon rectangle—and indeed, for all of the versions of the Moxon-based 2-band antenna. At most we find a slight shift in the operating point for the lower-band array, but well within the likely construction variables that any prototype would reveal.

Table 5. Moxon-Yagi C2: 15-meter performance

Frequency	21.0	21.225	21.45
Free-space Gain dBi	6.55	6.30	6.07
Front-to-back ratio dB	18.97	31.61	25.52
Feedpoint Z (R +/- jX Ω)	48.5 – j14.2	61.3 – j12.4	71.9 – j12.8
50-Ω SWR	1.34	1.35	1.52

Table 6. Moxon-Yagi C2: 10-meter performance

Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	6.36	6.69	7.07	0.71
Front-to-back ratio dB	12.60	14.25	14.87	2.27
Feedpoint Z (R +/- jX Ω)	38.6 – j7.6	39.9 + j3.4	38.6 + j16.2	1.3 + j23.8
50-Ω SWR	1.36	1.27	1.57	

The 10-meter sample performance numbers in **Table 6** show many of the same traits as the values for the single-director model (C1). The SWR curve is slightly skewed toward the lower end of the band while the front-to-back values favor the high end of the band. Note that the added director increases gain only at the lower end of the band while broadening the SWR curve somewhat, mostly due to a reduction in the total range of feedpoint reactance. However, as we shall see for many cases of adding an extra director, the average front-to-back value across the band is slightly lower than for the initial array.

Version of the antenna marked CC place the 10-meter driver ahead of the 15-meter driver. Model CC1 uses a single director and therefore roughly corresponds to model C1, but with a longer boom. CC1's outline appears in **Fig. 5**.

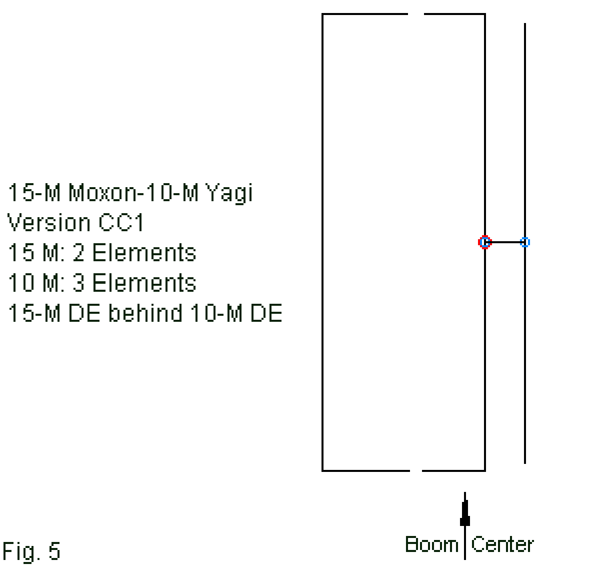


Fig. 5

As the dimensions in **Table 7** reveal, the single-director, forward driver array requires the same boom length (just under 12') as the double-director, rearward driver model. The repositioning of the 10-meter elements changes the driver length by a total of only 1" and the director length does not change at all. However, the compromise director position is closer to the driver than in model C1, although there is no partially active 15-meter element between the 10-meter elements.

Table 7. 15-meter Moxon—10-meter Yagi CC1 dimensions

15-meter Moxon Rectangle

Element	Diameter	Length
Both	0.865”	30”
	0.75	66
	0.625	84
	0.5	100
	0.375	105
Ref tail	0.375	39.5
DE tail	0.375	28.5
Gap		6
Total width		74

10-meter Yagi

Element	Diameter	Length
Both	0.75”	24”
	0.625	48
	0.5	72
DE tip	0.375	101.5
Dir tip	0.375	96

Boom length: 11.33’ plus ends

Array Spacing

15-m ref	0”
15-m DE	74
10-m DE	93
10-m Dir	136

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

The performance tables may prove surprising—not in the 15-meter table (**8**), but the 10-meter table (**9**). We might have expected performance improvements, but they prove to be scant.

