Stepped-Diameter Moxon Rectangles for 20 through 10 Meters

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The Moxon rectangle has proven itself to be an effective 2-element parasitic beam of good performance and compact size. The forward gain is slightly lower (by about 0.2 dB) than a standard reflector-driver Yagi, but the beamwidth is wider (by about 10 degrees) and the front-to-back ratio is very much improved (by an average of over 10 dB). The side-to-side dimension is about 70% of the comparable dimension in a Yagi, while the space between elements is about 0.13 to 0.14 wavelength.

We may design the Moxon rectangle for almost any feedpoint impedance from about 35 Ohms to about 100 Ohms. The lower the feedpoint impedance, the wider and narrower the beam becomes physically. Wider rectangles with lower feedpoint impedances tend to show slightly higher gain than higher impedance versions with squarer shapes.

The Moxon combines 2 forms of coupling to achieve its performance. First, we have the coupling between parallel elements, just as we find in a Yagi. However, Moxon beams bend the element ends toward each other, resulting in fairly close spacing of the tips. Hence, we have additional coupling. The gap between the element tips is fairly critical and varies depending upon the diameter of the element. Thinner elements require considerably closer spacing than thicker elements. Since there is some current in the side portions or tails of the elements, the beamwidth increases relative to a standard Yagi. As well, the side nulls move from the standard Yagi position of 90 degrees away from the main forward heading to between 110 and 120 degrees away from that heading.

Some years ago, I develop a set of algorithms for calculating the dimensions of any Moxon rectangle that uses a uniform-diameter element set. The initial algorithms focused on beams with a 50-Ohm feedpoint impedance, although I later added a different set for feedpoint impedances closer to 100 Ohms. The latter Moxon type has particular application in turnstile antennas used for fixed satellite operation. The main algorithms for 50-Ohm arrays allow a direct feedpoint connection with the usual coaxial cable, although a common-mode suppression (1:1) balun or ferrite-bead choke is a standard precaution at the feedpoint. **Fig. 1** shows the general outline of a Moxon rectangle, along with the conventional designations of the element dimensions used in design algorithms. A is the total side-to-side dimension of the antenna. B is the driver tail and D is the reflector tail. The most critical dimension is C, the gap between carefully aligned tails. E is the total front-to-back dimension of the beam and is the simple sum of B, C, and D.

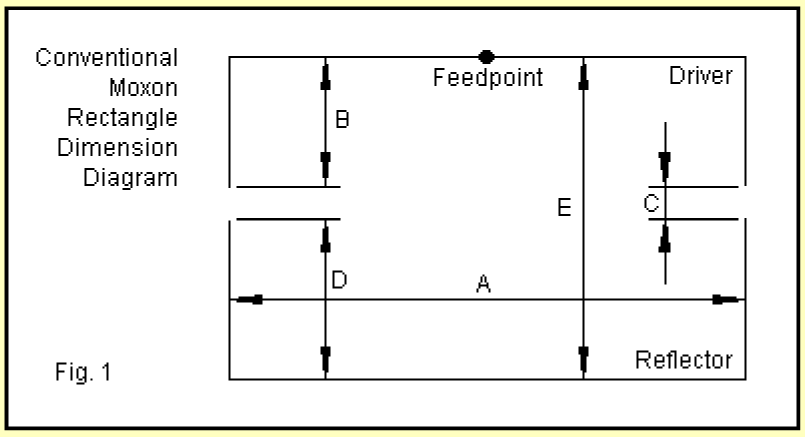


Fig. 1

The algorithms for uniform-diameter elements are highly useful at VHF and above, since virtually all arrays above the HF region use single tubes or rods for elements. However, over the years, I have received numerous requests to design for HF use some Moxons that use a tapered-diameter element schedule. The design of such Moxons has two challenges. First, an element with a stepped or tapered diameter that decreases as we move away from the element center will be physically longer than a comparable element with a uniform diameter. This fact changes the current distribution and results in a rectangle that is longer (side-to-side) and narrower (front-to-back) than an array that uses elements with a uniform diameter. Moreover, changing the diameter steps also changes the ultimate outer dimensions of the Moxon, including the required gap. The changes that may alter rectangle dimensions include not only the set of element diameters used, but also the length of each section of tubing along the element. The result of the stepped-diameter effect is that we can no longer rely on the Moxon calculator as a guide to design, although it may still provide a starting point for the necessary re-design work. The remainder of the work proceeds on a case-by-case basis.

Second, we must find a set of tubing steps that can withstand significant wind loads. Therefore, not all stepped diameter progressions are usable. With linear elements, we may use a program such as YagiStress to calculate the wind load for a given element design. However, these programs are set for linear elements, and the Moxon rectangle has a set of tails. The tails not only add weight to the end of the long portion of the element, but they introduce additional forms of loading. For example, the rectangle will show some stresses associated with wind-induced racking forces.

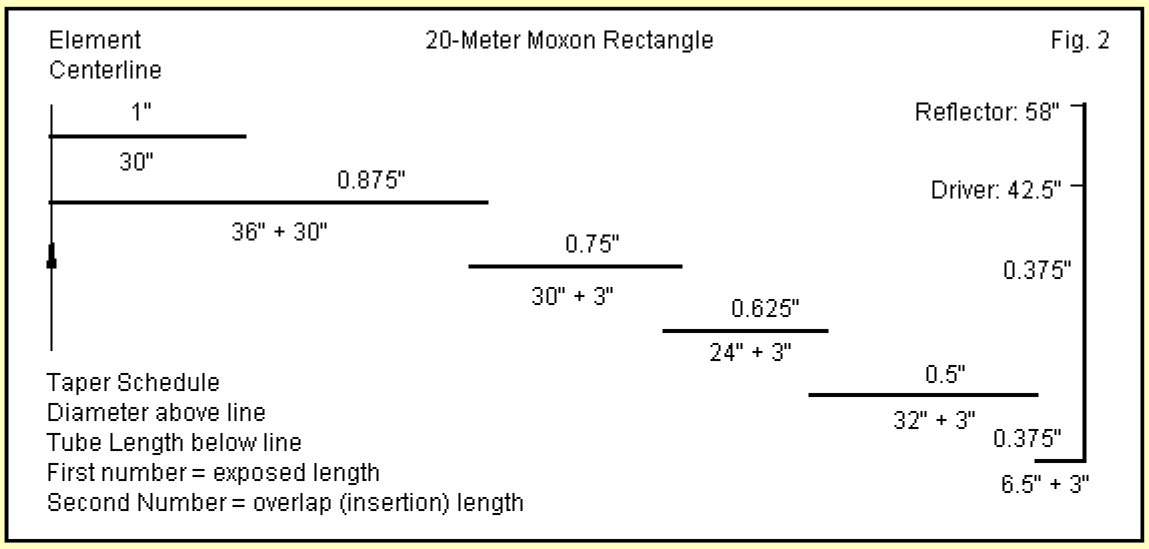
Despite the challenges, I have designed a series of HF Moxon rectangles using stepped-diameter element construction. The element structures should be able to withstand winds up to about 70-75 mph. U.S. antenna builders have an advantage due to the availability of 6063-T832 aluminum tubes. These tubes come in outside diameters that step in 1/8" increments from 3/8" upward. The wall thickness for readily available tubes (from sources such as Texas Towers) allows for close nesting of one tube size inside the next larger tube. The wall thickness is just under 1/16" (actually, 0.058") for a snug and strong fit with simple fasteners. For all of the designs in the set, the tail pieces use 3/8" tubes for their light weight. The center-most section of the 10-meter beam uses 3/4" stock. The diameter increases to 1" at 20 meters. For strength, the center-most element sections are doubled.

