MYY-TRI

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"MYY-Tri" stands for a Moxon rectangle-Yagi-Yagi tri-band array for 20, 15, and 10 meters. We may pronounce the label as "My Try." In effect, the antenna that we shall examine in these notes is a design exercise aimed at seeing if I could apply some of the principles recorded and illustrated in the 6-part series, "Designing Multi-Band Parasitic Beams" to a 3-band array. The series focused on 2-band beams in order to keep the principles as clear as circumstances permitted. However, most amateurs wish to cover at least three bands with their directional arrays. So I started working on a tri-band beam using a Moxon rectangle for 20 meters, with linear Yagi elements for the two upper bands. The result turned out to be two designs rather than just one, and there are at least 5 notable variations in all.

Be advised from the beginning that these notes cover only the design phase of the process of developing a multi-band beam. There are two facets to this caution. First, although many good monoband Yagis and Moxon rectangles can move directly from a NEC-based design to a working prototype with little or no further field adjustment, multi-band beams tend to require some working of the prototype to set the physical antenna to the performance parameters shown in the design. The close spacing of elements for different bands creates interactions that the models do not always register with precision. In addition, the boom-to-mast assembly is usually near the driven elements, which often creates some interactions that are not within the model at all. Second, the nature of these designs puts NEC at a disadvantage. NEC (either –2 or –4) is most accurate when using the Leeson corrections for HF elements with a stepped diameter structure. Unless, the taper schedule is extremely gentle, even NEC-4 will show slight differences between direct models and models using substitute uniform-diameter elements. However, because the Moxon rectangle used for 20 meters has non-linear elements, the correction system is unavailable. Therefore, the design work used NEC-4 alone. For these reasons, and because my facilities are not adequate to manage a physical prototype of the beam, we must stop at the end of the design work. See Part 1 of the original series on multi-band designs some basic construction suggestions.

Background: The basic tri-bander that we shall discuss provides essentially 2-element Yagi performance on each of the three bands. I shall use 7 elements and benefit to a small degree from the forward stagger effect to place the out-of-band elements—to the degree feasible—at the service of the band in use.

Such beams already exist on the commercial market. Some years ago, I developed the design for a Moxonized version of the well-known Force12 C3 antenna. (See "Moxon-Modifying the C3-Type Tri-bander" at http://www.antennex.com/archival/archive5/Jun02/Jun102/c3m.html.) The 7-element beam used a 16' boom. Some time after that design, Optibeam of Germany developed their OB6-3M beam using 6 elements on a 10' boom. The outlines of both beams appear in **Fig. 1**, along with the outlines of the designs that we shall explore. The present designs differ in several respects from either previous design. For example, the design based loosely (but not authoritatively) on the C3 retains the Force12 open-sleeve coupling. Both present designs use direct feedpoint connecting transmission lines. In that regard, they tend to resemble the Optibeam tri-band antenna.

Some Alternative Designs for a Moxon-Yagi-Yagi Tri-Band Array for 20, 15, and 10 Meters

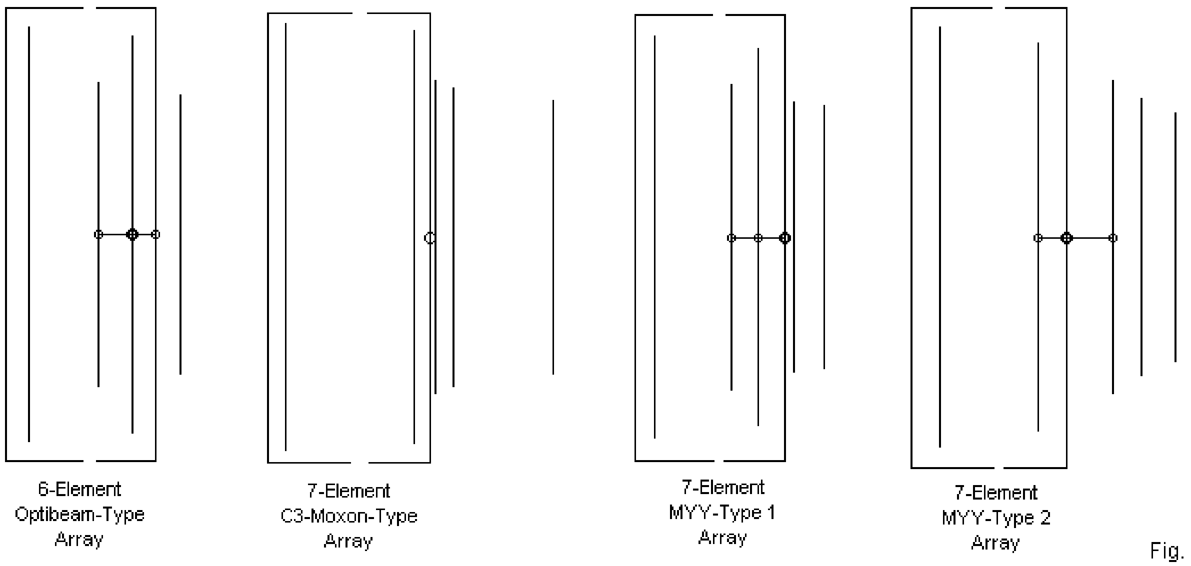


Fig. 1

However, the Optibeam design uses 6 elements with the single 10-meter director being a full-size element. Even the version (Type1) of the MYY that uses a similar driver placement has 7 elements, with relatively close spacing and a very significant taper to the lengths of the 10-meter directors. The Type-2 MYY uses a 10-meter driver position that is forward of the Moxon. As well, the tubing used in the present designs is U.S.-standard 6063-T832 tubing that is available in 0.125" diameter increments.

Inevitably, all four designs will use some principles in common, beginning with the Moxon rectangle for 20 meters. In the earlier design work with open-sleeve coupling, I used uniform-diameter Moxon elements for modeling convenience. That work was only to prove the principle. The present design uses a set of tapered-diameter elements applied in the past to the 20-meter design in "Stepped-Diameter Moxon Rectangles for 20 through 10 Meters" (see http://www.antennex.com/archival/archive8/Mar06/Mar106/moxstep.html.) The dimensions have been slightly adjusted to compensate for the influence of two other off-band drivers. The Moxon driver (like the 20-meter Yagi driver in the C3) marks a dividing point in arrays designed for good 2-element performance, a division that more complex beams often cannot enjoy. The 15-meter elements nest inside the two 20-meter elements, with some pattern enhancement by lower-level activity on the forward 10-meter element or elements. Most and sometimes all of the 10-meter elements are forward of the 20-meter driver, eliminating to a large degree the potential for the higher-band elements to act as reflectors, a condition that reduces performance unless the designer applies further compensation.

Since I do not have an authoritative model of the Optibeam array and since the modified C3 array was also based on approximation, I shall not try to present any performance numbers for the commercial arrays. Needless to say, the original (linear-element) C3 beam has been highly successful, and the Optibeam Moxon-Yagi design is well worth consideration for a reduction in side-to-side element length without a loss of performance. The German beam is a paradigm of sturdy construction designed to survive European winters, and its only drawback for some U.S. users is its weight.

Feeding and Modeling: In all of the variations on the basic tri-band design, the Moxon rectangle remains fixed. After initial variations from the monoband dimensions, I made no further adjustments, although in some variations of each type, further small changes are justified to raise the feedpoint impedance from its monoband value. However, the amount of these changes is likely to fall within the same range as the changes required in converting the designs to a physical antenna. As well, I limited the increment of element length change to 0.25" per half element. A commercial design might use increments as small as 0.1".

The performance of the Moxon rectangle does not vary from its monoband values by an operationally significant amount. The peak front-to-back ratio and the monoband resonant impedance occur about 1/3 the frequency span from the low to the high end of 20 meters. In a monoband rectangle, the front-to-back ratio and the SWR values are about equal at the band edges. Because the composite feedpoint impedance of the entire array is more complex, the SWR curves will not reflect this design decision. However, the front-to-back ratio remains reasonably well centered in the band. For 15 meters, the 2 linear elements form a driver-reflector Yagi, again, affected in small ways by the surrounding elements. As with virtually all multi-band beams, the rates of change in performance are higher than we would find in a monoband version of a 15-meter Yagi. On 10 meters, we have a 3-element Yagi with no reflector. The two directors provide performance that is able to cover all of 10 meters. The 2-director system used in these designs uses moderately close spacing. The forward-most director is shorter than one might usually expect. Its function is less to increase gain than it is to control the operating bandwidth of the array with respect both to the pattern shape and the feedpoint impedance. Hence, mid-band 10-meter performance remains under 7 dBi in free space.

Feeding the array relies on low-impedance direct transmission lines from the main feedpoint (to which we connect the feed cable) and the adjacent driver elements. Connecting-line characteristic impedances may range from about 50 Ω to 70 Ω, and we shall look at both values in the detailed sections on the beam variations. Since the lower limit for the characteristic impedance of lines using round bare conductors is about 80 Ω, the connecting lines must use flat-face conductors composed of square stock, L-stock, or even flat stock. **Table 1** lists some calculated values for the required gap between conductors with common stock face widths.

Table 1. Required gap between flat faces of transmission lines for 50 and 70 Ω

Width of flat face	0.25"	0.5"	0.75"
Impedance		Gap	
50	0.051"	0.102"	0.154"
70	0.083"	0.166"	0.249"

The larger gap needed for the higher impedance suggests that it might be easier to construct. However, it is more likely that any physical prototype should allow for some gap adjustment to arrive at the best SWR curves on each band above 20 meters.

