Designing Multi-Band Parasitic Beams
Part 2: A Small 15-10-Meter Design Example

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The design considerations for a multi-band parasitic beam antenna have many applications, ranging from very modest arrays to very long-boom complex antennas. In these notes, we shall design a very small beam for 15 and 10 meters, using 2 elements on each band. The total boom length will be less than 10'. However, the design will purposely make use of some variations on the basic ideas that we explored in order to show how the beam design must adapt them to a given design project.

The basic premise will be that someone who wishes to develop a short-boom array for 15 and 10 meters is likely also to be short on installation area. Therefore, the 35' spread of element lengths for the lower band may press the property lines. One option we might consider is loading the 15-meter elements to shorten them and to accept the reduce performance on that band. However, we have another option: to use for 15 meters a Moxon rectangle, which provides wide-band full driver-reflector performance with elements only about 70% of the length of linear 15-meter elements. Since 10-meter elements are considerable shorter, we can use a Yagi design for that band.

At least one of the Yagi elements must fit inside the outline crated by the Moxon rectangle. If we were design the array for 20 and 15 meters, the situation would create no challenges, since the frequency ratio between bands is about 1.5:1. However, the frequency ratio between 15 and 10 meters is only about 1.3:1. We may encounter a tight squeeze, but the existence of these notes suggests that we may successfully meet the challenge.

Expectations

Part 1 of this series provided us with reasonable expectations for monoband 2-element Yagi performance in the upper HF range. However, we do not yet have at hand any performance expectations of a Moxon rectangle. We should begin by becoming familiar with the structure and operation of this interesting parasitic beam. **Fig. 1** shows the rectangle's outline.

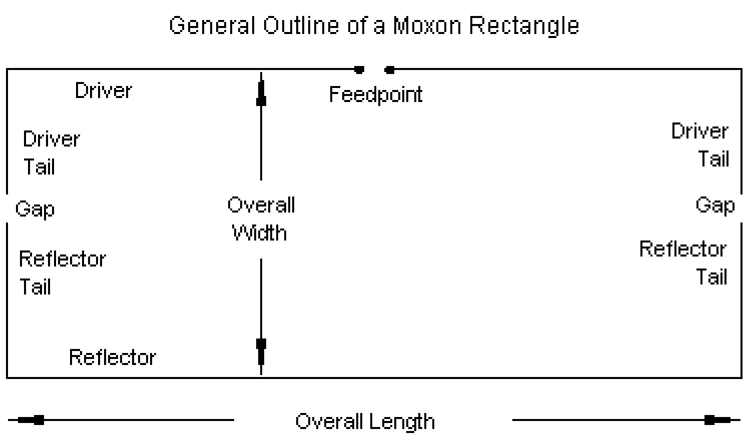


Fig. 1

The Moxon rectangle, which owes its origins to Les Moxon, G6XN (now SK), consists of two parallel elements, a driver and a reflector. The parallel portions of the elements exhibit the standard sort of mutual coupling that we obtain from the linear elements of a Yagi. However, the Moxon bends the outer end of each element toward the other element, as shown in the sketch. The driver tails and the reflector tails form a line, but leave a critical gap between the ends. The gap, in conjunction with the element diameter at those points, determines the coupling between the element ends. Hence, the Moxon rectangle makes use of two forms of coupling to obtain some unique radiation patterns. The overall length, the overall width, the tail lengths, and the gap together allow the designer to create a wide-band driver-reflector beam with a 50-Ω feedpoint impedance and generally desirable performance characteristics.

If we were using uniform-diameter elements, we might simply refer to some design algorithms that I developed several years ago to create the antenna structure. However, our Moxon rectangle (and the associated 10-meter Yagi) will use tapered diameter elements with standard U.S aluminum tubing sizes. To lighten the overall structure, I have modified the heavy-duty antenna element structure shown in Part 1. **Fig. 2** shows the structure employed not only in the design of the independent Moxon, but as well in the eventual multi-band beam.

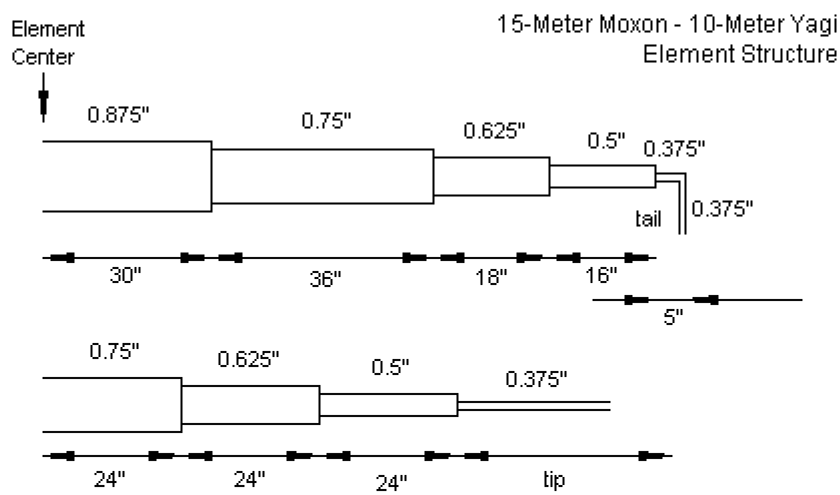


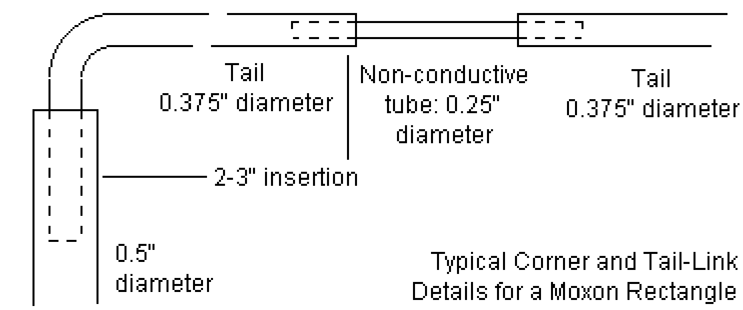
Fig. 2

Because the Moxon elements have a corner bend and since both antennas make use of 0.375" end sections, the wind-load will be reduced relative to the larger structure in Part 1. However, the resulting antennas should easily handle winds of about 75 miles per hour, with appropriate de-rating under significant ice loads.

Two structural aspects of the Moxon rectangle deserve special attention. First, the corners require a 90° bend. The radius of the bend should be small enough to preserve the antenna's dimensional integrity but large enough to prevent cracks from forming at the corner. Warming the tubing and bending around a form in a slow progression of effort generally succeeds in creating good corners.