Each beam in the set of 5 is a separate design for the HF bands from 20 through 10 meters based on NEC-4 models. To provide nearly equal front-to-back and 50-Ohm SWR values at the band edges, the design frequency for the wider amateur bands is about 1/3 the way up from the lowest frequency in the band. Since the gain of any 2-element parasitic array decreases with rising frequency across a defined passband, the designs tend to favor the lower end of the band with respect to gain. The amount of gain decrease depends upon the overall width of the band as measured in percentage. (The bandwidth of a passband as a percentage is determined by dividing the total width of the band by the center frequency--using the same units for both--and multiplying by 100.) For the smaller WARC bands, designing for the band center works very well. Because the progression of tube sizes and lengths varies from one band to the next, the beams are not direct scalings of those for any other band. However, all will show the same narrowing and widening relative to calculated models using elements with a uniform diameter.

The design notes that follow consist of tables, sketches, and graphs to show the design details and the performance potential of the beam on each band. The tables will include a comparison of the dimensions (A through E) of a calculated rectangle using a 1/2" element and the dimensions of the present design using stepped-diameter elements. Figures and tabulated data will provide a more detailed look at the element construction for each band. The potential performance--as modeled in free space--will appear in graphs, with a table sampling the numerical values at the band edges and at the design frequency. Finally, a set of free-space E-plane (azimuth) patterns will conclude the data collection for each band. I use free-space data because the patterns will vary slightly depending upon the antenna mounting height. Free-space patterns are generally almost identical to those obtained at the take-off angle for any antenna mounted at least 1 wavelength above ground. Of course, to all free-space gain values, you must add the ground reflection component, which usually runs between 5 and 6 dB, depending upon mounting height.

20 Meters

The 20-meter Moxon rectangle is the largest and beefiest of the entire set. It uses tubing sizes from 1" down to 3/8". Note in **Fig. 2** that the 7/8" tube runs from the its outer end back to the centerline, effectively doubling the tube wall thickness for the portion inside the 30" section of 1" diameter tube. The table compares the outer dimensions of the tapered model with a calculated 1/2" model. The side-to-side widening and front-to-back narrowing are evident. However, also note the reduction in the gap distance, which is a consequence of the other dimension changes based on the need to bring the array to its performance curves and a 50-Ohm feedpoint impedance.



A Comparison of the Dimensions of a Tapered Element Diameter Moxon and a Uniform-Diameter Moxon
20 Meters (14.15 MHz) See text for element diameter tapering schedule. Uniform diameter = 0.5"

Dimension	Tapered Model	Uniform Model
A	317"	301.78"
B	42.5"	43.07"
C	7.5"	10.88"
D	58"	57.19"
E	108"	111.14"

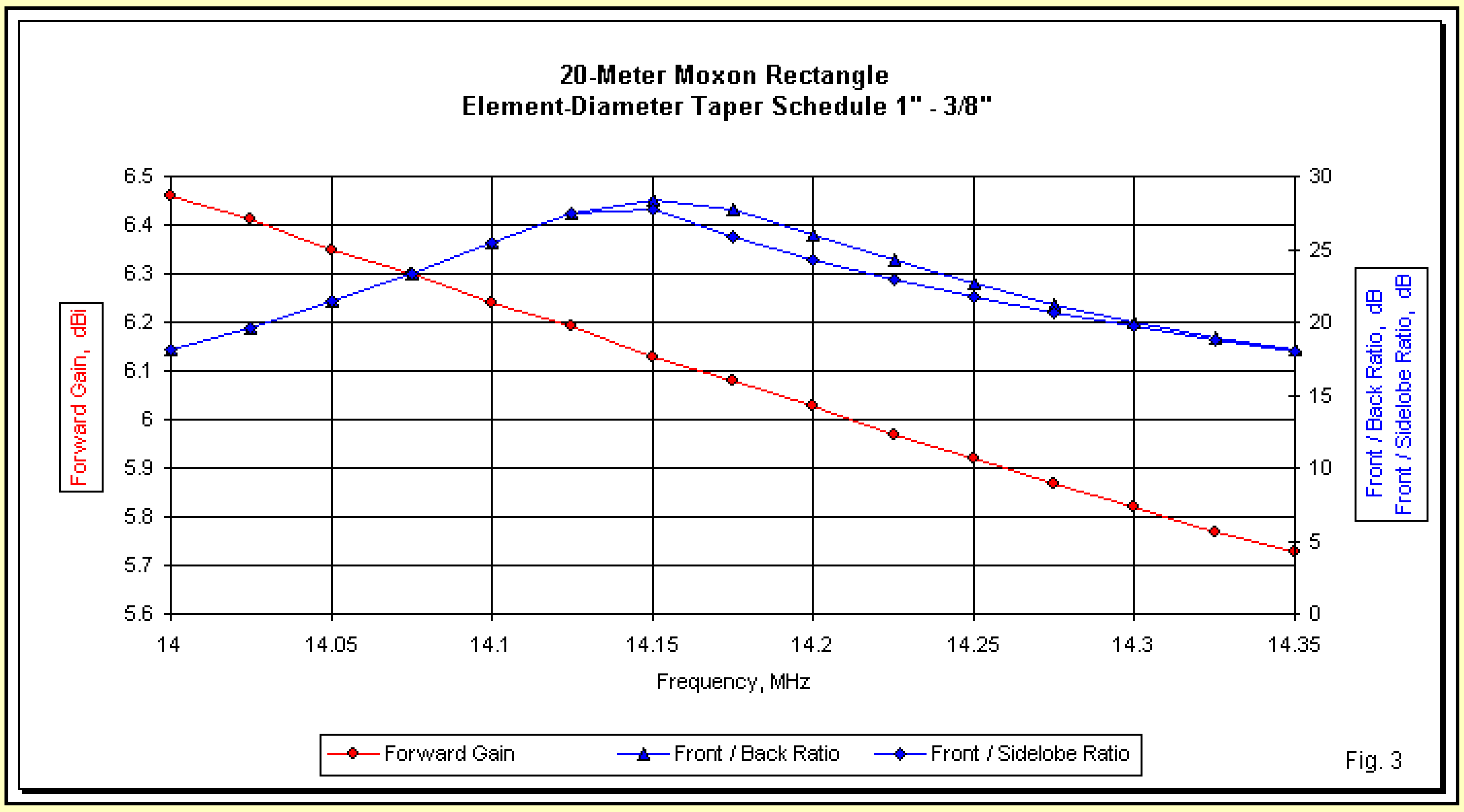
Half-Element Diameter Taper Schedule
The difference between the exposed length and the total length is the amount of the smaller diameter tube inserted into the larger tube. Trim about 1/4" from the largest diameter tube at the centerline of the driver element for the gap required for feedline connections. All dimensions are in inches.