In addition to the variation in the connecting-line characteristic impedance, the two types of tri-band designs offer different connection systems among the elements. If the main cable goes to the 20-meter driver in a Type-1 array, then the lines form a daisy chain to the 15-meter driver and finally the 10-meter driver. The left sketch in **Fig. 2** shows this arrangement. For a similar driver configuration, Optibeam runs the main cable to the 15-meter driver, with a line to the driver on each side, as shown in the center sketch. We shall explore this option using the 7 elements of the MYY-Tri design to see what differences (if any) that this arrangement makes.

On the right in the figure, we can see the Type-2 array feed system. By running the cable to the 20-meter driver, we automatically have a “centered” feedpoint with lines to the aft 15-meter driver and to the fore 10-meter driver.

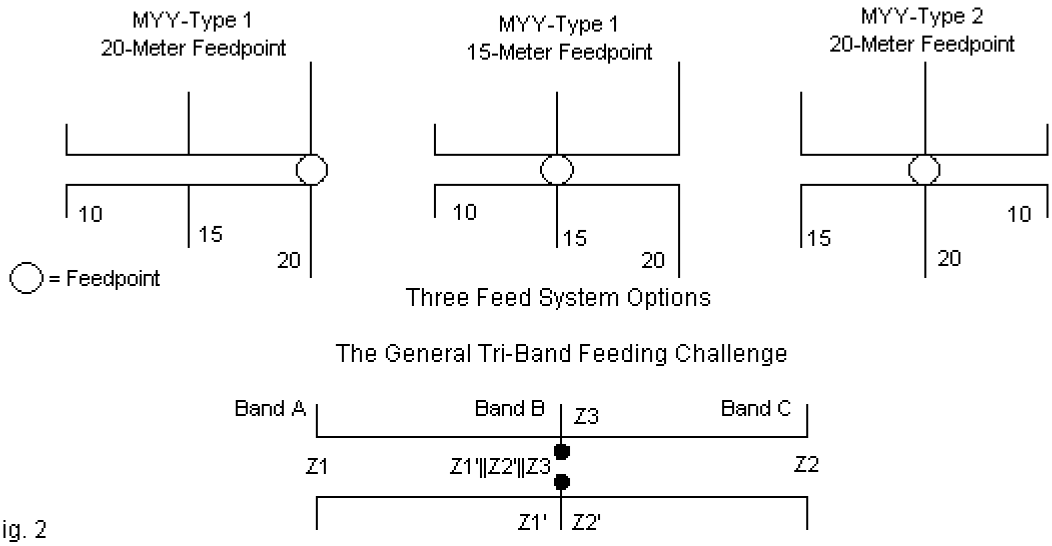


Fig. 2

The lower portion of the figure shows one of the reasons why a tri-band array becomes somewhat more difficult to design than a 2-band beam. The impedance at the junction with the feedline is a parallel value composed of the impedance of the beam on the active band and the transformed impedances of the off-band drivers (where “off-band” means a band other than the one being used). In theory, if we use a low-impedance line and drivers with low impedances when active, then the higher impedances that they show when another band is in use will also appear at the parallel junction of the lines. It is possible to design a tri-band beam using higher line impedances, but they tend to reduce the predictability of the impedances of the off bands at the parallel junction. As well, the impedance transformations may result in narrower SWR bandwidths on some bands. Therefore, a low-impedance system tends to provide the widest operating range for each band along with relative ease in design.

Nevertheless, the parallel junction of three drivers tends to reduce the net impedance. For example, the Moxon rectangle in monoband service would show a virtual 1:1 50-Ω SWR between 1/3 and ½ the span between the low and high end of 20 meters. The parallel combination of drivers does not permit this ideal condition. The resistive component of the impedance will be a bit less than 50 Ω, while the reactive component will nowhere pass through zero.

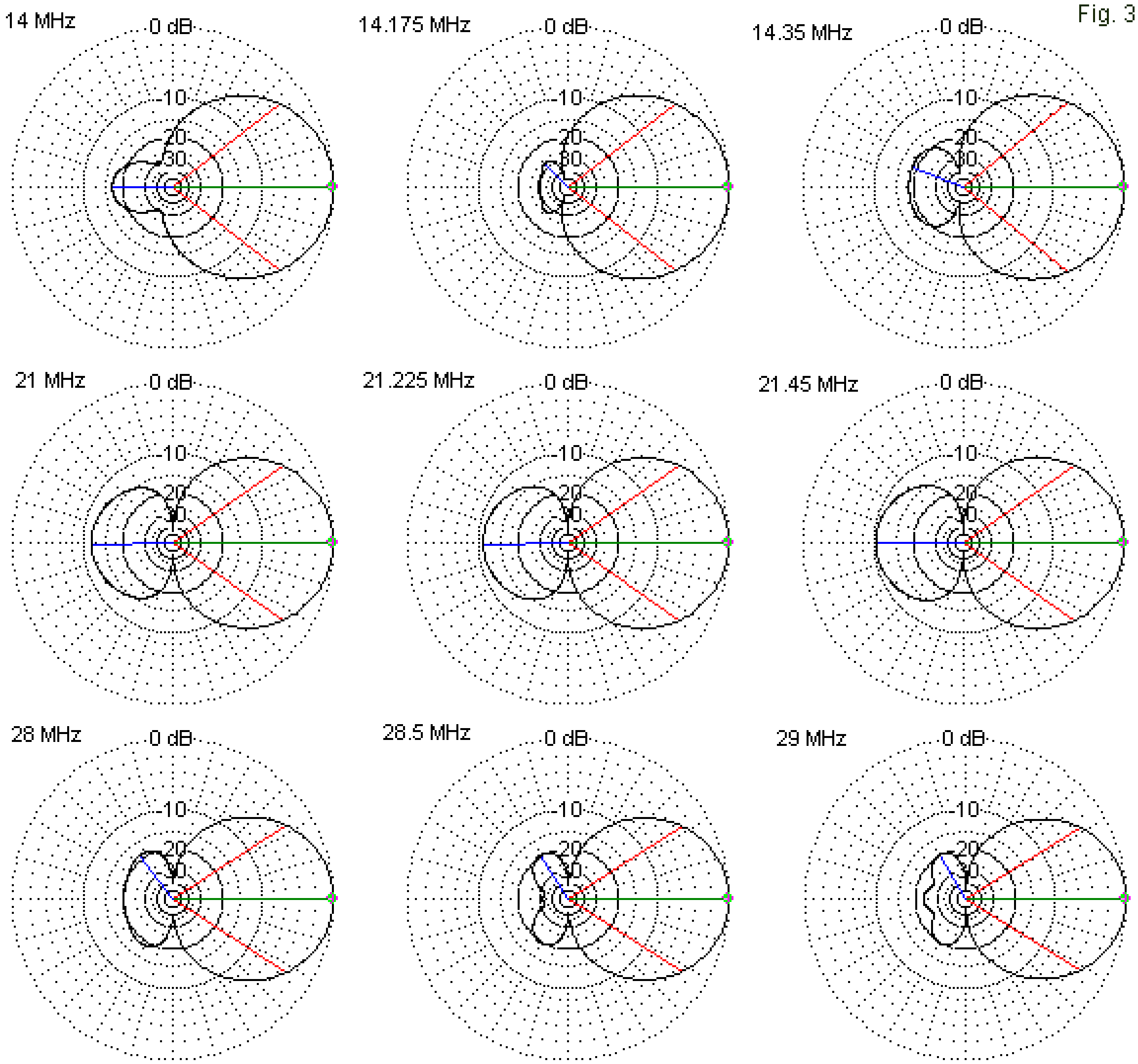
Since the exercise presumes the use of NEC-4 as the pre-prototype design vehicle, the element taper schedule shown in the dimension tables to come determines to a large degree the final length and spacing values. NEC-2 is not adequate, since the Leeson corrections are not available for the bent Moxon elements. The feed system also adds a constraint. To assure the correct combination of transformed impedances at the main junction of the connecting lines, all driven elements in the model must use the same geometry convention, moving either from left to right or from right to left in concert. Mixing driver orientations will result in errors relative to a physical antenna, errors that we cannot correct by simply reversing one or more of the connecting transmission lines.

The design challenges, of course, include all of the phenomena that we recorded for the 2-band designs.   The final dimensions represent a compromise among the main performance parameters of gain, front-to-back ratio, SWR bandwidth, and the rates of change of each value across each band. Hence, variations are always possible, even using the elements employed in this exercise. As well, as suggested in the last episode in that series, one may wish to replace the Moxon 20-meter elements with linear Yagi elements, with a small increase in the spacing between the driver and reflector elements for that band.

Type-1 MYY-Tri Designs

All variations of the Type-1 MYY-Tri design, with the 10-meter driver to the rear of the 15-meter and 20-meter drivers, yield very similar patterns. **Fig. 3** provides a gallery of typical patterns at the edges and the center of each band. Variations in the driver system may change some of the performance values slightly, but not the pattern shapes.

Fig. 3



Selected Free-Space E-Plane Patterns: Type-1 Tri-Band Array
10-Meter Driver Rearward, 50-Ohm Feedpoint Connection Line, Cable to 20-Meter Element

The 20-meter patterns are typical for any Moxon rectangle set for that band. The forward gain is within about 0.2-dB of 2-element Yagi performance, while the front-to-back ratio runs 5 to 15 dB higher. **Fig. 4** shows a typical gain and front-to-back sweep curve set for the Moxon portion of the array. As a driver-reflector parasitic beam, the array's gain curve decreases with rising frequency. The peak front-to-back ratio occurs between 14.15 and 14.20 MHz and so does not show up as a spike using the sweep increments of the graph.