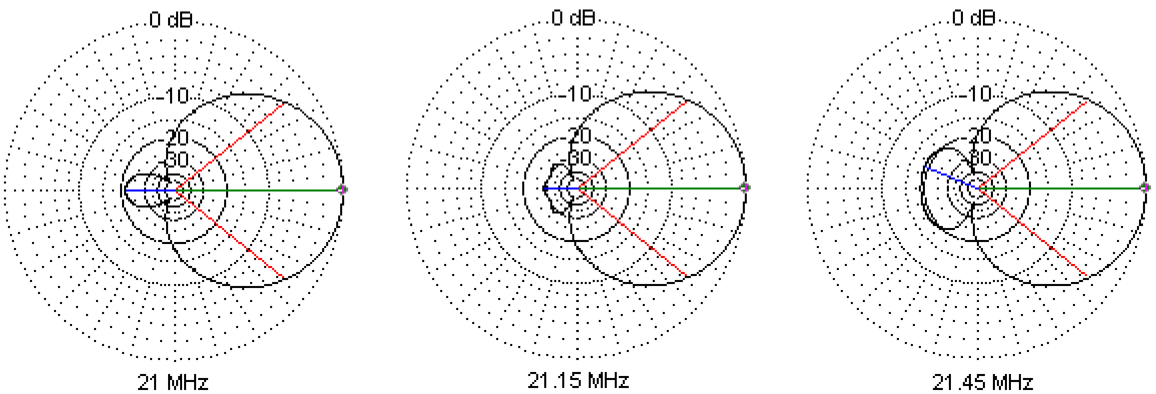
Fig. 3 shows the corner structure, including the required insertion overlap for the corner and tail sections. The sketch also shows one way to keep the gap well aligned. A section of 0.25" plastic rod (polycarbonate works well) provides a rigid link that generally does not disturb the overall flexibility of the antenna structure. One may use small stainless steel sheet metal screws as fasteners, but small hitch-pin clips provide an equally secure attachment with smaller holes. The center sections of the elements are amenable to the treatment shown in Part 1.

Fig. 3



Typical Corner and Tail-Link Details for a Moxon Rectangle

Settling on the element taper schedule is important, since a Moxon rectangle requires significant modification to operate successfully relative to the dimensions we would use for uniform-diameter elements. In general, the overall length from side-to-side will increase, and the front-to-back overall width will decrease for a given feedpoint impedance. In fact, the dimension of the Moxon rectangle will not change as we adapt the antenna to multi-band design, because the rectangle forms the lower-frequency antenna for the beam. We shall examine those dimensions in more detail later. At this point, we need to develop a set of reasonable performance expectations from the antenna.



15-Meter Moxon Rectangle: Free-Space E-Plane Patterns

Fig. 4

Fig. 4 shows three representative free-space E-plane patterns for an independent Moxon rectangle. The center pattern does not occur at the center of the band, because the design strategy for a Moxon rectangle calls for the design frequency to be about 1/3 the way up the operating passband. This procedure tends to ensure roughly equal values of 180° front-to-back ratio and 50-Ω SWR at both band edges. The forward gain of the Moxon rectangle is within about 0.2-dB of a standard driver-reflector Yagi with the same element spacing, but the beamwidth is considerably greater and the front-to-back ratio averages over 10-dB higher. The performance improvement results from using two forms of coupling between elements, which gives the reflector a current magnitude and phase angle that is close to ideal for maximizing the front-to-back ratio. **Table 1** provides modeled performance figures at the band edges and the band center for later comparison with what we obtain on 15 meters when we use the Moxon in the multi-band beam.

Table 1. Moxon Rectangle: 15-meter performance

Frequency	21.0	21.225	21.45
Free-space Gain dBi	6.32	6.02	5.74
Front-to-back ratio dB	21.42	26.90	18.43
Feedpoint Z (R +/- jX Ω)	42.9 – j6.6	52.6 + j3.1	61.0 + j10.9
50-Ω SWR	1.23	1.08	1.32

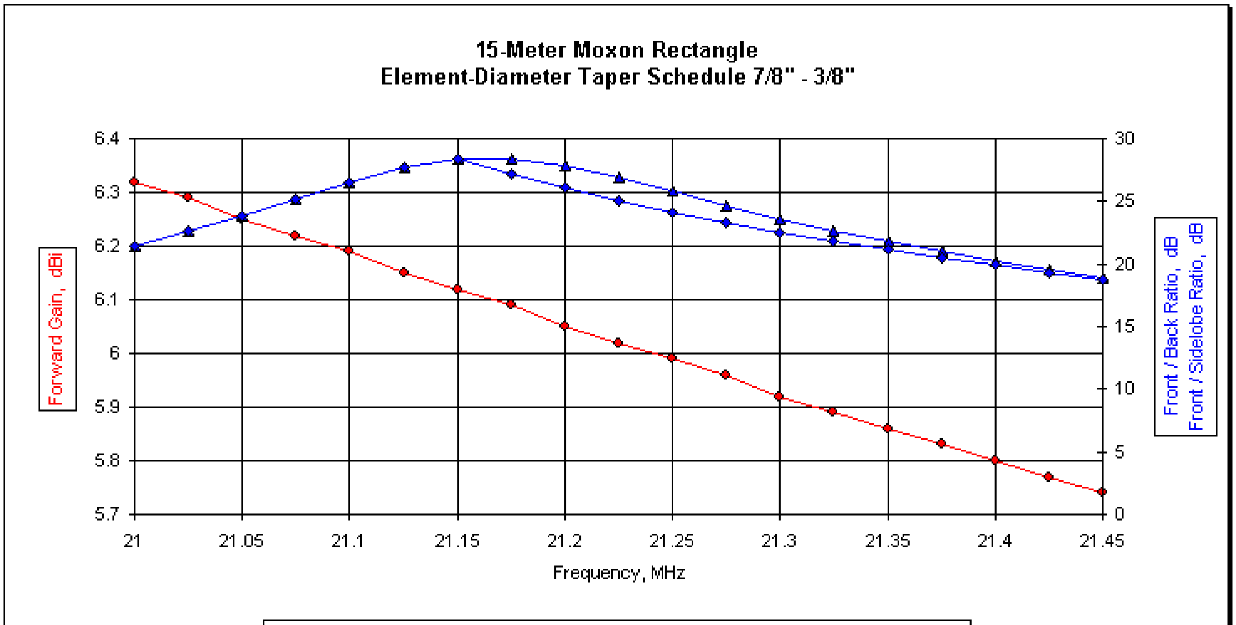


Fig. 5

Fig. 5 shows the sweep graph of the gain and the front-to-back ratio. Above the design frequency, the rearward lobes are stronger off axis, so the line labeled "Front/Sidelobe Ratio" shows the worst-case front-to-back ratio. Note that both values do not fall below 20 dB until the very upper limit of the 15-meter band. Like all driver-reflector parasitic beams, the forward gain decreases as the operating frequency in the passband increases. The gain change is less than about 0.6-dB across the entire band.