Diameter	Exposed Length	Total Length	Element Length
1"	30	30	30
0.875"	36	66	66
0.75"	30	33	96
0.625"	24	27	120
0.5"	32	35	152
0.375"	6.5 *	9.5 *	158.5 *

*** Add length of either driver or reflector tail to the length of the 0.375" diameter tube.**

The half-element table correlates directly with the sketch in **Fig. 2**. The second column lists the length of tube needed for both the exposed section and for insertion into the next larger tube size. Except for the doubled second section, the normal insertion length is about 3" as a compromise between strength and weight minimization. The 3/8" section length represents only the portions in the parallel element section. The tube will be bent at 90 degrees so that it includes the driver or reflector tail length, as applicable.

Fig. 3 graphs the free-space performance of the beam across 20 meters in terms of gain and front-to-back ratio. The front-to-back data includes the 180-degree ratio (labeled front-to-back) and the worst-case ratio (labeled front-to-side).



To translate the curves into representative numbers, the following table samples the data at 14, 14.15, and 14.35 MHz. The design frequency is 14.15 MHz.

Moxon Rectangle 20-Meter Performance
See text for dimensions.

Frequency MHz	Free-Space Gain dBi	Front-Back Ratio dB	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
14.0	**6.46**	**18.11**	**38.1 - j11.7**	**1.46**
14.15	**6.13**	**28.42**	**48.5 - j 0.2**	**1.03**
14.35	**5.73**	**18.09**	**60.6 + j11.6**	**1.33**

The table shows a slightly higher SWR at 14 MHz than at 14.35 MHz, since the design frequency is slightly greater than 1/3 the way up the passband. **Fig. 4** shows the resistance, reactance, and 50-Ohm SWR curves for the design across the entire band. It is possible to raise the impedance slightly at the design frequency and therefore to equalize the band-edge SWR values. However, for this exercise, I wanted to hold all dimension changes to increments of 1/2". As we move upward in frequency for the smaller Moxons in this series, it will be necessary to reduce the increment to 1/4". However, the easy dimension markers may ease the problem of replicating the design with physical element materials.

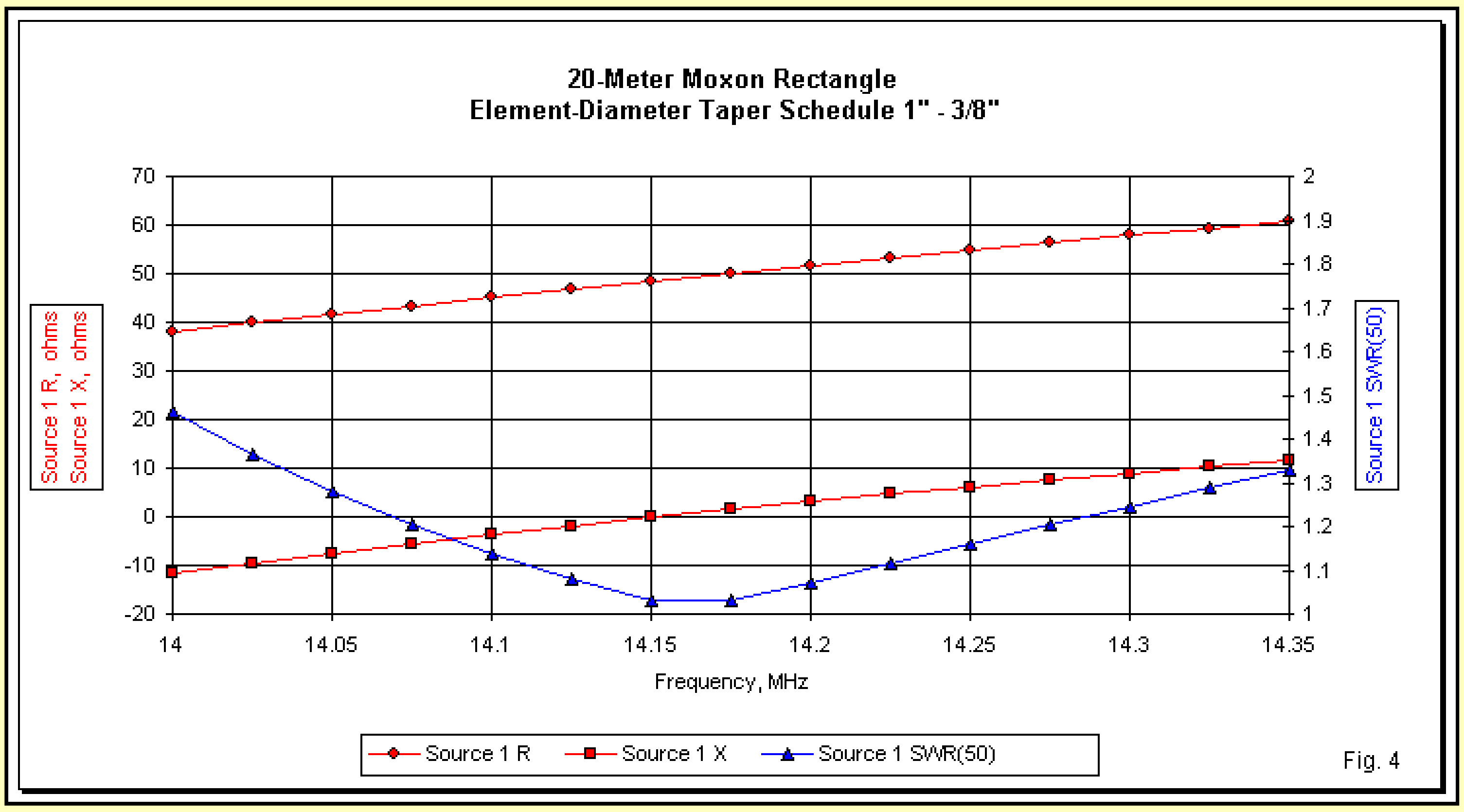
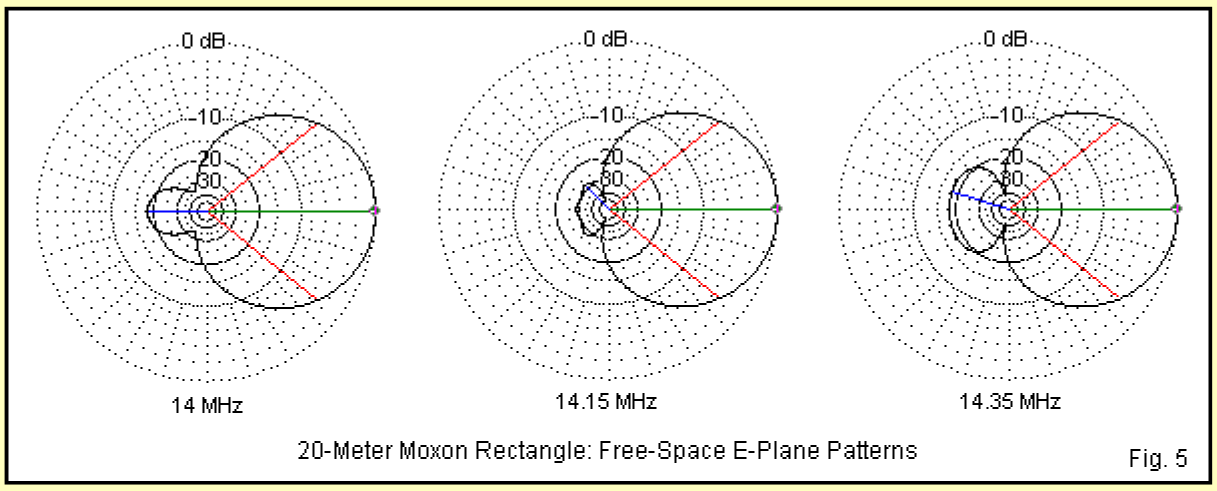