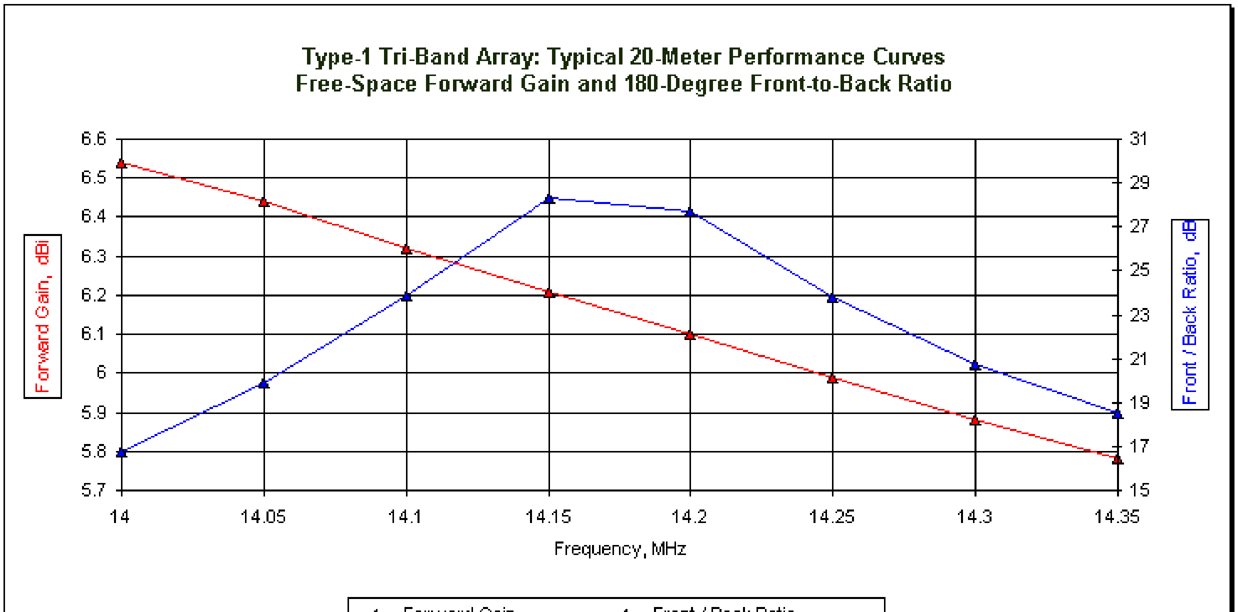


Fig. 4

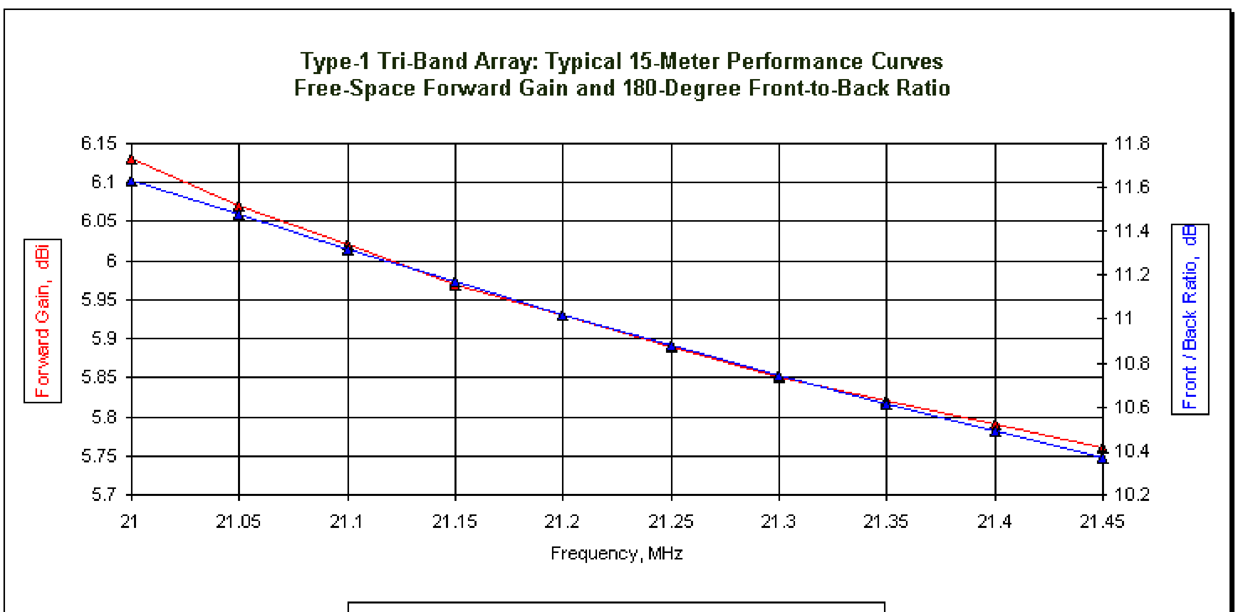


Fig. 5

The 15-meter patterns show the typical range for a driver-reflector Yagi, with a modest 10-12-dB range of the front-to-back ratio. **Fig. 5** provides the relevant frequency sweep curves for gain and front-to-back ratio. Both curves show very small decreases across the band. The gain curve is a function of the driver-reflector design of the 15-meter section of the array. The front-to-back curve emerges from necessary compromises between performance and SWR bandwidth concerns. Hence, the apparent congruence of the curves is both accidental—since one might peak the front-to-back ratio within the passband—and necessary—in terms of overall array performance.

On 10 meters, we find a wider range of rearward pattern changes, partly due to the wider band and partly due to the more rapid change in pattern shape for any Yagi that uses directors. Since the design uses directors, the gain rises with increasing frequency within the passband. The average gain is higher than the values that we obtain for the two lower bands, but shy of what we might obtain in a full-size monoband 3-element Yagi. In all of the MYY-Tri design variations, the goal has been to place the highest 180° front-to-back ratio near the center of the band to equalize as well as feasible the overall front-to-back ratio values at the band edges. The array version used for the sweeps, shown in **Fig. 6**, shows the peak value at 28.6 MHz. The value may drift up to 100 kHz in other variations of the design.

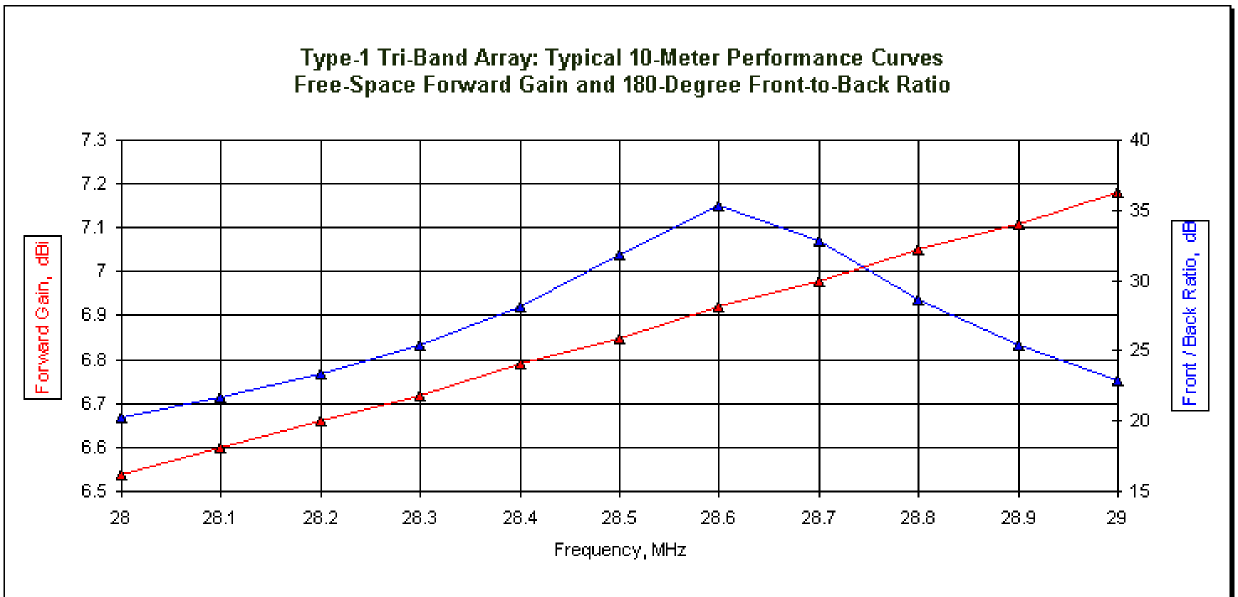


Fig. 6

We shall examine three variations of the Type-1 MYY-Tri, with the rearward 10-meter driver position. Since the progression of sweep values will not significantly change, we may rely largely on tabular data to see whatever differences arise from varying the feedpoint position and the connecting-line characteristic impedance.

Type 1: 20-Meter Element Feedpoint with a 50-Ω Connecting Line: The dimensions of the basic 7-element MYY design appear in **Table 2**. The table lists the element taper schedule for the 20-, 15-, and 10-meter elements by showing the progressive length of each element. All ssection lengths assume an additional 2" to 3" for insertion into the next larger size tube—except, of course, for the center section. The dimensions are for half elements, with the half not shown being a mirror image of the values listed. The tip sections show the ultimate half-length of each element, with special notations for the unchanging Moxon rectangle. Double the tip value to obtain the total element length. Subtract the sum of the interior half-element section from the tip value to obtain the exposed length of the tip section.