Table 8. Moxon-Yagi CC1: 15-meter performance

Frequency	21.0	21.225	21.45
Free-space Gain dBi	6.53	6.26	6.01
Front-to-back ratio dB	18.28	28.65	23.84
Feedpoint Z (R +/- jX Ω)	46.2 – j8.2	57.6 – j5.0	67.2 – j3.7
50-Ω SWR	1.21	1.18	1.35

Table 9. Moxon-Yagi CC1: 10-meter performance

Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	5.83	6.39	7.07	1.24
Front-to-back ratio dB	13.80	18.73	18.33	4.93
Feedpoint Z (R +/- jX Ω)	37.9 – j18.5	37.8 + j0.2	34.4 + j23.6	3.5 + j42.1
50-Ω SWR	1.65	1.32	1.95	

Although we do obtain some apparent improvement in the front-to-back curve (which peaks at about 28.8 MHz), we find a decline in gain at the low end of the passband. As well, the SWR curve is sharper than we found with either C1 or C2. From our work with models C1 and C2, we can recognize that the settings of the dimensions represent a compromise, but one that seems to teeter at the edge of multiple facets of performance. Perhaps the one major factor favoring this design is that the boom center falls well behind the 15-meter driver and is not far from the center of mass for the array.

If we add a second director to the array, we lose the convenient position for the mast, as shown in the outline for model CC2 in **Fig. 6**. The dimensions appear in **Table 10**. The boom length increases to over 15’. After examining the values for the element positions and lengths, we shall be interested in seeing if we obtain any added performance, especially relative to the original model, C1.

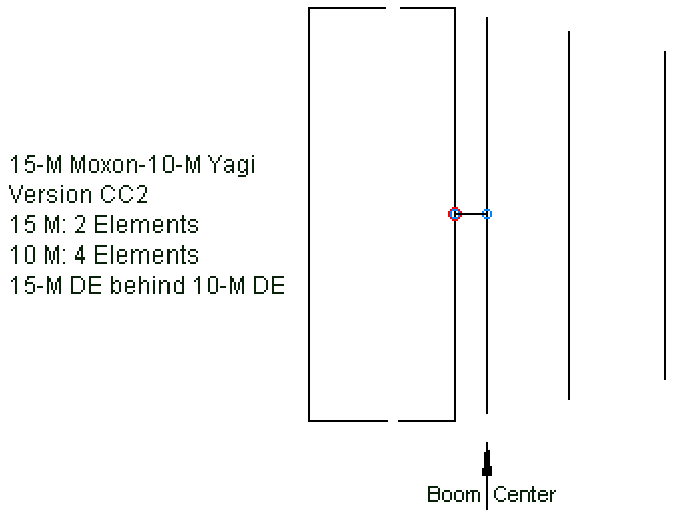


Fig. 6

Table 10. 15-meter Moxon—10-meter Yagi CC2 dimensions

15-meter Moxon Rectangle			10-meter Yagi		
Element	Diameter	Length	Element	Diameter	Length
Both	0.865"	30"	Both	0.75"	24"
	0.75	66		0.625	48
	0.625	84		0.5	72
	0.5	100	DE tip	0.375	101.5
	0.375	105	Dir 1 tip	0.375	93.75
Ref tail	0.375	39.5	Dir 2 tip	0.375	83.75
DE tail	0.375	28.5			
Gap		6			
Total width		74	Boom length: 15.08' plus ends		

Array Spacing	
15-m ref	0"
15-m DE	74
10-m DE	90
10-m Dir 1	132
10-m Dir 2	181

Notes:
1. Length values progressive from element center.
2. Reference Moxon dimensions to Fig. 6.
3. Spacing values references to parallel elements.
4. Driver-to-driver TL = 125 Ω, VF 1.0
5. Feedpoint: 15-meter (Moxon) DE

Table 11. Moxon-Yagi CC2: 15-meter performance

Frequency	21.0	21.225	21.45
Free-space Gain dBi	6.65	6.40	6.17
Front-to-back ratio dB	18.90	33.04	25.49
Feedpoint Z (R +/- jX Ω)	46.6 – j10.4	57.2 – j7.2	65.9 – j5.5
50-Ω SWR	1.25	1.21	1.34

As shown in **Table 11**, the 15-meter performance remains very stable. The values are consistent with all other tables for this array in the dual-band array. More interesting are the 10-

meter values shown in **Table 12**. In fact, the numbers are in line with those for model C2 on a shorter boom and not very much better than those for the original array.