The peak in the front-to-back ratio at the design frequency (about 21.15 MHz) reappears as a null in the 50-Ω SWR curve at about the same frequency. **Fig. 6** provides curves for the feedpoint resistance and reactance, as well as the 50-Ω SWR for the monoband version of the Moxon rectangle. The peak SWR value is only about 1.3:1, largely due to the very small changes in the feedpoint resistance and reactance from one band edge to the other. In fact, both values change by only 18 Ω in 450 kHz.

The net result of the monoband design work is a beam with relatively good performance values for a 2-element antenna and only modest performance changes over the 15-meter band. With close attention to the gap distance—the most critical design factor—the antenna becomes relatively forgiving of most other construction variables that occur between versions. It adheres to the suggestion made in Part 1 that the lower-band antenna should have wide-band characteristics. With a wide-band lower-frequency antenna, the designer can often focus on the elements for the upper band without having to revise the lower-band dimensions.

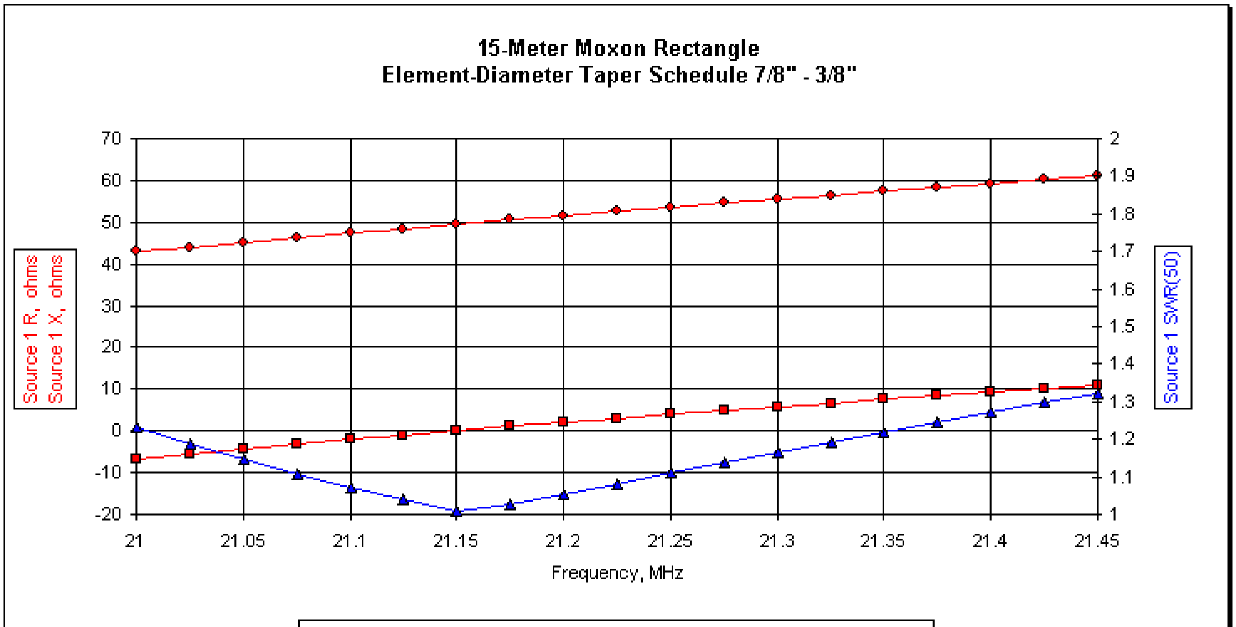


Fig. 6

The Electrical Design of a 15-Meter Moxon—10-Meter Yagi Combination

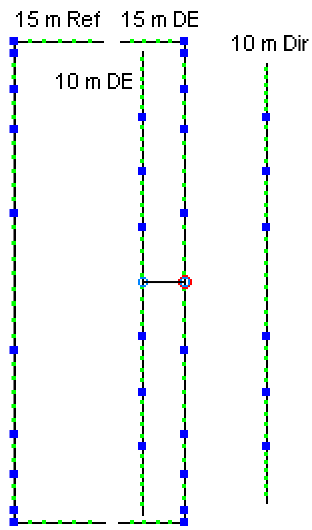
If we use a Moxon rectangle for 15 meters, we cannot easily try to nest another Moxon within the same area for use on 10 meters. Essentially, the gap coupling between the elements on each band—especially on the upper band—decay beyond retrieving. As well, the wide-band characteristics also decay. I have developed some nested Moxons for 12 and 17 meters, but they work only because these bands are so narrow. Even the first MHz of the 10-meter band gives us the widest of the upper HF bands. Hence, achieving a wide-band array is essential.

Using a Yagi structure for 10 meters presents its own challenges. Reflector elements for 2-element 10-meter Yagis are about 110" on each side of center. This dimension exceeds the Moxon width by about 5". If we wish to keep all of the elements on the same plane, we might have to replace the usual driver-reflector Yagi with a driver-director version.

We tend to think of driver-director Yagis as narrow band antennas. Hence, we might write them off too easily in the present context. Driver-director 2-element Yagis obtain high performance (superior gain and excellent front-to-back ratios) by using close element spacing. However, if we increase the element spacing and accept somewhat lesser performance, we can broaden the operating bandwidth. At the same time, we may increase the monoband feedpoint impedance. Finally, we might even be able to place the driver inside the Moxon rectangle.

The importance of placing the driver behind the 15-meter Moxon driver stems from a desire to keep the boom length as short as possible. A boom length of 10' or less is one project goal in order to form the most compact beam possible while maintaining adequate performance. The Moxon rectangle itself will be just over 6' from back to front. We shall need at least 5' as the element spacing on 10 meters to obtain coverage of the entire band. To keep the entire package within the target 10' boom limit, the 10-meter driver must rest inside the Moxon rectangle and yet be short enough that the element tips do not touch the Moxon driver tails. **Fig. 7** shows the outline of the semi-final design. (No multi-band design is ever absolutely finished.) The outline shows with blue dots the element sections, while the green dots indicate the segmentation of each wire in the design model.

Fig. 7



General Outline: 15-Meter Moxon Rectangle
and 10-Meter Yagi Combination

Table 2 provides the dimensional data for the array.