Table 2. MYY-Tri Type 1: 20-meter feedpoint, 50-Ω line: dimensions

10-meter Moxon Rectangle			15-meter Yagi			10-Meter Yagi		
Element	Diameter	Length	Element	Diameter	Length	Element	Diameter	Length
Both	1.0	30	Both	0.75"	24"	Both	0.625	36"
	0.875"	66"		0.625	60	DE tip	0.5	109
	0.75	96	Ref tip	0.5	144	Dir 1 tip	0.5	97.5
	0.625	120	DE tip	0.5	135.25	Dir 2 tip	0.5	94
	0.5	152						
	0.375	159						
Ref tail	0.375	57						
DE tail	0.375	42.75						
Gap		7.25						
Total width		107						

Array Spacing	
20-m ref	0"
15-m ref	19
10-m DE	69
15-m DE	87.5
20-m DE	107
10-m Dir1	114
10-m Dir 2	136

Notes:
1. Length values progressive from element center.
2. Reference Moxon dimensions to Fig. 1.
3. Spacing values reference to parallel elements.
4. 20-m-to-15-m TL = 50 Ω normal.
5. 15-m-to-10-m TL = 50 Ω normal.
5. Feedpoint: 20-meter (Moxon) DE
6. Boom length: 11.33' plus ends.

The sweep curves used this version of the Type-1 array. You may glean the performance values from those graphs or refer to **Table 3**.

Table 3. MYY-Tri Type 1: 20-meter feedpoint, 50-Ω line: performance

20 Meters				
Frequency	14.0	14.175	14.35	Δ
Free-space Gain dBi	6.54	6.15	5.78	0.76
Front-to-back ratio dB	16.76	28.99	18.52	12.23
Feedpoint Z (R +/- jX Ω)	31.1 – j14.4	47.6 – j13.5	61.3 – j18.5	30.2 + j5.0
50-Ω SWR	1.81	1.32	1.48	
15 Meters				
Frequency	21.0	21.225	21.45	Δ
Free-space Gain dBi	6.13	5.91	5.76	0.37
Front-to-back ratio dB	11.63	10.95	10.37	1.26
Feedpoint Z (R +/- jX Ω)	28.5 + j3.2	52.2 + j7.9	79.7 – j2.4	51.2 + j10.3
50-Ω SWR	1.83	1.28	1.55	
10 Meters				
Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	6.54	6.85	7.18	0.64
Front-to-back ratio dB	20.29	31.92	22.88	11.63
Feedpoint Z (R +/- jX Ω)	45.8 – j21.4	52.8 – j13.8	70.6 – j7.9	24.8 + j13.5
50-Ω SWR	1.30	1.26	1.77	

The Δ column provides a rough measure of the rates of change of performance values across each band. The 20-meter and 10-meter Δ values may be misleading to the degree that they record the 180° front-to-back values. Therefore, correlate all front-to-back values with the pattern gallery in **Fig. 3**. The values are just where we might expect them to fall, given the structure of each band's elements. The contributions of forward stagger effects might be numerically detectable, but would be operationally insignificant. Overall, the band-edge performance values and the relatively low rates of gain change across each band are hallmarks of a competent array.

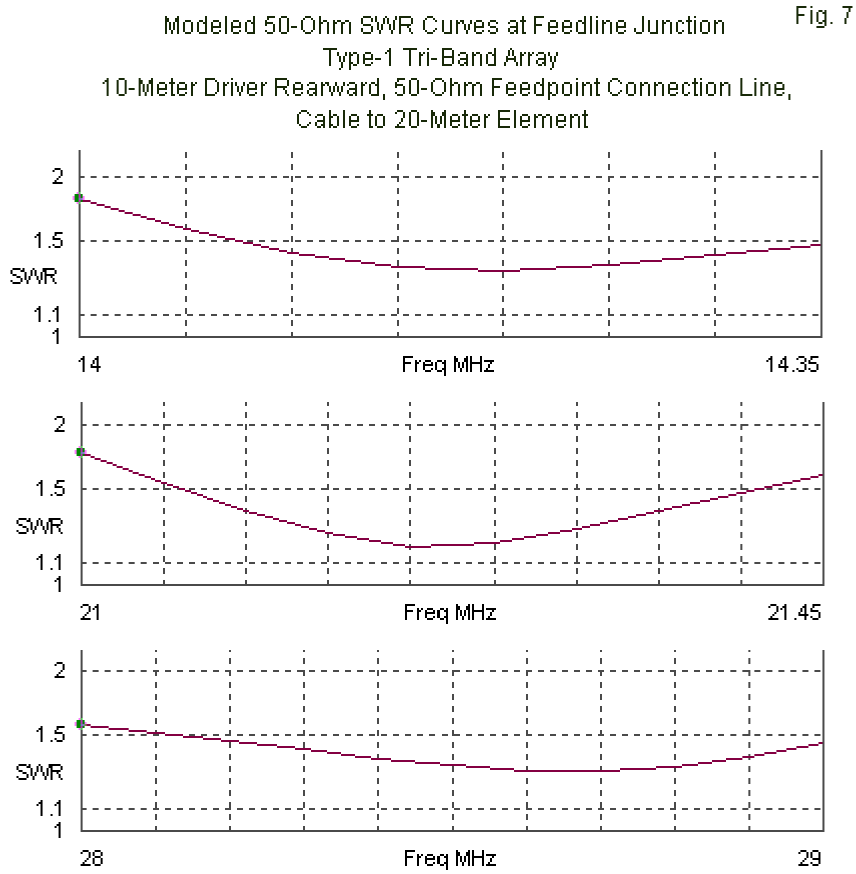


Fig. 7 shows the modeled free-space SWR curves for the three bands. All curves fall well within the normal 2:1 SWR standard used for amateur-band antennas. Changing the characteristic impedance of the connecting line among drivers to 70 Ω creates such small changes that I shall bypass this option in these notes. Nevertheless, one might wish to lower the minimum value of the 20-meter Moxon curve and perhaps improve the general values in the 10-meter curve. Therefore, it is useful to check the use of the 15-meter driver as the main feedline connection point and avoid the daisy chain of lines to the 10-meter driver. Optibeam uses this system for its own design that employs only a single 10-meter director. The technique is worth examination.

Type 1: 15-Meter Element Feedpoint with a 50-Ω Connecting Line: Placing the feedline cable on the 15-meter element requires some small changes in the tip lengths of the elements (excluding the constant 20-meter Moxon elements). **Table 4** provides a complete dimension set that uses the same rules of reading that applied to **Table 2**. The use of a complete dimension table allows one to extract the dimensions as a whole rather than having to gather together pieces from multiple tables to have an experimental set of design dimensions. Comparing dimensions sets will require examination of 15- and 10-meter tips lengths and the element spacing values. In general, all of the required dimensional changes affect the 15-meter element positions and lengths. The 10-meter element set requires no changes, while the 20-meter elements remain fixed as an initial design decision.

Table 4. MYY-Tri Type 1: 15-meter feedpoint, 50-Ω line: dimensions

10-meter Moxon Rectangle			15-meter Yagi			10-Meter Yagi		
Element	Diameter	Length	Element	Diameter	Length	Element	Diameter	Length
Both	1.0	30	Both	0.75”	24”	Both	0.625	36”
	0.875”	66”		0.625	60	DE tip	0.5	109
	0.75	96	Ref tip	0.5	143.5	Dir 1 tip	0.5	97.5
	0.625	120	DE tip	0.5	136	Dir 2 tip	0.5	94
	0.5	152						
	0.375	159						
Ref tail	0.375	57						
DE tail	0.375	42.75						
Gap		7.25						
Total width		107						

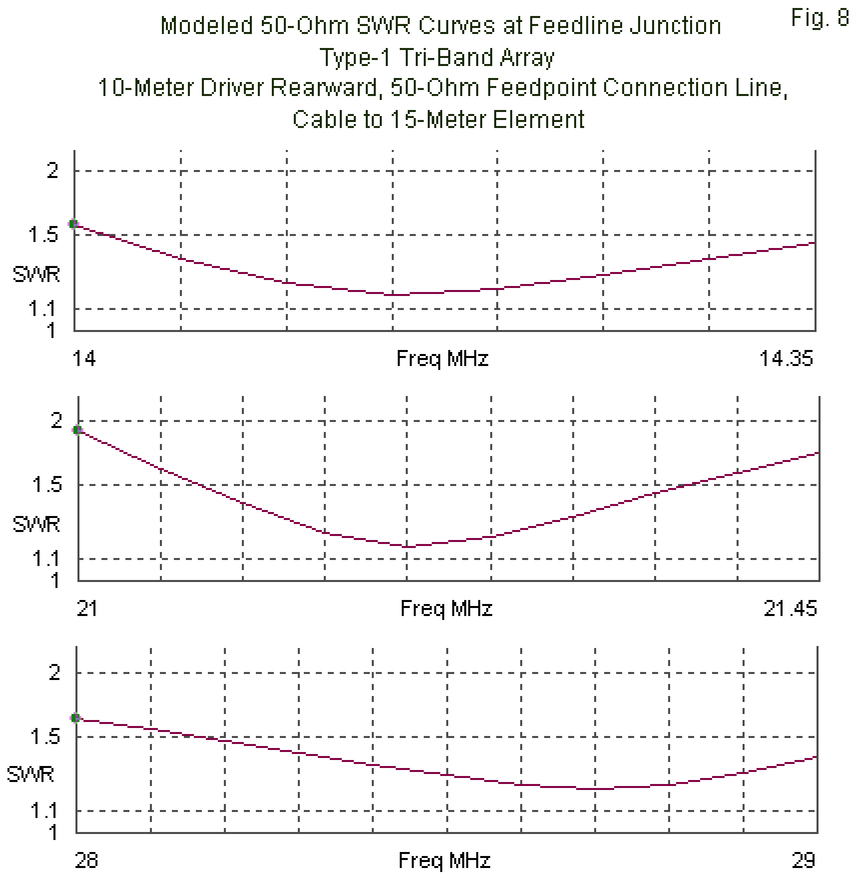
Array Spacing		Notes:	
20-m ref	0”		1. Length values progressive from element center.
15-m ref	17.5		2. Reference Moxon dimensions to Fig. 1.
10-m DE	69		3. Spacing values reference to parallel elements.
15-m DE	87.5		4. 15-m-to-20-m TL = 70 Ω normal.
20-m DE	107		5. 15-m-to-10-m TL = 70 Ω normal.
10-m Dir1	114		5. Feedpoint: 15-meter (Moxon) DE
10-m Dir 2	136		6. Boom length: 11.33’ plus ends.