Table 12. Moxon-Yagi CC2: 10-meter performance

Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	6.33	6.73	7.16	0.83
Front-to-back ratio dB	12.88	13.64	13.38	0.76
Feedpoint Z (R +/- jX Ω)	38.2 – j18.6	44.6 + j3.2	49.0 + j25.2	10.8 + j43.8
50-Ω SWR	1.65	1.14	1.66	

One way—but certainly not always the best way, to evaluate the performance of a multi-band array is to see if the performance values for the two bands are comparable. (There are a number of larger tri-band arrays in which the 10-meter performance is much better on average than the performance on the lower two bands. There are significant reasons for this situation, one of which is the requirement for using control directors for 10 meters that bracket the lower-band elements, especially the 20-meter elements, which can control the frequency range of the 10-meter passband.) Therefore, it may be useful to graph the 15-meter performance of the Moxon rectangle. Since the performance numbers are so tightly grouped, we may use a frequency sweep for model C1 to stand in for the entire set of models on the lower band. **Fig. 7** provides a sweep of the free-space forward gain and the 180° front-to-back ratio. As we noted in Part 2, the Moxon rectangle shows a gain curve typical of driver-reflector parasitic arrays, with declining gain as the operating frequency rises. Between 21.225 and 21.27 MHz, we would find a relatively sharp peak in the front-to-back ratio. However, even without final tweaking, the lowest front-to-back value on 15 meters is above 18 dB, a high value for a driver-reflector parasitic array.

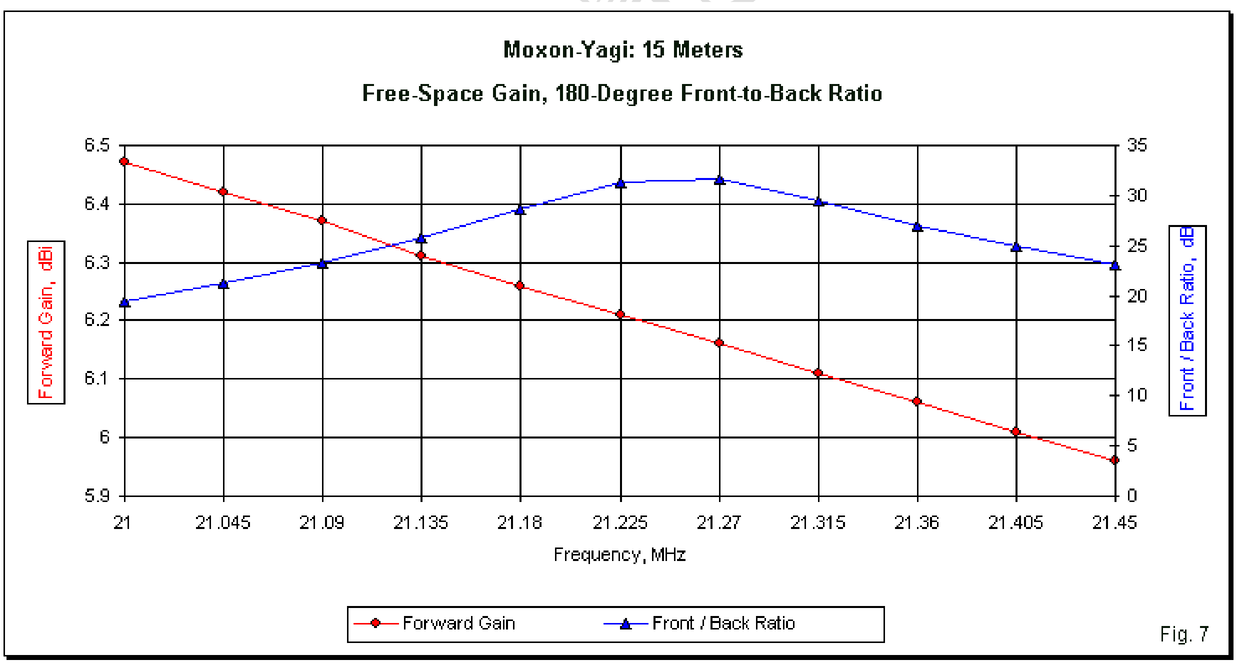


Fig. 8 reviews the feedpoint conditions across the 15-meter band. The graph shows the feedpoint resistance, reactance, and 50-Ω SWR value. The reactance values are all capacitive, suggesting that the array driver is a bit short. However, the SWR curve is at odds with the front-to-back curve, which places its peak above the center of the band.