Table 2. 15-meter Moxon—10-meter Yagi 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			

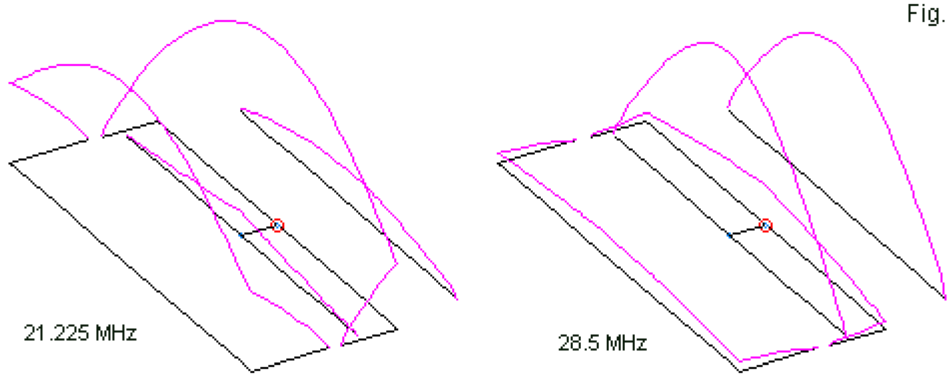
Array Spacing	
15-m ref	0"
10-m DE	56
15-m DE	74
10-m Dir	110

Notes:
1. Length values progressive from element center.
2. Reference Moxon dimensions to Fig. 7.
3. Spacing values references to parallel elements.
4. Driver-to-driver TL = 125 Ω, VF 1.0
5. Feedpoint: 15-meter (Moxon) DE

The overall array feedpoint appears on the 15-meter driver. The transmission line from the array feedpoint to the 10-meter driver feedpoint consists of a 125-Ω line with a velocity factor of 1.0, indicating a fabricated line for the purpose. It is possible to construct a 125-Ω transmission line from 2 round wires. The lower impedance limit for round wires is around 80 Ω, depending upon the exact wire diameter, before the wire touch. At the desired impedance, square wires permit a gap or face-to-face spacing that is about 1.45 times the gap between round wires. With face widths of about 0.25", the required spacing is 0.22". For 0.5" faces, the spacing is 0.43". and for 0.75" materials, the spacing increases to 0.65".

The dimensions of the 15-meter Moxon rectangle do not change between its monoband use and it presence in the 2-band array. However, the elements of the 10-meter portion of the beam require careful placement to achieve a collection of goals that do not always move in the same direction. We need to arrive at a driver placement (along with the director) that will allow the 15-meter impedance to be relatively undisturbed relative to its monoband values but also produce an acceptable or 50-Ω-compatible impedance from 28.0 to 29.0 MHz. As well, the driver (as indicated in the dimensions) must be short enough to fit between the driver tails without significantly detuning them. Finally, the director must have a length and position that provide acceptable 10-meter performance while allowing the desired feedpoint impedance.

Fig. 8



Relative Current Magnitudes on the Elements of a 2-Band
Moxon Rectangle-Yagi on 15 and 10 Meters

As shown in **Fig. 8**, the two bands do interact, but not severely. On 15 meters, we find a small current magnitude on the 10-meter driver, but generally less than 1/10 the peak value on the 15-meter driver. The current on the 10-meter director actually aids the forward gain of the Moxon, but not so much as to be operationally significant. On 10 meters, the 15-meter driver shows some activity. Its chief function is to require adjustment of the 10-meter driver length to compensate, since we now have a pair of roughly (if not crudely) phased driver elements. The 10-meter elements show the highest activity. The low current magnitude on the 15-meter reflector indicates why the array does not have a 10-meter reflector. Such a reflector element would show no higher current magnitude and hence not significantly affect the array performance. As we shall see, the off-band activity level is not so high as to make the dimensions of the array excessively finicky, although in any multi-band parasitic array, one must use far greater care with construction than one needs to employ with a monoband beam.

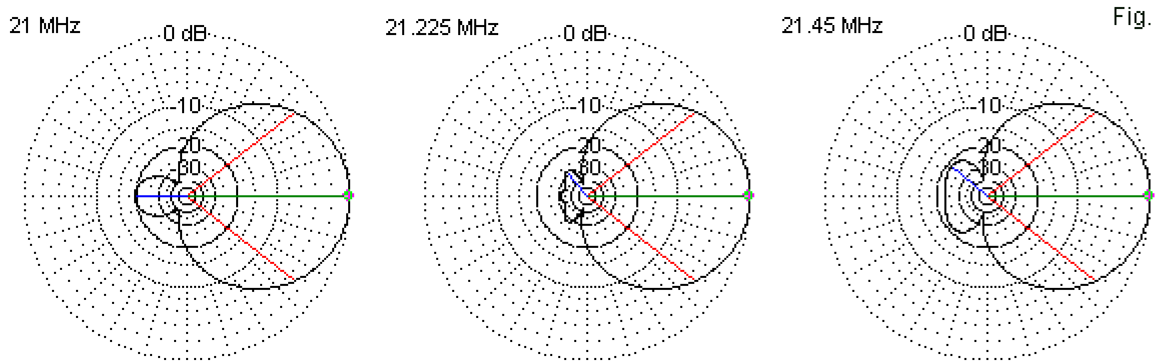
15-Meter Performance: On 15 meters, we obtain essentially the same performance that we would accrue from a monoband version of the Moxon rectangle. **Table 2** samples the performance numbers, while **Fig. 9** supplies the associated free-space E-plane patterns/

Table 3. Moxon-Yagi: 15-meter performance

Frequency	21.0	21.225	21.45
Free-space Gain dBi	6.47	6.21	5.96
Front-to-back ratio dB	19.45	31.36	23.19

Feedpoint Z (R +/- jX Ω)	46.5 – j11.5	59.4 – j8.0	70.6 – j6.8
50-Ω SWR	1.28	1.25	1.44

Fig. 9



Free-Space E-Plane Patterns: Moxon-Yagi Combination: 15 Meters

There is virtually no difference between the radiation patterns in **Fig. 9** and those in **Fig. 4**. The gain entries show a slight improvement, although it amounts to an undetectable 0.2 dB or less. The gain differential across the band remains at about 0.6-dB. The gain and front-to-back curves in **Fig. 10** go some distance toward showing the difference between monoband and multi-band 15-meter front-to-back values. The peak front-to-back value has moved upward in the band by about 100 kHz. As a result, the dip below the 20-dB level now occurs at the low end of the band rather than the upper end.