Fig. 4

The 20-meter band is fairly wide (about 2.5%), and so the patterns in **Fig. 5** show a fair amount of evolution. However, they are superior in front-to-back ratio and equal in gain to the patterns for any standard 2-element reflector-driver Yagi design. The blue line in the rear lobe shows the heading for the worst-case front-to-back reading that appears in the curve in **Fig. 3**. The red lines show the beamwidth of the forward lobe. As well, draw a virtual vertical line through the pattern rings to see how far the side nulls are from 90 degrees relative to the forward lobe line.



14 MHz

14.15 MHz

14.35 MHz

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

Fig. 5

17 Meters

On 17 meters, we may design the Moxon rectangle for the center of the 100-kHz band, since the band is only about 0.5% wide. In terms of proportion, the dimension that differs most between the uniform-diameter and the tapered-diameter versions is the gap. **Fig. 6** and the following table provide the dimensions for the array. Because the side-to-side dimension is about 70" shorter than the 20-meter Moxon, we may use 7/8" tubes at the center.

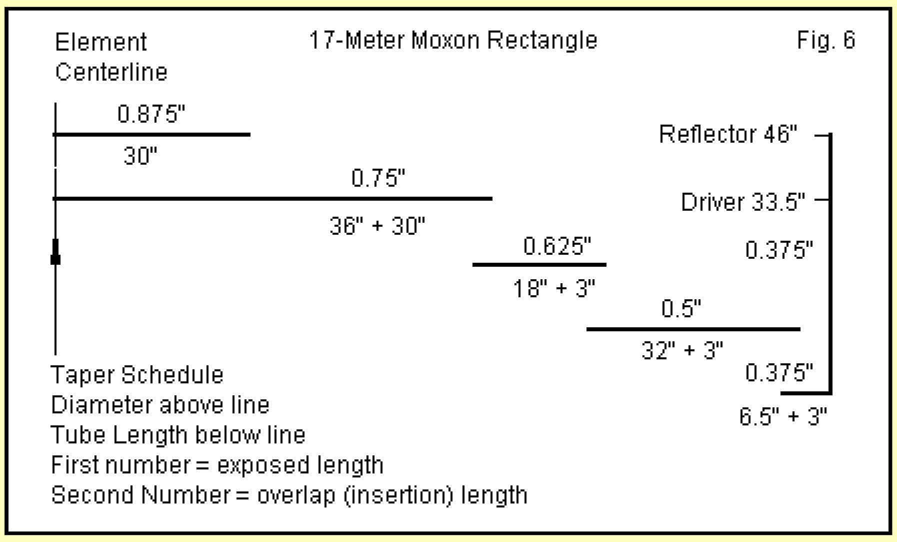


Fig. 6

`A Comparison of the Dimensions of a Tapered Element Diameter Moxon and a Uniform-Diameter Moxon`
`17 Meters (18.118 MHz)  See text for element diameter tapering schedule.  Uniform diameter = 0.5"`

Dimension	Tapered Model	Uniform Model
A	245"	235.40"
B	33.5"	33.16"
C	6.5"	8.94"

D	46"	44.73"
E	86"	86.89"

Half-Element Diameter Taper Schedule
The difference between the exposed length and the total length is the amount of the smaller diameter tube inserted into the larger tube. Trim about 1/4" from the largest diameter tube at the centerline of the driver element for the gap required for feedline connections. All dimensions are in inches.

Diameter	Exposed Length	Total Length	Element Length
0.875"	30	30	30
0.75"	36	66	66
0.625"	18	21	84
0.5"	32	35	116
0.375"	6.5 *	9.5 *	122.5 *

* Add length of either driver or reflector tail to the length of the 0.375" diameter tube.

As shown in **Fig. 7**, the gain and front-to-back ratio vary only a small amount across the 17-meter band. The gain curve is steep only because the total range is well under 0.2 dB. As well, the gain records only to 2 decimal places, giving the curve a somewhat stair-step quality. The actual change is smooth.