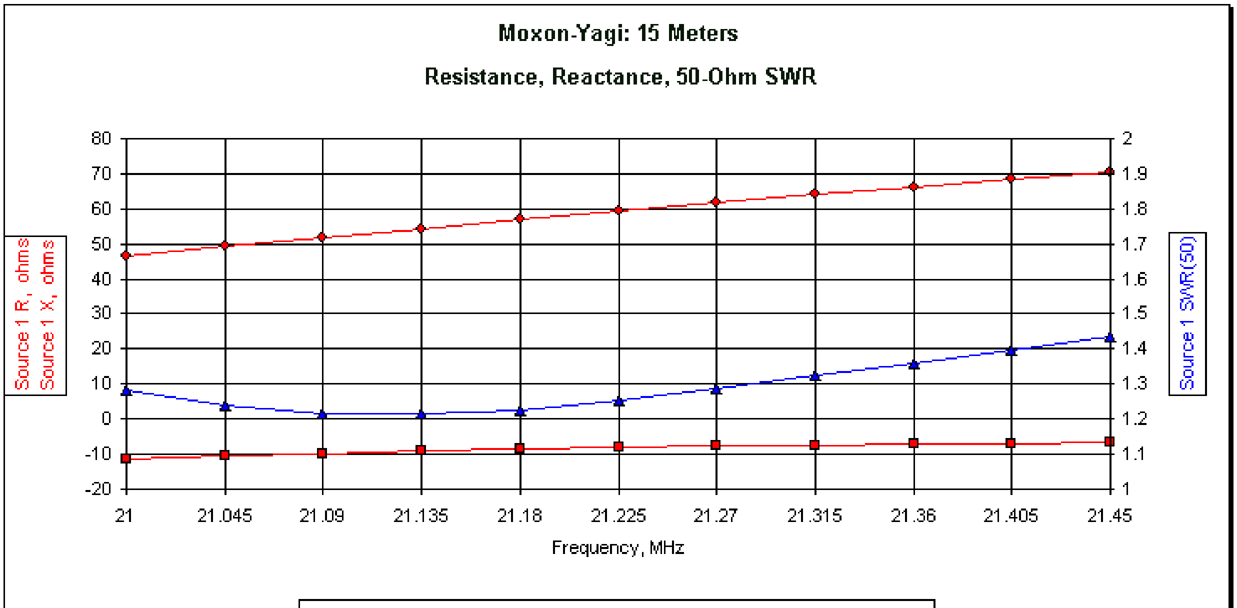


Fig. 8

If we look only at the gain figures for all four models on 10 meters, we can simultaneously compare them to each other and to the 15-meter gain values. **Fig. 9** provides the data, with indications of which model belongs with which line. Note that the gain values tend to converge at the upper end of the first MHz of 10 meters and show their greatest divergence at the lower end of the band. Given the requirements for compromise element positions and lengths, the models with the driver forward of the Moxon element show both the highest and lowest gain values. The two models with an extra director show the highest gain values, with the original model (C1) having intermediate values.