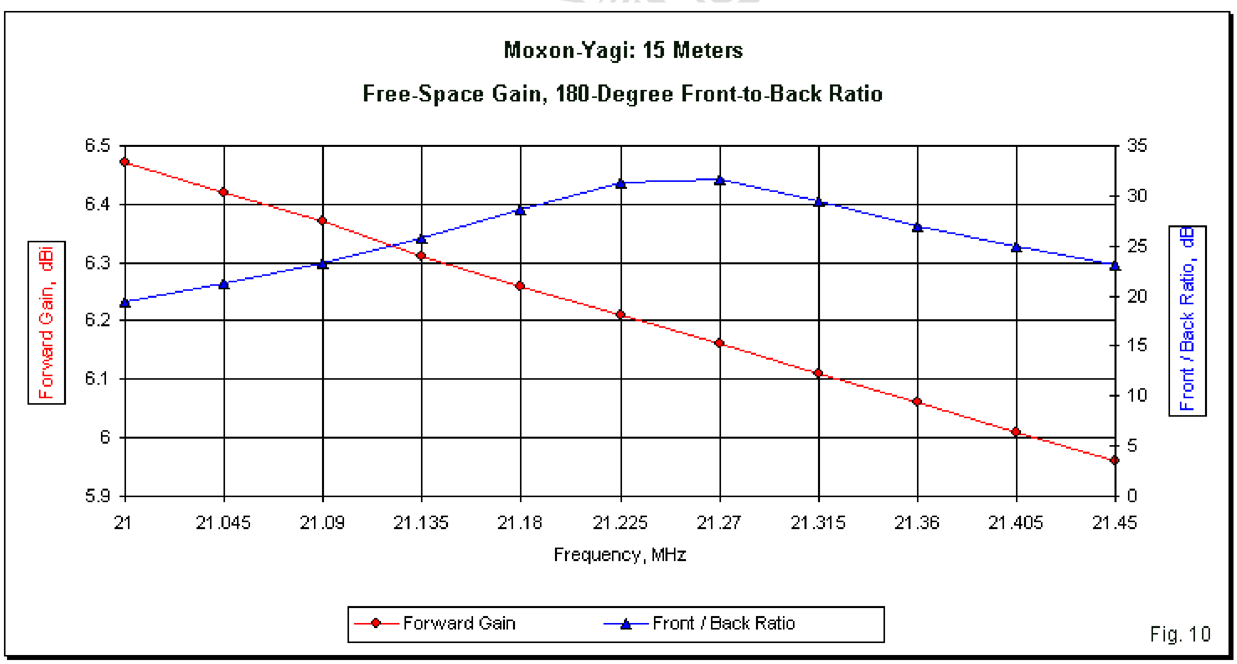


Fig. 10

The main feedpoint on the 15-meter driver now contains a parallel combination of the impedances of the 15-meter driver and the transformed off-band impedance of the 10-meter element. As a consequence, the impedance values shift downward, but not so far as to disable the Moxon from use with a 50-Ω cable or even enough to require adjustment of the Moxon driver elements. The SWR nowhere rises to 1.5:1, as shown in the modeled resistance, reactance, and SWR curves in **Fig. 11**. The resistance across the band changes by about 24 Ω, an increase over the differential for the monoband Moxon. However, The reactance change drops to about 5 Ω, thereby reducing the effect of the resistance change on the SWR across the band. However, the overall shift due to the presence of the 10-meter driver and the transmission line is a small displacement of the SWR lower in frequency by about 50 kHz.

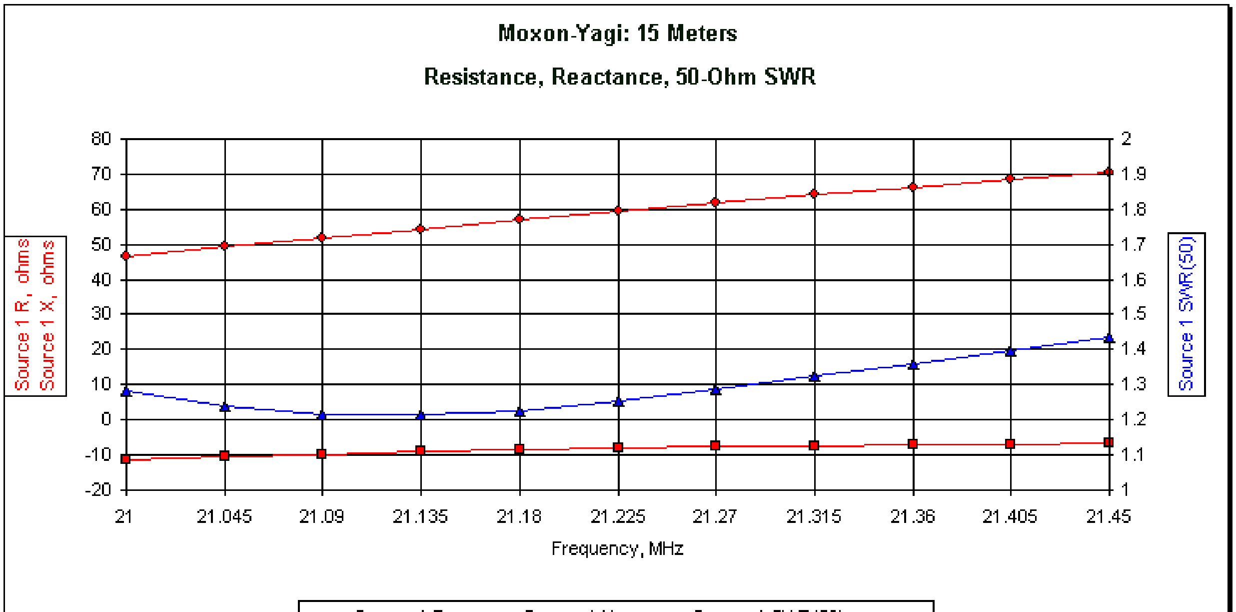
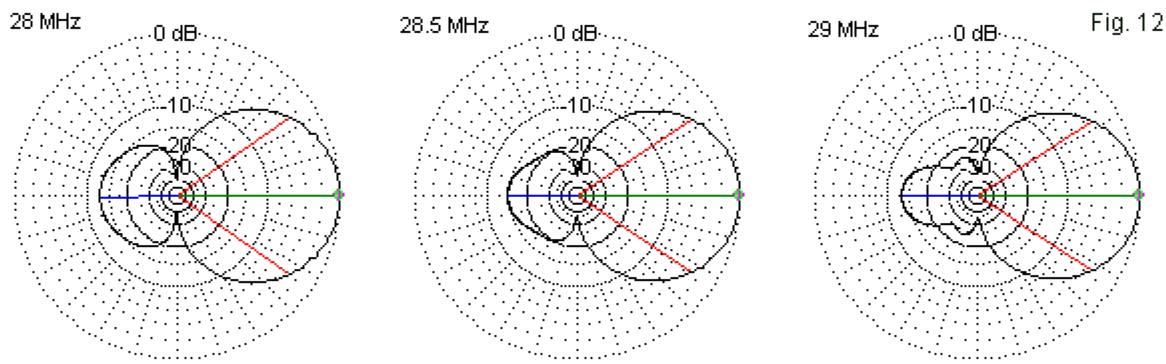


Fig. 11

Virtually all of the performance changes created by the presence of the 10-meter elements fall within the normal construction variations for a monoband version of the lower-band antenna. Therefore, modifying the 15-meter dimensions to better center the values loses any justification.