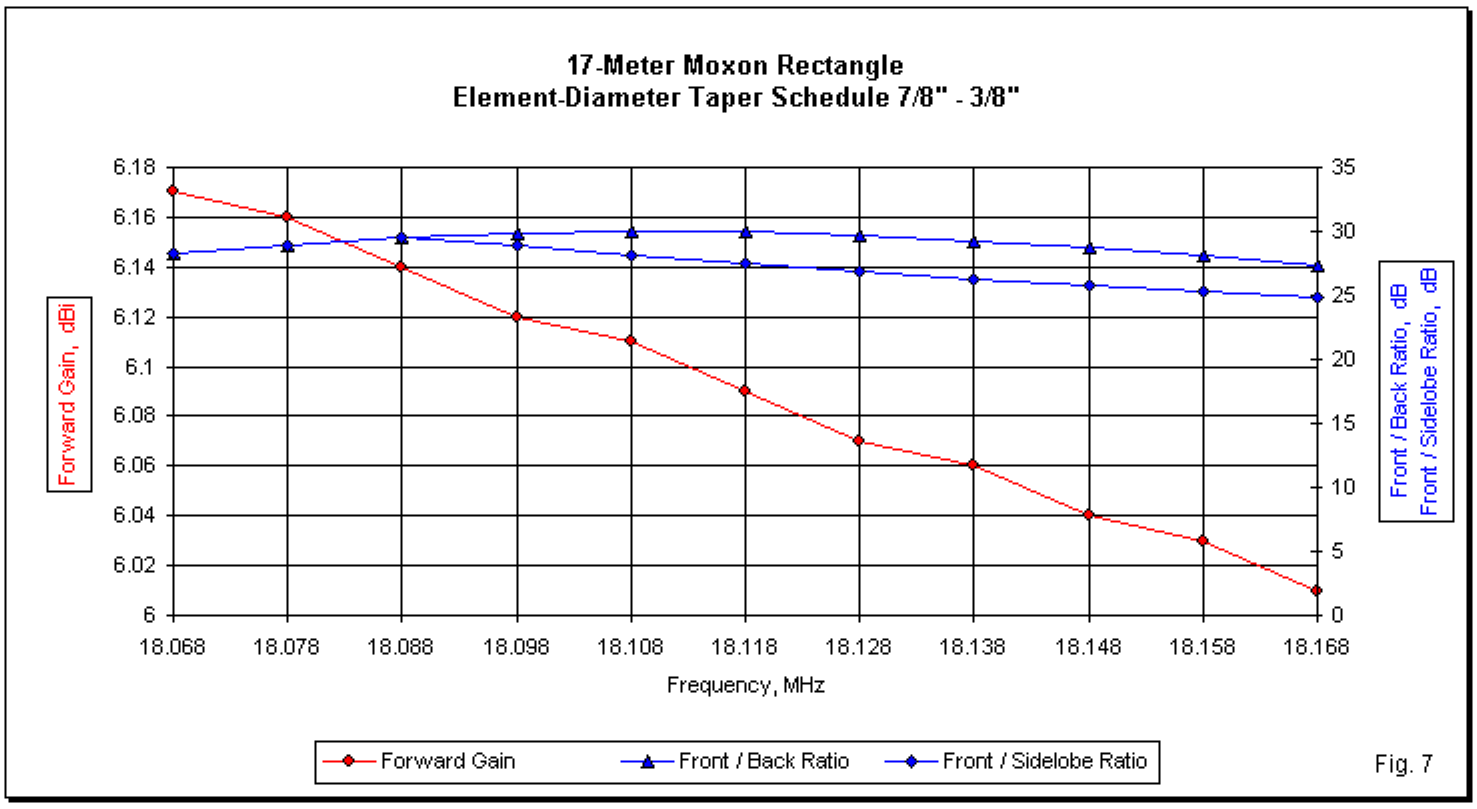


Fig. 7

The following table translates the curves into spot values at the band edges and center. **Fig. 8** provides a graphic view of the very small changes in resistance, reactance, and 50-Ohm SWR.

Moxon Rectangle 17-Meter Performance
See text for dimensions.

Frequency MHz	**Free-Space Gain dBi**	**Front-Back Ratio dB**	**Feedpoint Impedance R +/- jX Ohms**	**50-Ohm SWR**
18.068	**6.17**	**28.24**	**48.0 - j 2.7**	**1.07**
18.118	**6.09**	**30.01**	**50.6 - j 0.2**	**1.01**
18.168	**6.01**	**27.40**	**53.1 + j 2.1**	**1.08**

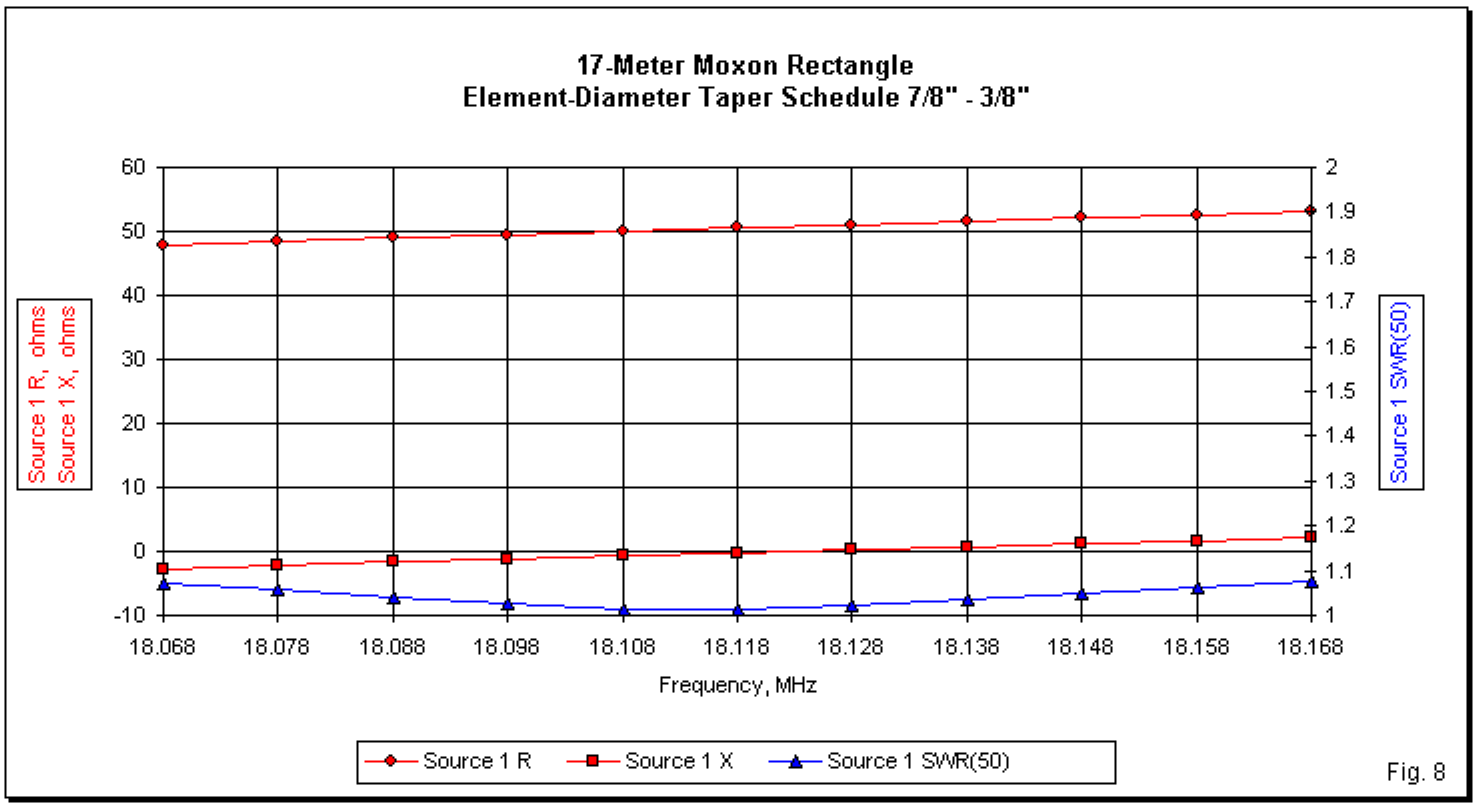
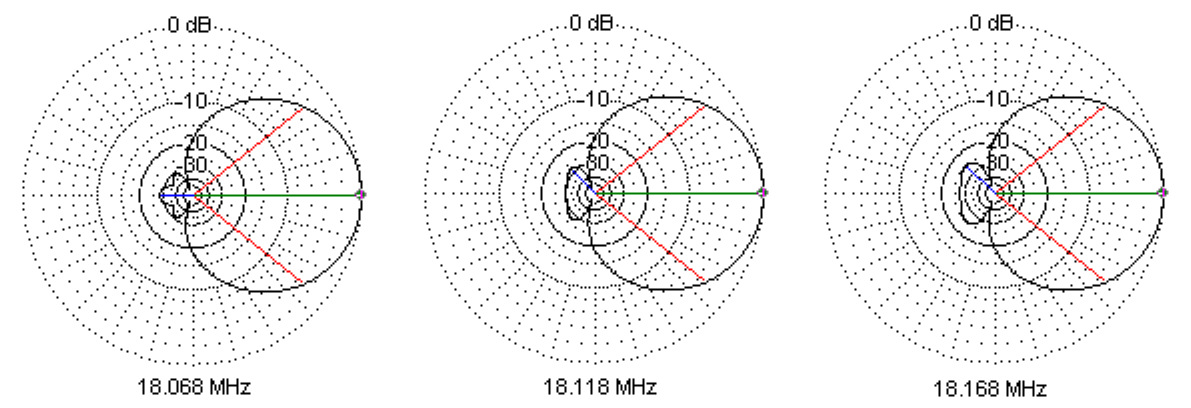