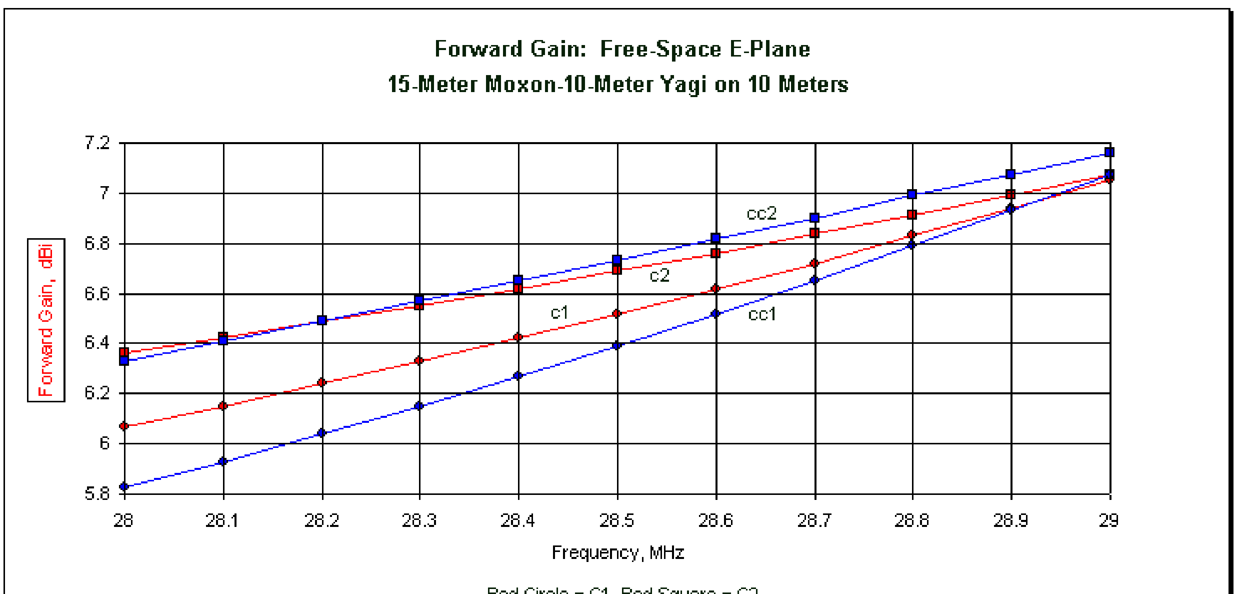


Fig. 9

The greatest range in gain is only about a half-dB, and it occurs only at the lower end of the operating passband. Otherwise, the range of gain values is consistent with the values we can derive from the Moxon rectangle, despite the fact that each element set favors opposite ends of its band. The graph suggests that gain would not be a significant reason for choosing among the possible designs.