Table 5 shows the performance values that go with the revised main feedpoint.

Table 5. MYY-Tri Type 1: 15-meter feedpoint, 50-Ω line: performance

20 Meters				
Frequency	14.0	14.175	14.35	Δ
Free-space Gain dBi	6.55	6.16	5.79	0.76
Front-to-back ratio dB	16.66	28.98	18.69	12.32
Feedpoint Z (R +/- jX Ω)	33.8 – j9.0	51.9 – j7.7	67.2 – j12.9	33.4 + j5.2
50-Ω SWR	1.57	1.17	1.44	
15 Meters				
Frequency	21.0	21.225	21.45	Δ
Free-space Gain dBi	6.25	6.01	5.84	0.41
Front-to-back ratio dB	11.96	11.35	10.74	1.22
Feedpoint Z (R +/- jX Ω)	27.4 – j9.3	51.9 – j7.5	75.7 – j22.6	48.3 + j15.1
50-Ω SWR	1.92	1.16	1.73	
10 Meters				
Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	6.67	6.94	7.21	0.54
Front-to-back ratio dB	23.90	40.40	20.85	19.55
Feedpoint Z (R +/- jX Ω)	41.3 – j20.4	49.2 – j11.9	68.2 – j4.4	26.9 + j16.0
50-Ω SWR	1.62	1.27	1.38	

The data make clear that from an operational standpoint, the revision of the main feedpoint location has made only numerical differences in performance. Operationally, we could not distinguish between either of the Type-1 arrays that we have so far examined. Perhaps the largest changes occur with respect to the shape of the 50-Ω SWR curves when we measure those values at the main feedpoint to which we attach the cable. **Fig. 8** provides the curves for comparison with those in **Fig. 7**.



The most notable improvement occurs in the 20-meter SWR sweep, with lower values across the band. The 10-meter curve has simply shifted its frequency of lowest value. Had we chosen to make slight changes in the 10-meter dimensions, we might have better centered that curve, but such changes would not have improved performance on that band. In contrast, the 15-meter curve has become steeper, with a higher average band-edge value. Unless the SWR values on one band are more important than on some other band, there is little to choose in shifting the feedpoint position using a 50-Ω connecting line.

Type 1: 15-Meter Element Feedpoint with a 70-Ω Connecting Line: The transition to a 70-Ω connecting line among feedpoints while using the 15-meter driver as the junction with the main feedline involves no changes in dimensions. The only required change is to revise the characteristic impedance of the connecting lines to 70 Ω. We encountered the same general situation when applying 70-Ω lines to the initial version of MYY-Tri with the daisy chain feed for 10 meters. The changes in performance were not significant enough to show, and the SWR curves merely shifted position a bit. Both 15 and 10 meters showed SWR curves that changed which end had the slightly higher value. In the case of using 70-Ω lines with the 15-meter element main feedpoint, the performance values have enough differences to justify a new record in **Table 6**. The key differences will lie in the impedance lines.

Table 6. MYY-Tri Type 1: 15-meter feedpoint, 70-Ω line: performance

20 Meters				
Frequency	14.0	14.175	14.35	Δ
Free-space Gain dBi	6.55	6.16	5.79	0.76
Front-to-back ratio dB	16.67	28.99	18.70	12.32
Feedpoint Z (R +/- jX Ω)	35.8 – j5.0	54.6 – j0.9	71.7 – j3.0	35.9 + j4.1
50-Ω SWR	1.43	1.10	1.44	
15 Meters				
Frequency	21.0	21.225	21.45	Δ
Free-space Gain dBi	6.26	6.01	5.85	0.41
Front-to-back ratio dB	11.99	11.37	10.78	1.21
Feedpoint Z (R +/- jX Ω)	29.6 – j7.3	54.2 – j1.1	82.6 – j9.0	53.0 + j7.9
50-Ω SWR	1.74	1.09	1.68	
10 Meters				
Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	6.66	6.93	7.20	0.54
Front-to-back ratio dB	24.13	39.80	20.79	19.01
Feedpoint Z (R +/- jX Ω)	47.1 – j14.7	52.8 – j2.4	68.1 + j12.8	21.0 + j27.5
50-Ω SWR	1.36	1.07	1.46	

Modeled 50-Ohm SWR Curves at Feedline Junction
Type-1 Tri-Band Array
10-Meter Driver Rearward, 70-Ohm Feedpoint Connection Line,
Cable to 15-Meter Element

Fig. 9

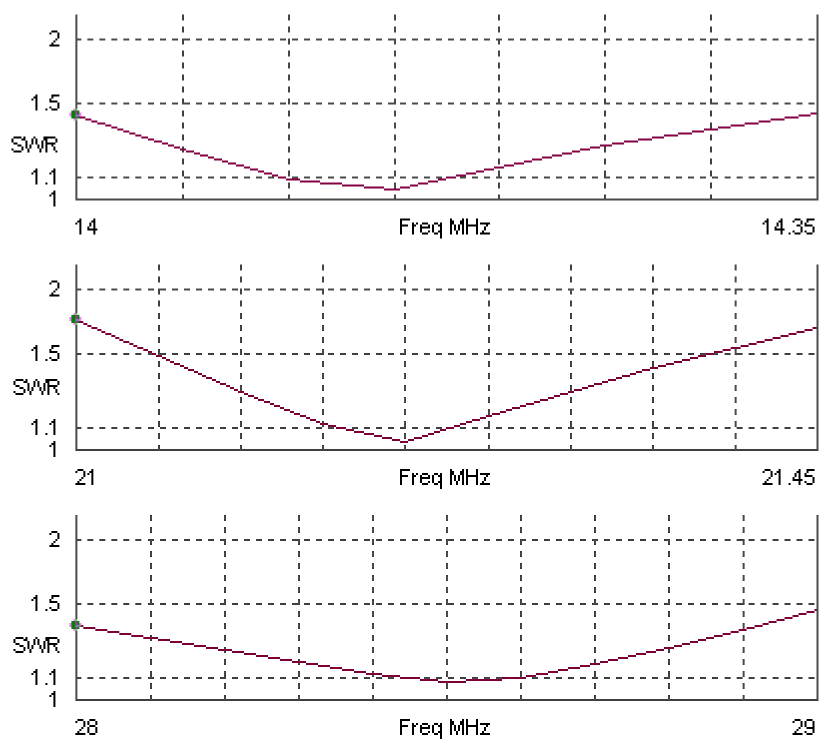


Fig. 9 provides the relevant set of SWR curves. With a 70-Ω connecting line, all three SWR curves improve in the sense of more closely approaching a 1:1 value somewhere within the passband. Only the 15-meter curve has values that rise above 1.5:1 at the band edges. On the other hand, the values for gain and front-to-back ratio do not change—in some cases, not even numerically, let alone operationally. Therefore, the situation leaves us with two questions.

First, how worthwhile are the seeming improvements of using a 70-Ω line with the main feedline connected to the 15-meter element? Unless one is operating with an amplifier that limits the SWR to 1.5:1 before shutting down, the differences among the three sets of SWR curves are operationally meaningless in terms of received and transmitted signal strength. (If a sensitive amplifier is in use, then it is likely that the station should be using monoband beams with SWR values that do not rise above about 1.3:1 anywhere in the passband.)

Second, how achievable are the lower SWR curves within a physical prototype that one may construct? The answer here depends on many variables, most of which concern the physical implementation of the array. I have already recommended that the connecting lines have some variability of gap spacing to allow for adjustment to the best compromise among curves for all three bands. Line construction, connectors, and a host of small influences may affect the actual characteristic impedance of the connecting lines. As well, the support mast and its hardware may (and likely will) be close to at least one of the drivers and its connecting line. The presence of the metal mass can detune the line slightly.

In the end, the design models can provide guidelines for construction. However, final tuning for the best set of SWR curves will require extensive field adjustment. The goal of these notes has been to provide a set of usable dimensions and feedlines specifications that provide a range of values within which most physical implementations can work. But the design notes cannot eliminate the need for testing, measurement, and adjustment.