10-Meter Performance: 2-element Yagi performance on 10 meters does not have as rigorous a comparator as the Moxon performance did on 15 meters. The performance goal included finding a director placement and length that would achieve at least the performance level of the 10-meter 2-element Yagi sampled in Part 1. That beam showed a free-space gain range from about 6.4 dBi at 28.0 MHz down to about 5.7 dBi at 29.0 MHz. The front-to-back level averaged about 11 dB with very little change across the band.

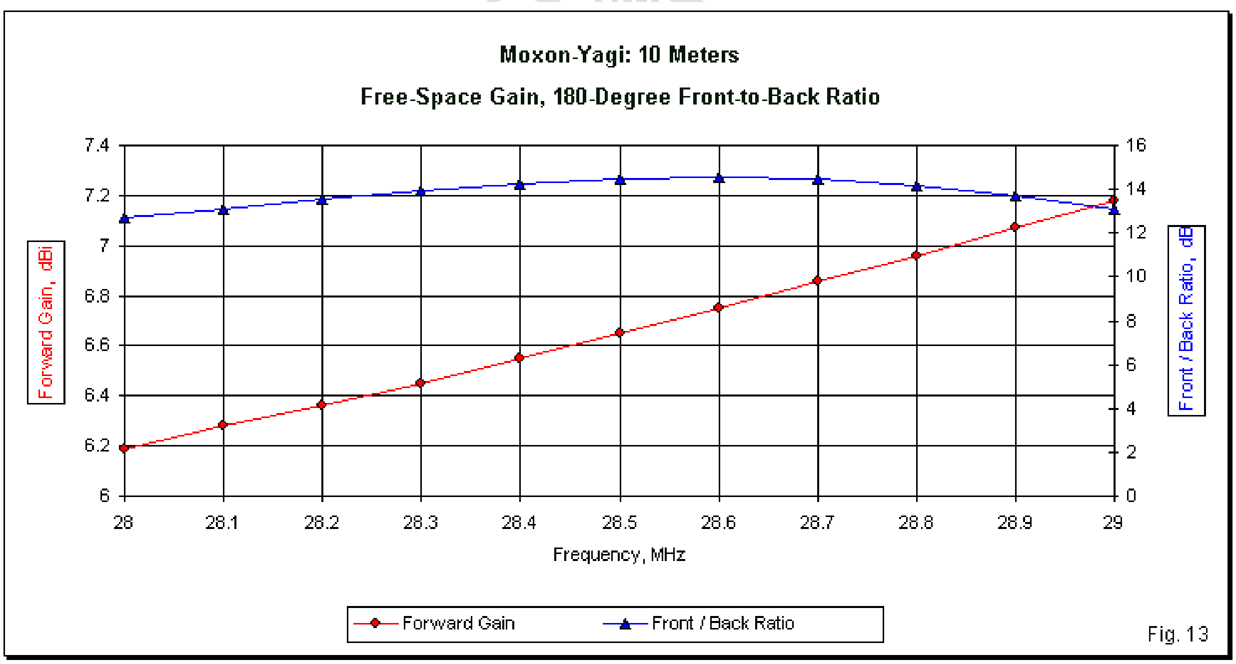


Free-Space E-Plane Patterns: Moxon-Yagi Combination: 10 Meters

The free-space plots in **Fig. 12** suggest that the multi-band array achieves a set of well-behaved radiation patterns, with a suggestion of some improvement to the front-to-back levels. The numbers in **Table 4** confirm the impression. The front-to-back levels average 2-3 dB improvement over a standard driver-reflector Yagi.

Table 4. Moxon-Yagi: 10-meter performance

Frequency	28.0	28.5	29.0
Free-space Gain dBi	6.19	6.65	7.18
Front-to-back ratio dB	12.68	14.47	13.11
Feedpoint Z (R +/- jX Ω)	39.9 – j7.7	39.2 + j5.7	35.1 + j23.6
50-Ω SWR	1.33	1.32	1.92



The gain values, as shown in **Fig. 13**, show a considerable difference from the values for a driver-reflector array. Because the multi-band 10-meter section uses a director, the gain values increase with a rising operating frequency. The use of the director provides a gain improvement of about 0.5-dB over a monoband driver-reflector Yagi, although the gain change across the band is close to 1-dB. To what degree the gain values result from the director alone and to what degree the 15-meter reflector activity plays a role is impossible to determine, since without the reflector, the array is seriously detuned. Nevertheless, in most beams, the director has a far greater influence on array gain than the reflector, whose role is significantly diminished.

The higher band in any multi-band Yagi tends to show a narrower operating passband and more rapid changes in gain than a corresponding monoband beam. The gain differential across 10 meters is one indicator of this phenomenon. The other indicator is the feedpoint properties, where we use the single parallel feedpoint position to take our readings. This feedpoint has as one parallel component the off-band impedance of the 15-meter Moxon driver. The other component is the transformed impedance of the 10-meter driver. With the connection line shown, the net impedance at the feedpoint remains well within limits for effective 10-meter operation.

Fig. 14 provides the curves of the resistance, reactance, and 50-Ω SWR across 10 meters. The SWR value reaches its lowest level at about 28.3 MHz. Although the SWR never drops to a 1:1 value, it remains below about 1.6:1 through 28.8 MHz and is below 2:1 at the upper end of the passband. The resistive component is quite stable and changes by only 4 Ω across the band. However, the reactance changes by about 30 Ω from the bottom to the top of the passband. Its nearly linear rise across the band results in the slope of the SWR curve.