Fig. 8

Although the front-to-back curves in **Fig. 7** suggest a growing divergence between 180-degree and worst-case values, the patterns in **Fig. 9** show that the spreading curves are a function of the very small actual change in front-to-back values. Had the curves extended well above the upper end of the 17-meter band, the 180-degree front-to-back ratio would decrease, while the worst case value would almost hold steady. The result would be a return to an overlapping curve, as shown in the comparable 20-meter curve.

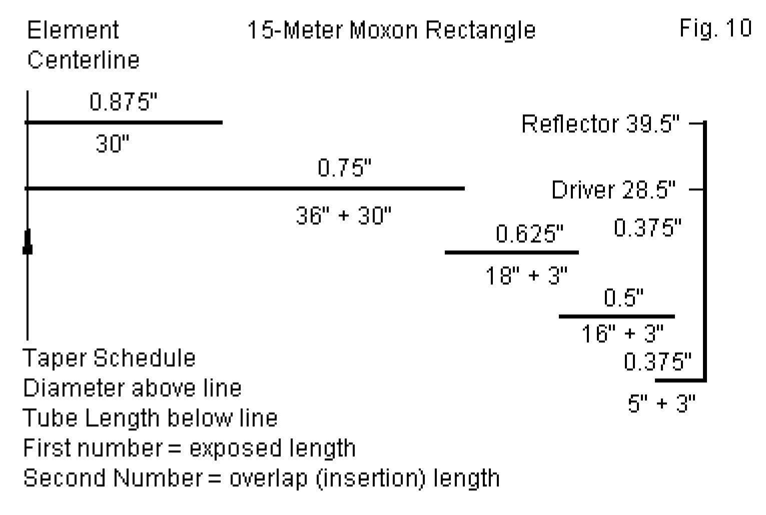


17-Meter Moxon Rectangle: Free-Space E-Plane Patterns

Fig. 9

15 Meters

15 Meters returns us to a fairly wide amateur band (2.1%). As a result, we may bring to the Moxon rectangle for this band similar expectations to those developed from the 20-meter results. The decreasing size of the Moxon rectangle, shown in the element taper sketch in **Fig. 10**, allows us to use the same center tube size that we used in the 17-meter array. In fact, the structure is the same until the beam nears the end of the rectangle's long dimension.



A Comparison of the Dimensions of a Tapered Element Diameter Moxon and a Uniform-Diameter Moxon
15 Meters (21.15 MHz) See text for element diameter tapering schedule. Uniform diameter = 0.5"

Dimension	Tapered Model	Uniform Model
A	210.5"	201.49"
B	28.5"	28.14"
C	6"	7.91"
D	39.5"	38.36"
E	74"	74.41"

Half-Element Diameter Taper Schedule
The difference between the exposed length and the total length is the amount of the smaller diameter tube inserted into the larger tube. Trim about 1/4" from the largest diameter tube at the centerline of the driver element for the gap required for feedline connections. All dimensions are in inches.

Diameter	Exposed Length	Total Length	Element Length
0.875"	30	30	30
0.75"	36	66	66
0.625"	18	21	84
0.5"	16	19	100
0.375"	5 *	8 *	105 *

* Add length of either driver or reflector tail to the length of the 0.375" diameter tube.

Because the 15-meter band is slightly smaller than 20 meters in terms of bandwidth recorded as a percentage (2.1% vs. 2.5%), we can expect slightly shallower curves on 15 meters than on 20 meters. As shown in the gain and front-to-back curves in **Fig. 11**, the gain range is under 0.6 dB (compared to more than 0.7 dB on 20 meters). Both band-edge front-to-back ratio values are higher on 15 than on 20.