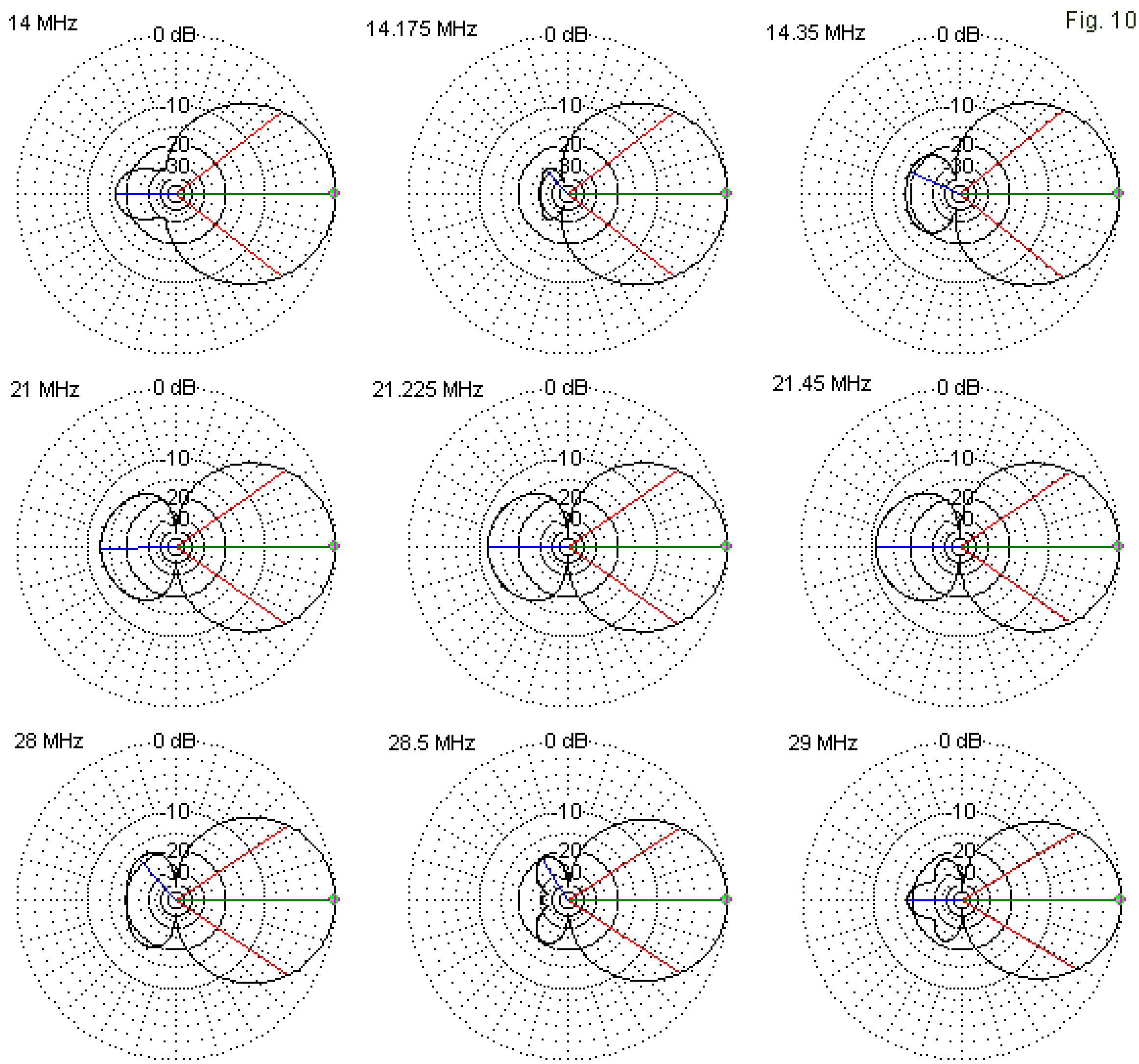
Type-2 MYY-Tri Designs

The general outline for Type-2 MYY-Tri arrays appears in **Fig. 1** on the far right. The basic design difference is the movement of the 10-meter driver forward of the 20-meter driver. Moving the 10-meter driver also forces a forward movement of the 10-meter directors. One consequence of this move is to lengthen the boom from just over 11' to about 15.5'. A second consequence is that we shall only view two variations on the scheme, one using a 50-Ω connecting line set, the other using a 70-Ω set of lines. With the main feedline connected to the 20-meter element, we now have automatic freedom from any daisy chaining of the connecting lines.

Relative to the Type-1 design, the Moxon rectangle for 20 maters will not undergo any revision. Whether this portion of the array should receiving final tweaking may be a function of the results that we obtain with the original configuration. However, we shall see some differences in the dimensions for 15 and 10 meters, mostly in terms of the length of the elements as we shift the impedance of the connecting lines.

Perhaps the bottom-line question involves whether we obtain anything useful for the beam revision. If we place the boom–to-mast assembly just behind the 15-meter driver, we might still be a bit off with respect to the array's center of mass, but we might thereby minimize unwanted influences on the connecting lines. However, we may relevantly ask whether we achieve any useful performance improvements over the versions with the shorter boom. The answer to this question emerges from the performance notes to follow.

Fig. 10 provides us with a gallery of patterns for the Type-2 design. Without careful scrutiny and comparison, we would be hard-pressed to notice any differences from the Type-1 patterns in **Fig. 3**. Since the gallery does not show values for maximum gain, we can only evaluate the general acceptability of the patterns. The 20-meter patterns are typical Moxon rectangle free-space plots, so their acceptability rests on the acceptance of the Moxon rectangle as the low-band radiator set. On 15 meters, we have typical deriver-reflector Yagi patterns, while on 10 meters, we see equally typical 3-element Yagi patterns.



Selected Free-Space E-Plane Patterns: Type-2 Tri-Band Array
10-Meter Driver Forward, 50-Ohm Feedpoint Connection Line, Cable to 20-Meter Element

Not only are the patterns similar between Type-1 and Type-2 array designs, but so too are the sweep curves of free-space forward gain and 180° front-to-back ratio. **Fig. 11** provides a sweep graph for the 20-meter operation of the Type-2 version of the beam. Compare the values and the curve slopes with those in **Fig. 4**. Virtually any detected difference will be operationally incidental. For example, the invisible peak front-to-back ratio still occurs between 14.15 and 14.20 MHz.