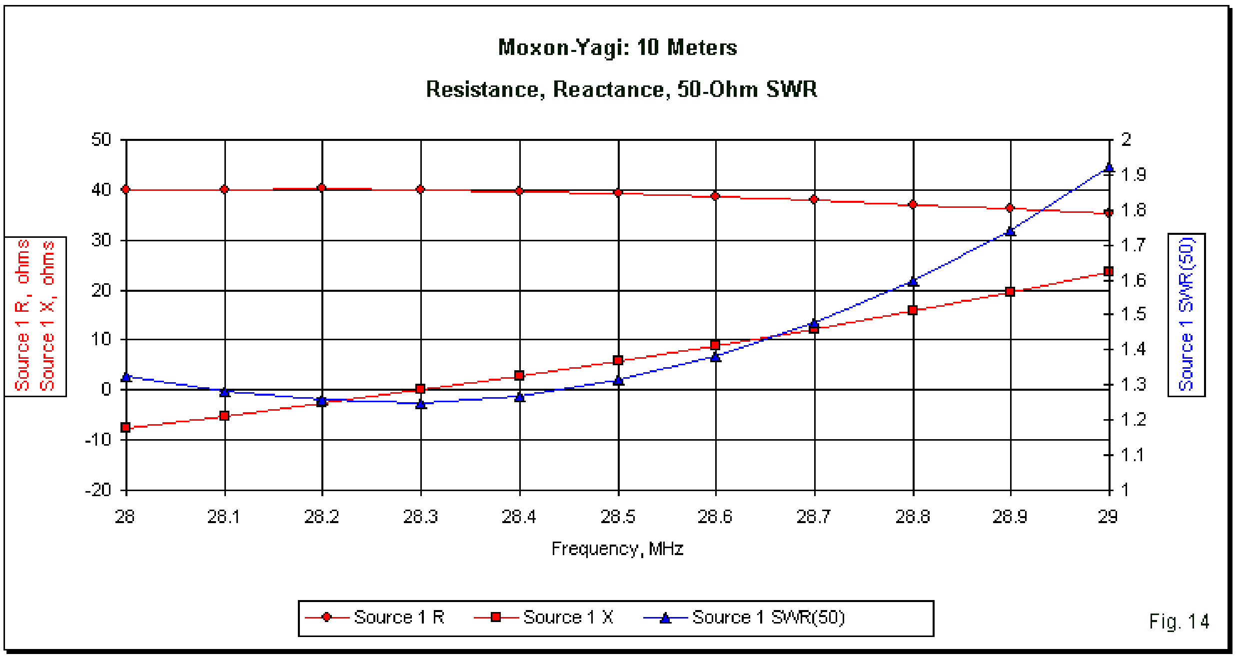


Fig. 14

The final combined product is a multi-band 15-10-meter parasitic beam that does not differ in principle from various commercial products, although the latter generally try to cover 3 bands. However, adding a third band to the array would have obscured the application of the design principles in Part 1 to the sample beam.

The array that we have been examining has a final challenge for a builder. The physical center of the antenna in the front-to-back dimensions is just behind the 10-meter driver. The center of mass is closer to the 15-meter Moxon driver. Standard boom-to-mast mounting systems tend to use a plate and U-bolts to strap the beam to the mast. However, that system would be ill advised in this case, since the mast and plate would fall directly in the region of the transmission-line that connects the two drivers. Good mounting techniques might include a top-mounting Tee system or an offset system. Alternatively, one might insert enough short sections of tubing into the rear of the boom to move the center of mass back far enough to allow a standard mount behind the 10-meter driver. Since the overall beam weight is not great, one might use a polycarbonate plate rather than the usual aluminum material.

A Modification to and Test of the Array Design

The patterns of current magnitude shown in **Fig. 8** suggested that the 10-meter and 15-meter sections of the overall beam were relatively but by no means completely independent of each other. The degree to which the sections are independent shows up also in the degree to which we may make changes without totally disrupting performance on either band. For example, dropping the connecting-line characteristic impedance to 100 Ω does center the 50-Ω SWR minimum at the middle of the passband, resulting in a small increase in the SWR at the lower end of the band but a maximum value of 1.8:1 at 29.0 MHz. The price for the change is an average drop in the front-to-back ratio of about 0.5 dB. The basic design retains the 125-Ω line for two reasons. First, the wider spacing between transmission-line conductors allows for slightly easier construction. Second, we might replace the parallel 125-Ω Line with a length of RG-63 coaxial cable (with the broad not grounded). RG-63 has a characteristic impedance of 125 Ω nominal with a velocity factor of 0.8.

The revision of the transmission-line properties does require small revisions in the dimensions of the array. **Table 5** lists the complete dimensions for the array as modified, with the changes highlighted. The revisions require no changes to the element lengths. However, both 10-meter elements move back (toward the Moxon elements) by 3". The change in the 10-meter element positions increases the physical length of the transmission line from 18" to 21". Although the velocity factor increases the electrical length of the line even more (to nearly 27"), the change in the 10-meter element positions—especially the driver—has also changed the impedance at the driver feedpoint. Therefore, the required transformation for an acceptable composite feedpoint impedance has also changed.

Table 5. 15-meter Moxon—10-meter Yagi dimensions: modification

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
Dir tip	0.375	96

Array Spacing

15-m ref	0"
10-m DE	*53*
15-m DE	74
10-m Dir	*107*

Notes:
1. Length values progressive from element center.
2. Reference Moxon dimensions to Fig. 1.
3. Spacing values references to parallel elements.
4. Driver-to-driver TL = *125 Ω, VF 0.8*
5. Feedpoint: 15-meter (Moxon) DE

We do not need further graphs and patterns, since the revisions have virtually no effect upon the 15-meter performance of the array. Compare the modeled values in **Table 6** with those in **Table 3** to confirmed to what degree the 15-meter Moxon is unaffected by the modifications.

Table 6. Moxon-Yagi: 15-meter performance: modification

Frequency	21.0	21.225	21.45
Free-space Gain dBi	6.47	6.21	5.97
Front-to-back ratio dB	19.50	31.42	23.30
Feedpoint Z (R +/- jX Ω)	45.2 – j13.1	58.1 – j11.1	69.4 – j11.4
50-Ω SWR	1.34	1.29	1.46

On 10 meters, the performance differences are numerically more evident but operationally of equal insignificance. Compare **Table 7** with **Table 4** for some relevant details. The 10-meter gain decreases by about 0.2-dB, but the front-to-back ratio increases slightly, especially at the upper end of the band. The 50-Ω SWR curve shows its lowest value at the lower end of the band, but the 29.0-MHz value is the same with both direct-connection lines.

Table 7. Moxon-Yagi: 10-meter performance: modification

Frequency	28.0	28.5	29.0
Free-space Gain dBi	6.01	6.47	7.02
Front-to-back ratio dB	12.72	15.35	15.13
Feedpoint Z (R +/- jX Ω)	45.3 + j0.8	43.8 + j11.3	39.2 + j27.4
50-Ω SWR	1.11	1.32	1.92

In the end, no operational difference emerges between the two methods of making the direct connection between the driver elements. In either form, the Moxon-Yagi combination for 15 and 10 meters is a modest but highly serviceable 2-band parasitic array. With significant care in construction (as befits any multi-band array), the antenna should be reproducible in the average amateur home shop.