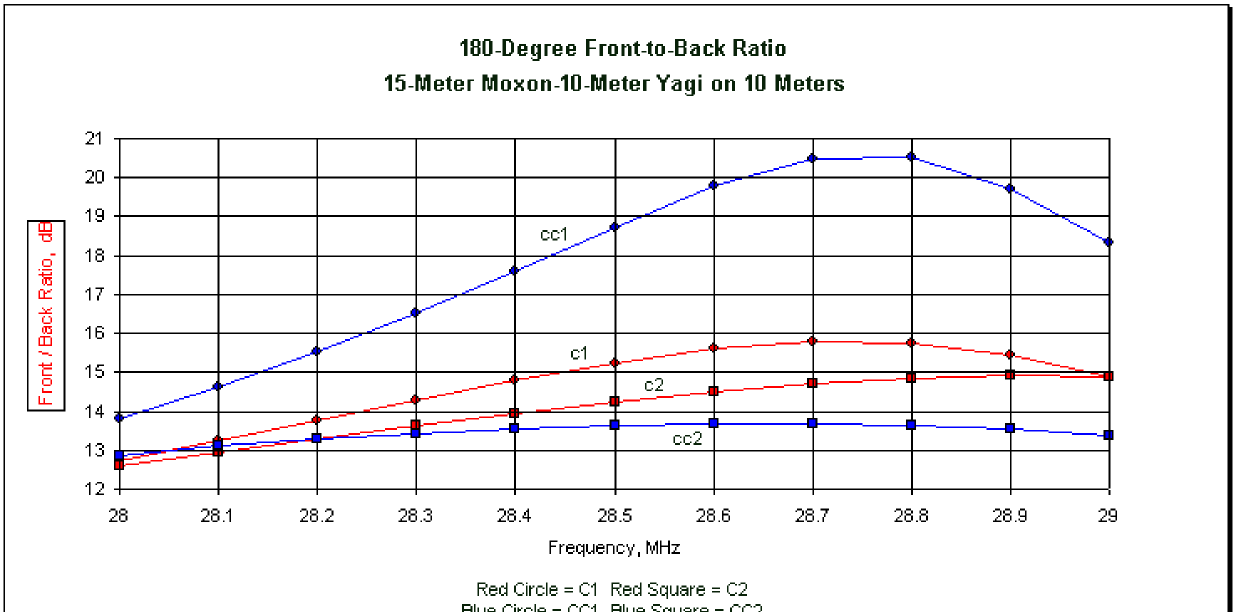


Fig. 10

Fig. 10 provides a similar graph of the front-to-back ratio values for all four versions of the 10-meter elements. The sweep shows a clearly superior model in this category, CC1, the 1-director forward-driver model that requires a 12' boom. The performance level, especially in the middle and upper regions of the passband, is more consistent with the superior front-to-back performance on 15 meters. In addition, model CC1 showed a boom center that appeared to be the most ideal of all of the models in this set. Despite these advantages, model CC1 also showed the lowest gain levels of all of the models in the set.

In contrast, model C1, the original model with a single 10-meter director and the driver behind the Moxon driver, holds an intermediate position in the gain and the front-to-back graphs. C1's front-to-back ratio is better than we find with a driver-reflector Yagi and has a wider bandwidth than we might find with a driver-director Yagi. Unlike the troublesome boom center of the 2-director models, the position on C1—while not optimal—appears adaptable for an adequate mast mounting point.

Before we settle the issues at hand, let's also examine the 50-Ω SWR curves for all four arrays. **Fig. 11** provides the data lines. The curves immediately show two facets of the design work. Both models with forward 10-meter drivers have sharper SWR curves than the two curves for models with rearward 10-meter drivers. In general, broader curves allow the most room for construction variables while still assuring acceptable performance below the SWR limits (in this case, 2:1).

Both curves for models with multiple directors (C2 and CC2) show broader and less skewed curves than their respective single-director counterparts. Despite the lower minimum SWR value for CC2, model C2 with its rearward 10-meter driver shows better SWR values at both ends of the 10-meter passband. In general, only the curves for model CC1 shows an upper-end value about which one might have some concern. The concern is not that we cannot adjust the elements to keep the SWR curve below the 2:1 limit. Instead, the concern is that in adjusting the position or the length of one or more elements to achieve this goal, we may degrade the array's performance in some other category. For example, model C1 cannot afford any further losses in gain at the low end of the 10-meter band.