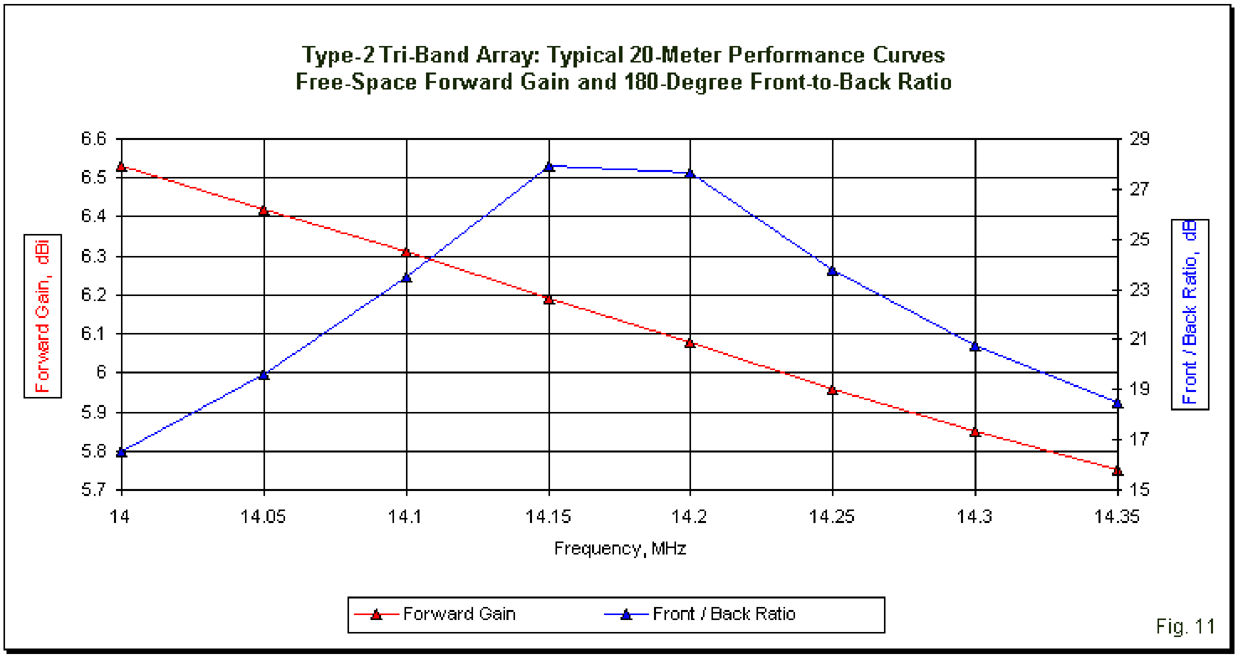


Fig. 11

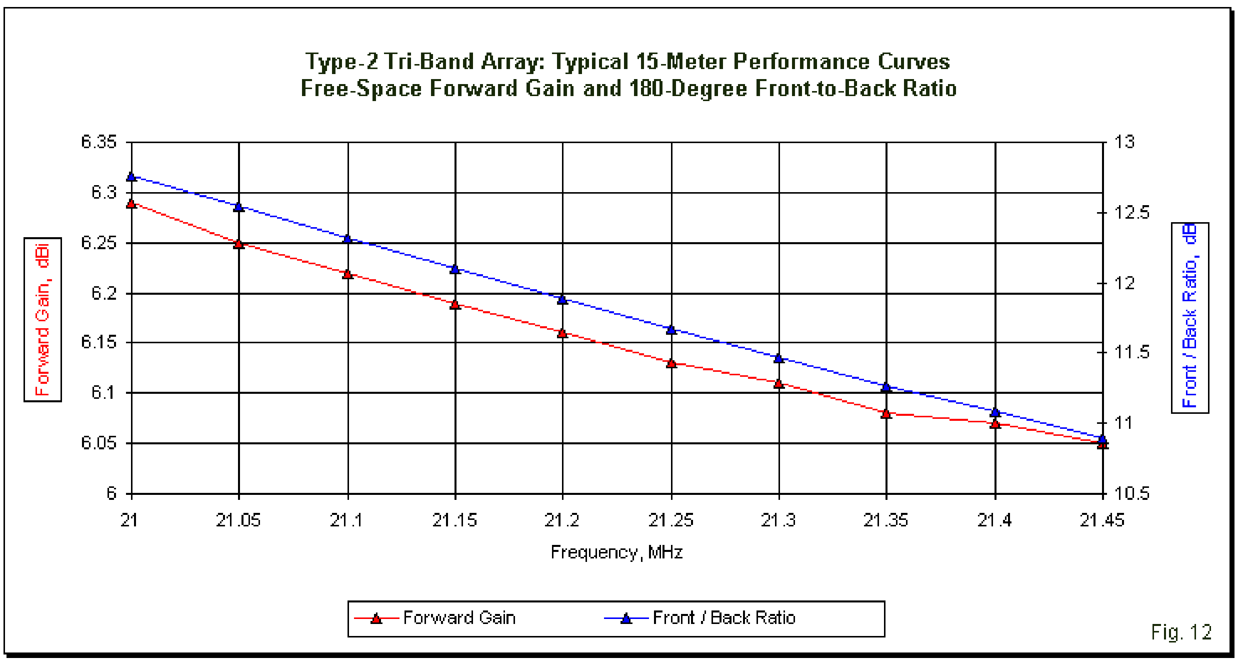


Fig. 12

The 15-meter curves, in **Fig. 12**, result in almost parallel lines, very similar to those for the Type-1 array in **Fig. 5**. The Y-axes do not use the same increments, so the absence of overlap between the two lines does not itself create a meaningful difference in performance. For the 10-meter sweep in **Fig. 13**, the relevant graph to compare is **Fig. 6**. In both cases, the design goal was to set the peak 180° front-to-back value at mid-band. As well, both graphs show a rising gain value with increasing frequency within the pass band. To determine whether the longer boom is worthwhile, we shall have to examine the modeled performance values for each band.

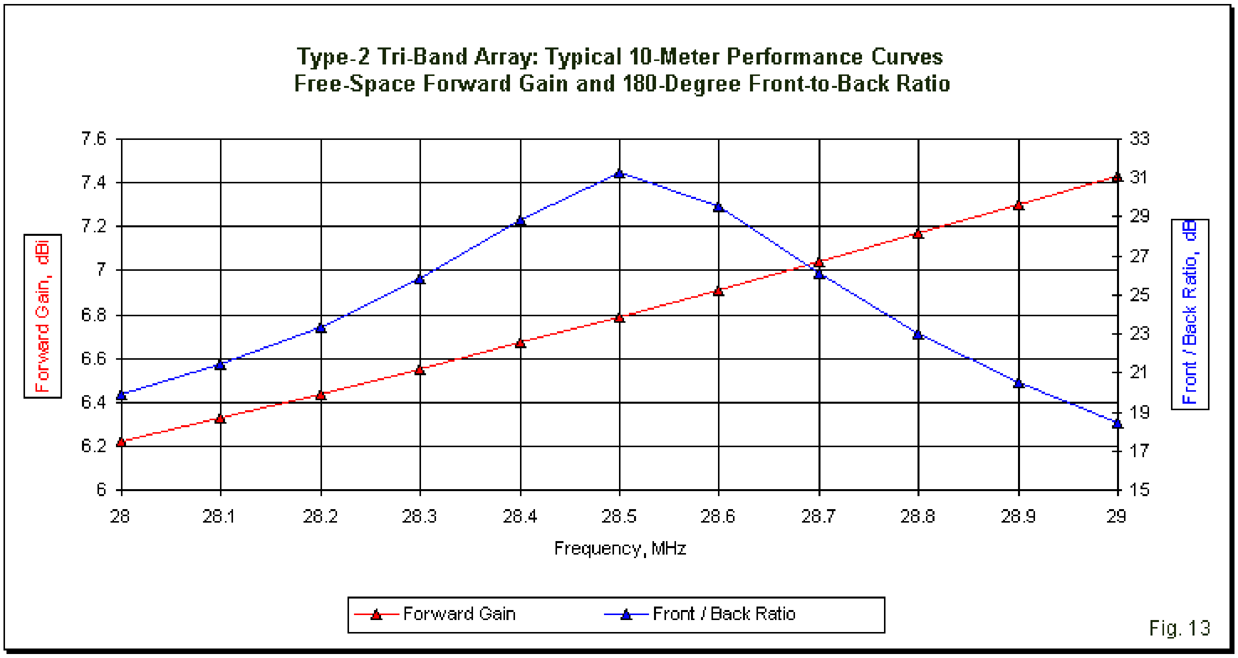


Fig. 13

Type 2: 20-Meter Element Feedpoint with a 50-Ω Connecting Line: The initial version of the Type-2 array uses 50-Ω connecting lines from the lower-band driver to each of the upper-band drivers. The move from Type-1 to Type-2 arrays does not change the element taper schedule used by any of the elements. The dimensions appear in **Table 7**, and they use the same reading rules that we set for reading both **Table 2** and for **Table 4**.

Table 7. MYY-Tri Type 2: 20-meter feedpoint, 50-Ω line: dimensions

10-meter Moxon Rectangle			15-meter Yagi			10-Meter Yagi		
Element	Diameter	Length	Element	Diameter	Length	Element	Diameter	Length
Both	1.0	30	Both	0.75”	24”	Both	0.625	36”
	0.875”	66”		0.625	60	DE tip	0.5	108
	0.75	96	Ref tip	0.5	144.5	Dir 1 tip	0.5	96.25
	0.625	120	DE tip	0.5	135	Dir 2 tip	0.5	86.5
	0.5	152						
	0.375	159						
Ref tail	0.375	57						
DE tail	0.375	42.75						
Gap		7.25						
Total width		107						

Array Spacing	
20-m ref	0”
15-m ref	20
15-m DE	87.5
20-m DE	107
10-m DE	139
10-m Dir1	161
10-m Dir 2	186

Notes:
1. Length values progressive from element center.
2. Reference Moxon dimensions to Fig. 1.
3. Spacing values reference to parallel elements.
4. 20-m-to-15-m TL = 50 Ω normal.
5. 20-m-to-10-m TL = 50 Ω normal.
5. Feedpoint: 20-meter (Moxon) DE
6. Boom length: 15.5’ plus ends.

Except for the revised element spacing occasioned by setting the entire 10-meter section forward of the Moxon rectangle, the linear element length changes are small. Nevertheless, they are critical to obtaining acceptable performance. Comparing the element lengths to those for the Type-1 array may give a feel for the sensitivity of upper band element lengths within a multi-band beam.

The modeled free-space performance values for our first Type-2 array appear in **Table 8**. Compare these numbers relevantly with any of the Type-1 arrays whose numbers appear in **Tables 3**, **5**, and **6**.

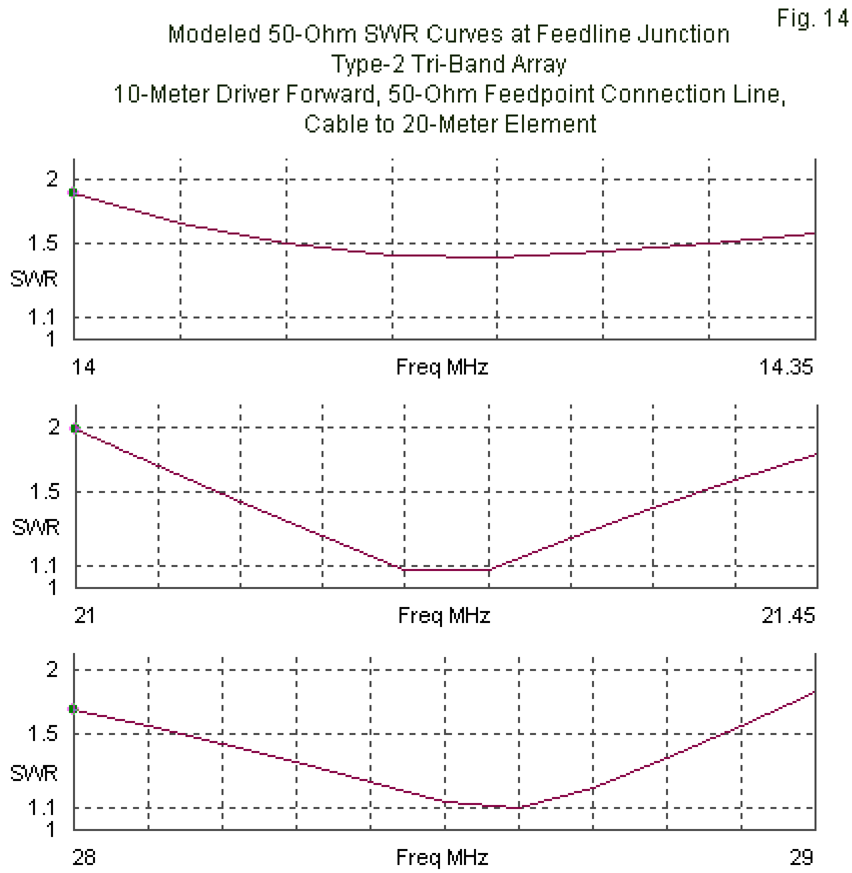
Table 8. MYY-Tri Type 2: 20-meter feedpoint, 50-Ω line: performance

20 Meters				
Frequency	14.0	14.175	14.35	Δ
Free-space Gain dBi	6.53	6.13	5.75	0.78
Front-to-back ratio dB	16.56	28.72	18.49	12.16
Feedpoint Z (R +/- jX Ω)	30.5 – j15.2	46.0 – j16.3	57.7 – j23.0	27.2 + j7.8
50-Ω SWR	1.87	1.42	1.56	
15 Meters				
Frequency	21.0	21.225	21.45	Δ
Free-space Gain dBi	6.29	6.14	6.05	0.21
Front-to-back ratio dB	12.76	11.77	10.90	1.81
Feedpoint Z (R +/- jX Ω)	25.8 – j6.7	50.1 – j1.6	83.0 – j17.3	57.2 + j15.7
50-Ω SWR	1.96	1.03	1.77	
10 Meters				
Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	6.22	6.79	7.43	1.21
Front-to-back ratio dB	19.87	31.26	18.42	12.84
Feedpoint Z (R +/- jX Ω)	34.5 – j14.8	48.6 – j5.6	90.7 + j1.9	56.2 + j16.7
50-Ω SWR	1.67	1.12	1.82	

With 50-Ω connecting lines, the Type-2 array shows only marginal improvements, for example, in the 15-meter gain values. However, it shows some disturbing trends in other areas. The disturbances are not sufficiently great to disable the beam, but they are worth noticing. For example, the 10-meter front-to-back ratio falls below 20 dB at the band edges as a result of the greater rate of performance value change across the passband when compared to a Type-1 array. The phenomenon also shows up in the higher Δ value for the gain across the band. On 15 meters, we find that the gain changes hardly at all across that bad, but the front-to-back ratio changes considerably more than a counterpart Type-1 array.