Conclusion

The essential purpose of these notes is not to create a building project so much as it is to illustrate the principles of multi-band parasitic beam design on a small scale. The small scale of our sample array has allowed us to examine a number of facets of the design process in detail while keeping the text to a reasonable size. If the exercise results in a usable antenna for those whose situations call for compact size, so much the better. With a modest (10') boom and short Moxon elements, the array that we have used as a focal point may in fact fulfill a need.

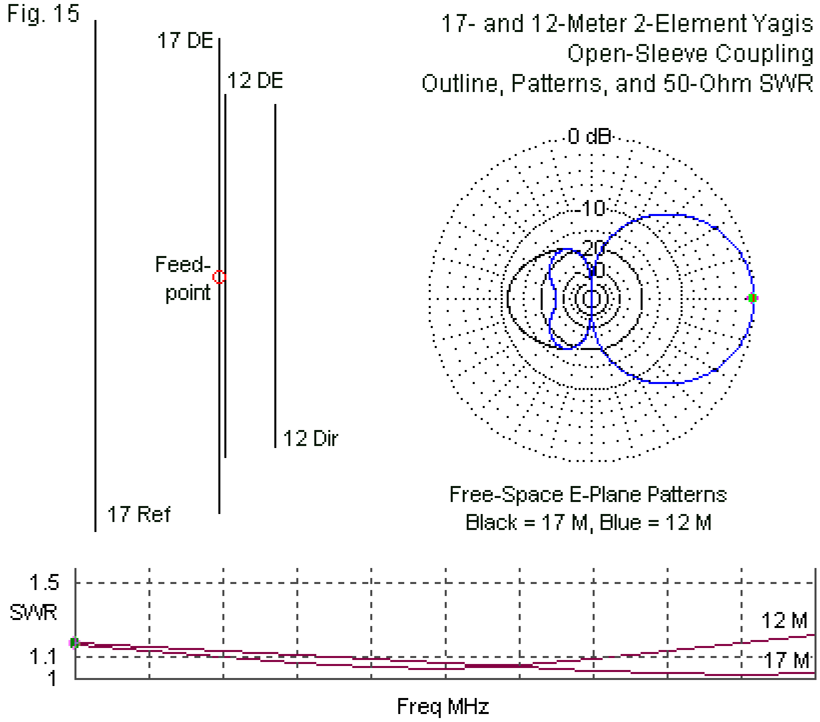
The reasons for using 15 and 10 meters as the test bands for the simple design and others still to come involve both bandwidth and frequency separation. Because the ratio of frequencies is only about 1.3:1, the bands created a physical challenge for our Moxon-Yagi design, one that the final element dimensions overcame. A 20-15-meter combination would have been easier to physically set up, with good clearance between the 15-meter Yagi driver and the 20-meter Moxon tails.

In addition, the 15-10-meter combination uses a stable design on the lower band with a narrower bandwidth (about 2.1%) with a less stable upper-band elements set that had to cover a greater operating bandwidth (about 3.5%). The bandwidth difficulties would have been less daunting had we used a 20-15-meter combination, where the bandwidth would decrease from 2.5% to 2.1% as we moved from the lower to the upper band.

Because the sets of elements are fairly well isolated or free of interactions (except for the drivers, of course), the array has only hinted at some of the principles that we explored in Part 1. For example, the effects of "forward stagger" only managed to increase gain by less than 0.2-dB, a value that is less than convincing that forward stagger is the source. Entire beams, such as the monumental 5-band array by ON4ANT, have used forward stagger exclusively—with separate feedlines on drivers for each band—to achieve excellent results. (For further information on the ON4ANT array, see http://www.cebik.com/content/a10/yagi/on4ant.html, "Three Forward-Stagger 5-Band Yagis from ON4ANT.")

In addition, we have designed the 2-band Moxon-Yagi combination using direct-feed techniques. We originally noted that open-sleeve coupling techniques tended to show narrower operating bandwidth properties on upper bands than direct-feed or closed-sleeve methods. However, for the home antenna builder, these techniques have application, especially on beams designed for the narrower amateur bands, such as 30, 17, and 12 meters. (For some applications of open-sleeve coupling, see http://www.cebik.com/content/a10/yagi/bb.html, "Director/Driven Element 2-Element Yagis: Some Ideas for 12 and 17 Meters." See also "Basic Beams for 12 and 17 Meters," *QST* (August, 2000), pp. 57-62.) **Fig. 15** shows the outline, patterns, and SWR curves of a driver-reflector Yagi for 17 meters open-sleeve coupled to a driver-director Yagi for 12-meters.

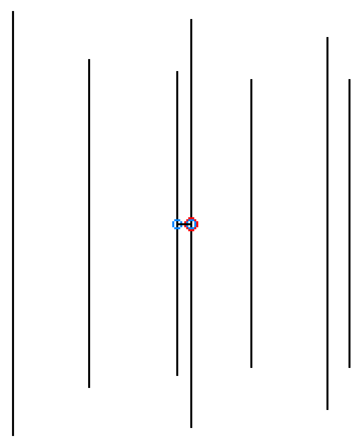
Fig. 15



The listed references provide some potential construction details of this array. What the graphic cannot show is the need for careful field adjustment of the 12-meter driver position and length to obtain an acceptable 50-Ω SWR value for the upper band. Nevertheless, once one has found correct dimensions anywhere within 12 meters, the settings are good for the entire band. Although there are successful commercial beams available for the wider bands in the upper HF region, I would recommend that use of the open-sleeve coupling technique for multi-band amateur beams be left to the commercial antenna makers, who have the facilities, test equipment, and experience to make the adjustment phase of the effort routine. On the other hand, the technique is more readily adaptable to beam combinations for the narrower amateur bands where one may set aside concerns for widely separated band-edge SWR values and focus on a single test frequency when making adjustments.

All of the beams that we have considered in the part of our work are fairly simple, when considered on a band-by-band basis. The 2 lower band elements form a wide-band parasitic beam that is both broadband and stable. Adjustments to the upper-band elements had little if any effect on the lower-band elements. In general, this principle is applicable to multi-band beams of any complexity level, although the need to make small adjustments may rise with the number of elements per band and the number of bands covered by the array. Even the open-sleeve sample in **Fig. 15** uses a wide-band design for 17 meters that provides both a 50-Ω feedpoint and stability in the presence of the 12-meter elements.

Fig. 16



3-Element 15-Meter--4-Element 10-Meter Yagi Combination

The next step in multi-band array complexity is to increase the element count from 2 to at least 3 elements per band. **Fig. 16** shows the general outline of one potential design for the larger array, again using 15 and 10 meters as the operating bands. As we shall discover in Part 3, the 4th element for 10 meters is not optional. However, it will force us to make some design decisions along the way.