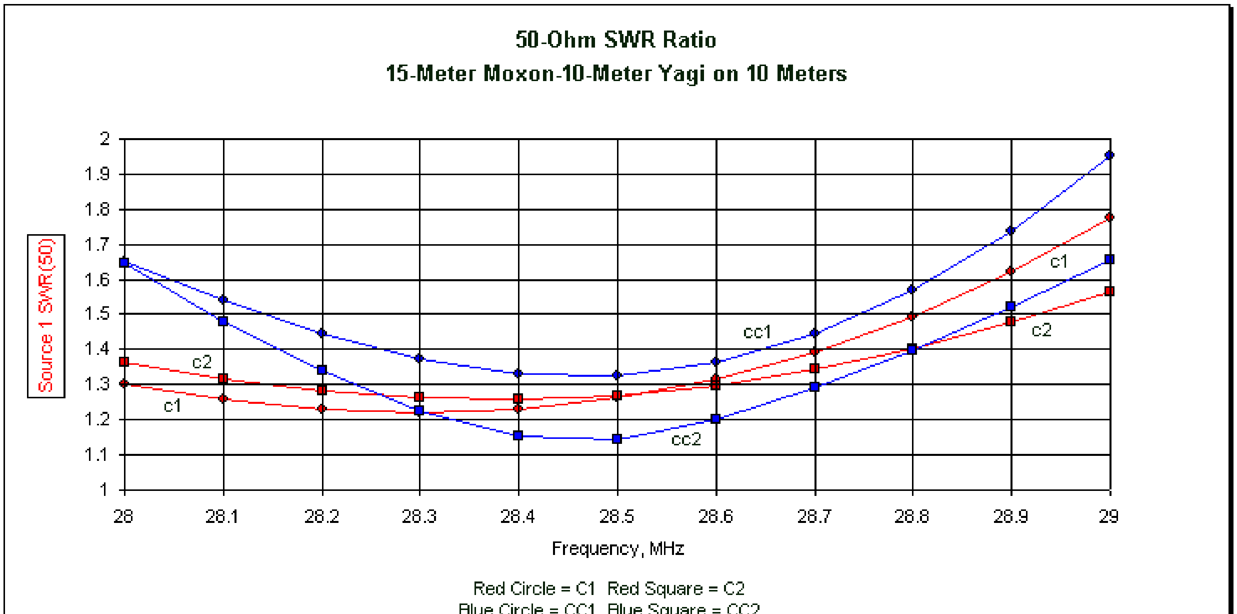


Fig. 11

The final decision will rest largely on the set of requirements that one brings to the design exercise—assuming that it occurs in preparation for a subsequent building exercise. In general, there appears to be nothing that favors the addition of a second director in this array. The gain does not go up significantly, and the front-to-back ratio actually decreases, given the requirements for a usable set of 50-Ω SWR values across the entire first MHz of 10 meters.

If a 12' boom is acceptable, model CC1 with its forward-position 10-meter driver offers the best front-to-back ratio and the easiest challenge for mast connection. However, its SWR and gain curves are less than stellar. In contrast, model C1, with a rearward 10-meter drive offers the shortest boom with slightly better gain values and lesser front-to-back numbers. As well, the mounting position behind the 10-meter driver may still require some mass compensation to place the center of mass at the mast connection point. How one weights the various factors in making a decision is a measure of both site restrictions and operating needs.

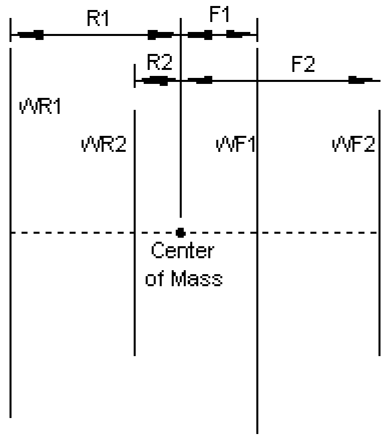
Of course, one may also create variations of any of these four designs. As I noted during the discussion, other dimensions are possible and they will result in changes to the operating curves over the passband. As well, one may also re-design any of the arrays to focus on a narrower passband. In multi-band beam design, there is no single final answer, but only designs that are better and worse for some specified set of limitations of passband, SWR, boom length, mast mounting, site area, and numerous other variables that we bring to the design table.

Boom Center vs. the Center of Mass

In these notes, we have used the center of the boom length as a stand-in for the array center of mass. Ultimately, the balance point for a multi-element array is the center of mass, which may or may not coincide with the boom center. When the array has an odd number of elements, the two positions hardly ever match.

The most precise way to determine the center of mass is to build a prototype and then to find the balance point along the boom. In many design exercises, you may need to estimate that position before making all of the final decisions that determine the exact masses involved. There is a fairly straightforward method that, with a little trial and error, can result in a reasonable approximation of the center of mass. **Fig. 12** provides a guide.

Fig. 12



Estimating the Center of Mass

If the designated point is the center of mass (CM), then the sum of the rearward weights (WR1 and WR2) times the rearward distances (R1 and R2) will equal the sum of forward weights (WF1 and WF2) times the forward distances (F1 and F2). That is,

$$WR1*R1 + WR2*R2 = WF1*F1 + WF2*F2$$

The values of the distances will vary with the boom length and the trial positions that we might use to zero in on an effective value for CM. The units of measure do not matter so long as we use the same units throughout. Indeed, in the absence of specific weight information on the proposed elements, we can use relative values based on the element lengths and diameters. For example, for the Yagi elements specified in these models, setting the 10-meter elements at 1 and the 15-meter elements at 1.5 is a usable approximation for initial purposes. Later, we can replace those values with others based on the weight of the tubing and center assemblies. In the end, the final determination must await the prototype.

Conclusion

I had hoped to cover both the simple Moxon-Yagi combination and the more complex Yagi-Yagi combination in this episode. However, each of the 4 Moxon-Yagi combinations has required enough compromises to extend the discussion into a full episode. If we wish to perform a similar comparison among the more complex Yagi-Yagi combination for 15 and 10 meters, we shall need one final session.

It is important that we give the Yagi-Yagi combination due space. We have 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 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 present 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.

So we still have a bit of work to do.