Whether or not the numbers themselves draw any operational concern, the rapid changes in value have a consequence for replicating a design like the Type-2 beam with 50-Ω connecting lines. Faster rates of performance change signal a higher sensitivity to small changes in dimension, especially when making field adjustments in preparation for operation. The higher the rate of performance change per increment of frequency or for an equivalent change in an element's length, the easier it will be for the builder to set the beam dimensions at a point that seems to defy adjustment into proper operation.

The rapid changes in performance across the bands also carry a penalty into the SWR curves, which appear in **Fig. 14**. Although both the 10-meter and the 15-meter curves reach very low values within the passbands, the band-edge values tend to be higher when taken together than they do in corresponding curves for the Type-1 arrays. In addition, the 20-meter SWR curve suggests a need for some significant re-design of the Moxon rectangle. With the drive arrangement shown in the dimensions, the 20-meter SWR curve has uniformly high values (although not outside a basic acceptable range). The culprit is a relatively high capacitive reactance across the band that results from the off-band impedance values of the other drivers, as transformed by the connecting lines.



Type 2: 20-Meter Element Feedpoint with a 70-Ω Connecting Line: We may achieve some improvement in the performance curves of the Type-2 array by replacing the 50-Ω connecting lines by 70-Ω lines. The required changes to dimensions, shown in **Table 9**, involve the element lengths for 15 and 10 meters.

Table 9. MYY-Tri Type 2: 20-meter feedpoint, 70-Ω line: dimensions

10-meter Moxon Rectangle			15-meter Yagi			10-Meter Yagi		
Element	Diameter	Length	Element	Diameter	Length	Element	Diameter	Length
Both	1.0	30	Both	0.75"	24"	Both	0.625	36"
	0.875"	66"		0.625	60	DE tip	0.5	108
	0.75	96	Ref tip	0.5	144.25	Dir 1 tip	0.5	96.
	0.625	120	DE tip	0.5	134.5	Dir 2 tip	0.5	86
	0.5	152						
	0.375	159						
Ref tail	0.375	57						
DE tail	0.375	42.75						
Gap		7.25						
Total width		107						

Array Spacing	
20-m ref	0”
15-m ref	20
15-m DE	87.5
20-m DE	107
10-m DE	139
10-m Dir1	161
10-m Dir 2	186

Notes:
1. Length values progressive from element center.
2. Reference Moxon dimensions to Fig. 1.
3. Spacing values reference to parallel elements.
4. 20-m-to-15-m TL = 70 Ω normal.
5. 20-m-to-10-m TL = 70 Ω normal.
5. Feedpoint: 20-meter (Moxon) DE
6. Boom length: 15.5’ plus ends.

The performance values that result from the changes appear in **Table 10**.

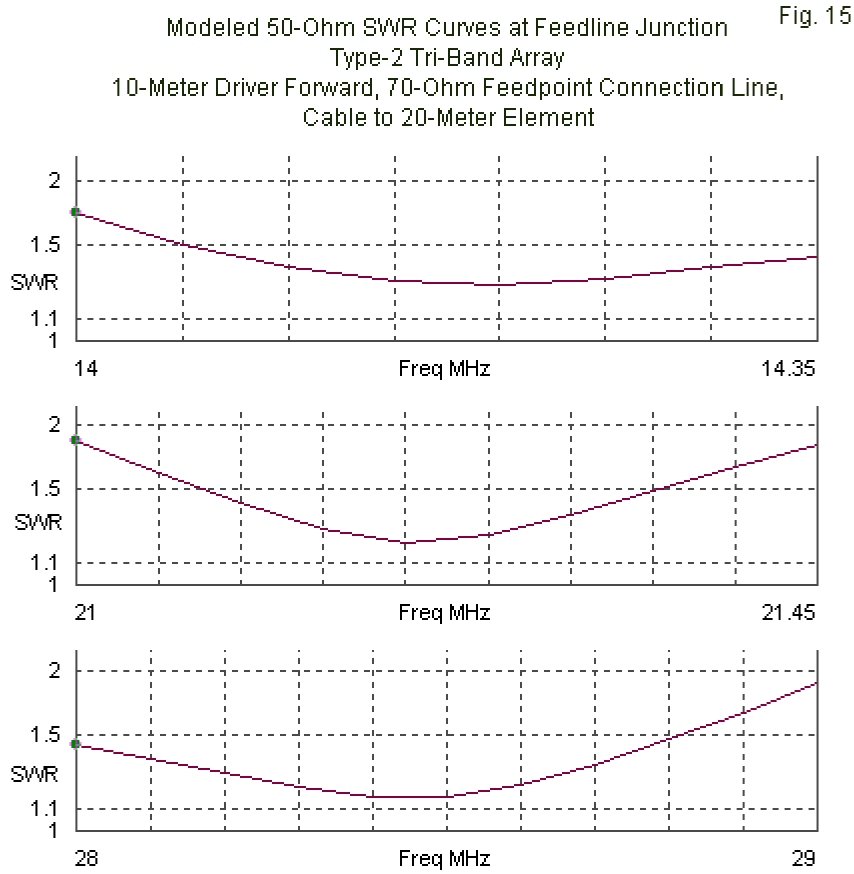
Table 10. MYY-Tri Type 2: 20-meter feedpoint, 70-Ω line: performance

20 Meters				
Frequency	14.0	14.175	14.35	Δ
Free-space Gain dBi	6.53	6.13	5.75	0.78
Front-to-back ratio dB	16.55	28.72	18.50	12.17
Feedpoint Z (R +/- jX Ω)	32.4 – j13.4	48.9 – j11.7	63.0 – j15.4	30.6 + j3.7
50-Ω SWR	1.72	1.27	1.43	
15 Meters				
Frequency	21.0	21.225	21.45	Δ
Free-space Gain dBi	6.32	6.16	6.06	0.26
Front-to-back ratio dB	12.81	11.83	10.95	1.86
Feedpoint Z (R +/- jX Ω)	27.0 – j2.7	50.6 + j9.3	89.6 + j9.6	62.6 + j12.3
50-Ω SWR	1.86	1.20	1.82	
10 Meters				
Frequency	28.0	28.5	29.0	Δ
Free-space Gain dBi	6.16	6.72	7.37	1.21
Front-to-back ratio dB	19.08	30.19	19.49	11.11
Feedpoint Z (R +/- jX Ω)	37.0 – j8.8	46.0 + j5.5	68.4 + j32.9	31.4 + j41.7
50-Ω SWR	1.44	1.15	1.88	

Although we can find small numerical changes in the various performance entries for the forward gain and the front-to-back ratio, they do not add up to anything that we could detect in operation. The value changes across the 3 passbands also do not change significantly. The move from 50-Ω to 70-Ω connecting lines creates virtually no change in the current distribution among the elements in the array at any frequency.

Although the higher characteristic impedance of the new set of lines does not change performance, it does change the impedance values that appear at the main feedpoint on all of the bands. For example, on 20 meters, the capacitive reactance is considerably reduced, thereby lowering the SWR values across the band (since the resistive component did not materially change). In contrast, on 10 meters, the range of feedpoint resistance values has decreased, while the range of reactance values has increased. The changes result in lower SWR values in the lower half of the band. On 15 meters, we see only modest changes in the ranges of the two impedance components, but the SWR value at the low end of the band is somewhat better.

The sum of the changes is a set of somewhat flatter SWR curves, as shown in **Fig. 15**. Despite the improvement and the fact that all of the curves fit well within standards for amateur-band beam operation with a 50-Ω feedline, the curves are not as promising as some of the sets that we viewed in connection with the Type-1 arrays.



Conclusion

The design exercise has established that we can indeed reach workable 7-element tri-band array dimensions with acceptable performance specifications using directly connected drivers in a variety of configurations. The use of connecting lines with characteristic impedance values between 50 Ω and 70 Ω is most promising for a successful array. In all cases, however, we must be aware of the sensitivity of upper-band element dimensions, especially during field adjustment. As well, we should be prepared to alter the connecting-line gap as part of the adjustment process.

In general, the Type-2 array does not offer enough advantages to overcome its tendency toward increased rates of performance change across the upper bands, the increased sharpness of some of the SWR curves, or the additional 3.5' of required boom length. In the end, one of the Type-1 arrays might serve better, even if only marginally so. As well, one may replace the Moxon rectangle with linear Yagi elements with only a small cost in additional boom length. Once you are comfortable with the way in which elements interact when interlaced, the possibilities for variations become endless—and so do the missteps that give the design process both enduring interest and endless frustration.