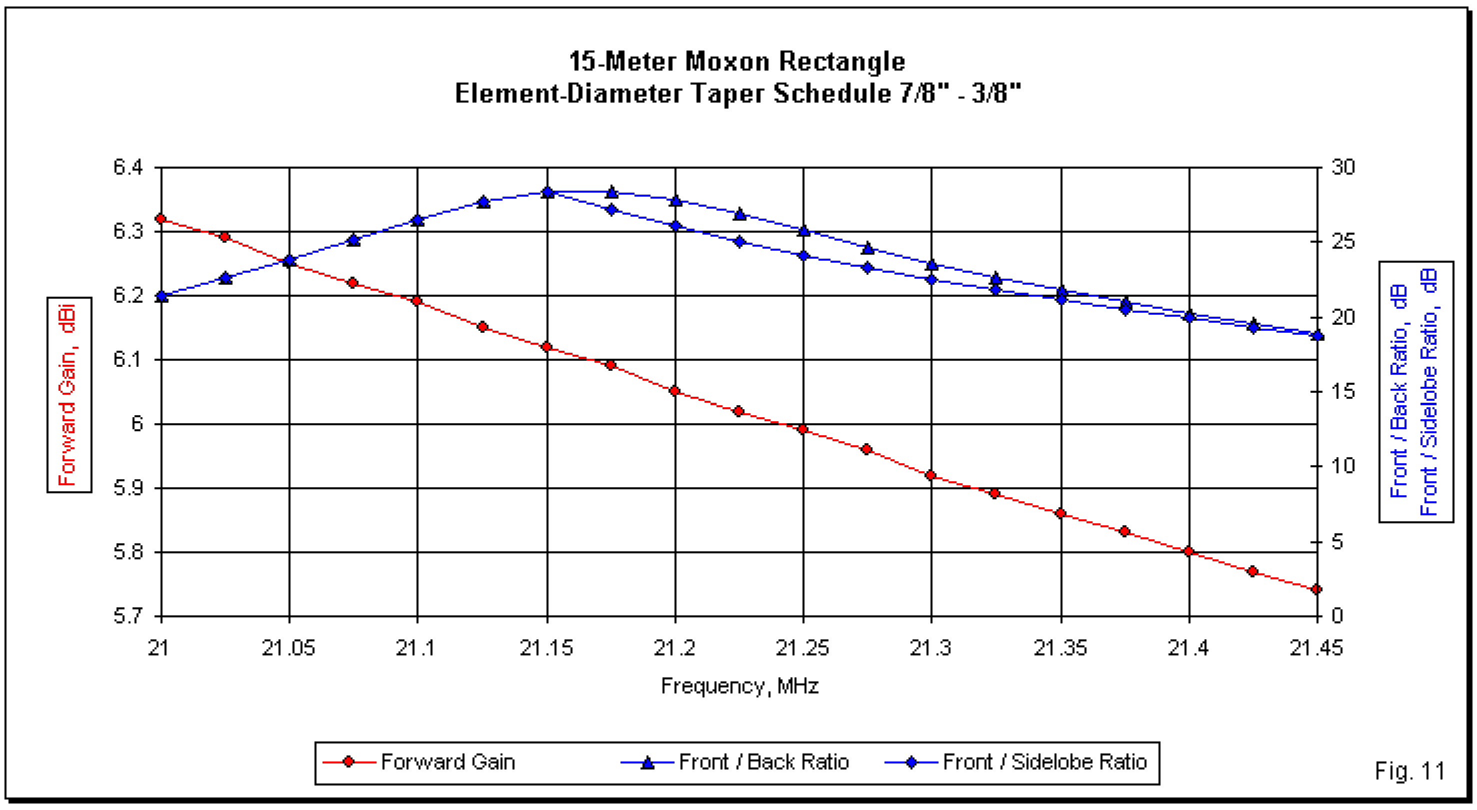


Fig. 11

The table provides selected performance values at the band edges and at the design frequency. 21.15 MHz is exactly 1/3 the way up the total passband for the array. **Fig. 12** converts the spot values for the feedpoint impedance components and the 50-Ohm SWR into smooth curves across the band. A comparison of corresponding curves for 20 and 15 meters tells us that the Moxon rectangle performance is consistent from band to band once we find the right dimensions for the selected element-diameter taper schedule. The rate of gain decrease and the rates of resistance and reactance increase across the band are very nearly linear.

Moxon Rectangle 15-Meter Performance
See text for dimensions.

Frequency MHz	Free-Space Gain dBi	Front-Back Ratio dB	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
21.0	6.32	21.41	42.9 - j 6.6	1.23
21.15	6.12	28.38	49.5 + j 0.1	1.01
21.45	5.74	18.93	61.0 + j10.9	1.32

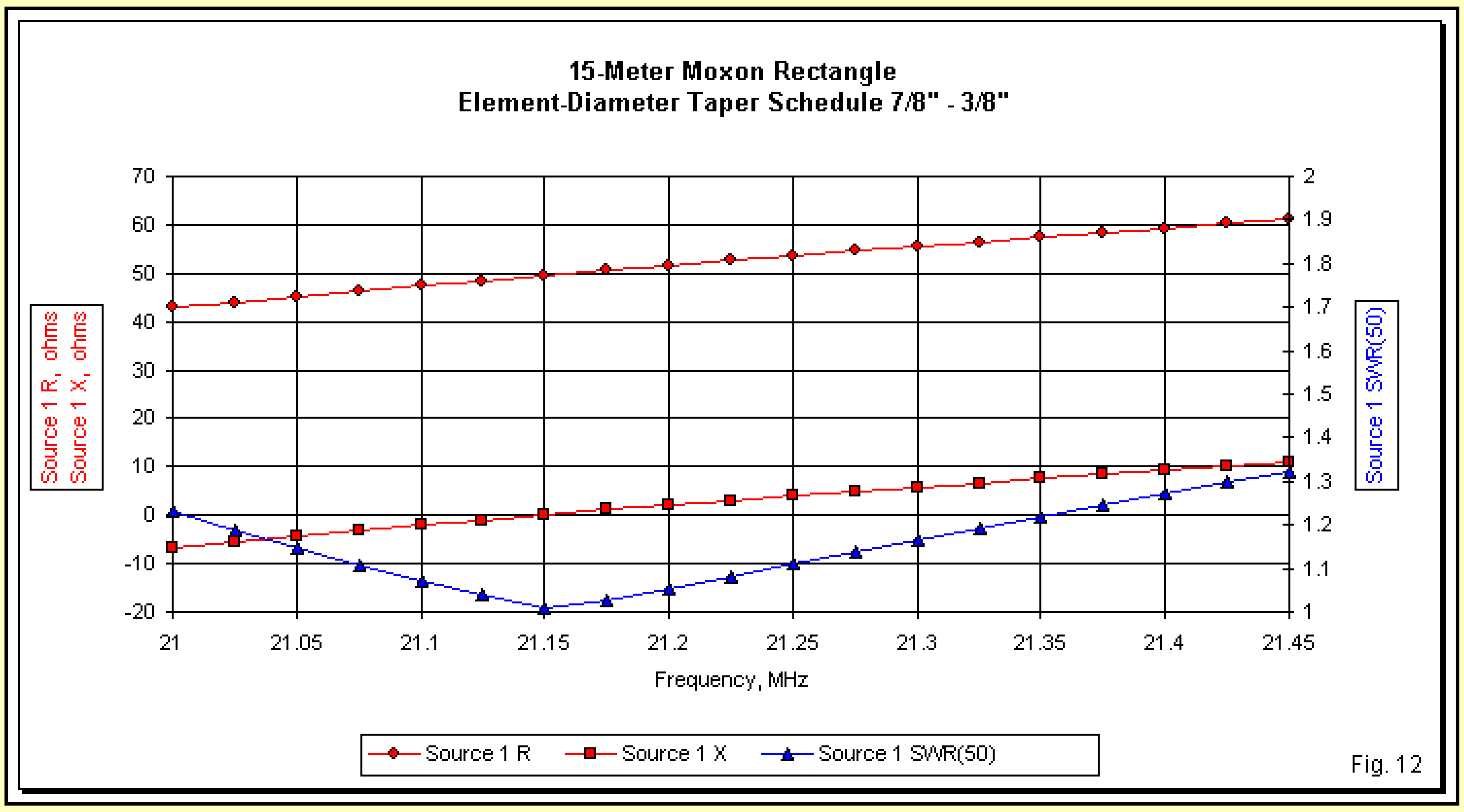
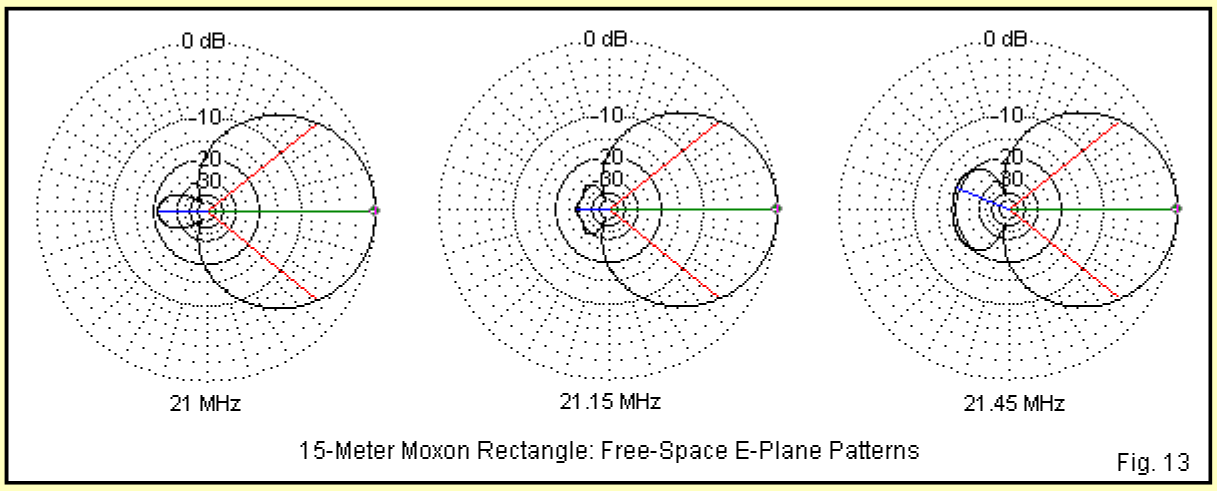


Fig. 12

Further evidence of band-to-band consistency of performance appears in the free-space E-plane (azimuth) patterns shown in **Fig. 13**. The patterns virtually replicate those for 20 meters. Note that we obtain this performance by re-optimizing the design for each band after selecting the desired element-diameter taper schedule.

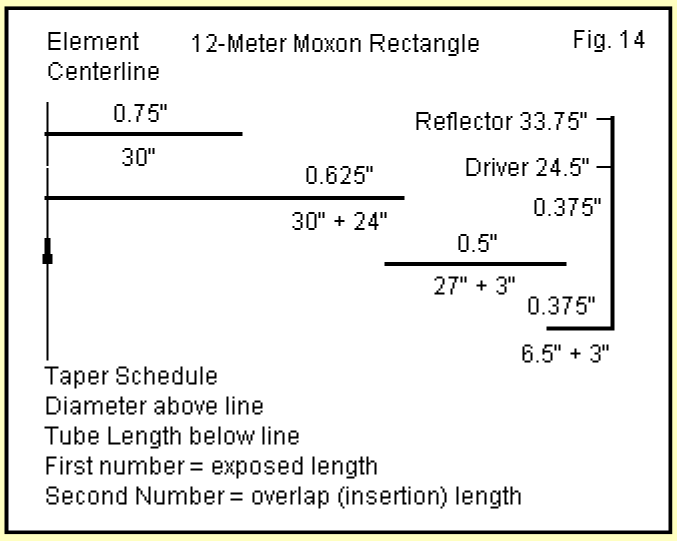


15-Meter Moxon Rectangle: Free-Space E-Plane Patterns

Fig. 13

12 Meters

12 meters returns us to a band only 100 kHz wide. However, as a percentage, the band has shrunk to only 0.4%. Hence, we should expect flatter curves than those we obtained for 17 meters. As well, the beam size has shrunk so that we may use 3/4" tubes at the very center, as shown in the tables and in **Fig. 14**. The total side-to-side dimension of a 12-meter Moxon rectangle is just over 14.5', with a width just over 5'.



A Comparison of the Dimensions of a Tapered Element Diameter Moxon and a Uniform-Diameter Moxon
12 Meters (24.94 MHz) See text for element diameter tapering schedule. Uniform diameter = 0.5"

Dimension	Tapered Model	Uniform Model
A	175"	170.72"
B	24.5"	23.61"
C	4.25"	6.94"

D	33.75"	32.56"
E	62.5"	63.12"

Half-Element Diameter Taper Schedule
The difference between the exposed length and the total length is the amount of the smaller diameter tube inserted into the larger tube. Trim about 1/4" from the largest diameter tube at the centerline of the driver element for the gap required for feedline connections. All dimensions are in inches.

Diameter	Exposed Length	Total Length	Element Length
0.75"	30	30	30
0.625"	24	54	54
0.5"	27	30	81
0.375"	6.5 *	9.5 *	87.5 *

* Add length of either driver or reflector tail to the length of the 0.375" diameter tube.

The performance of the beam is almost invariant across the band with a 0.1-dB change in gain, as shown by the gain values in **Fig. 15**. Once more, the limitations in the decimal places of the gain reports provides the stair-steps in the graph. Because the worst-case front-to-back ratio remains almost constant across the band, it makes little difference that the peak 180-degree front-to-back ratio occurs at the upper band edge. To move that peak to the band's center frequency would have required a number of dimensions that used smaller fractions of an inch than the quarter-inch limit that I set.

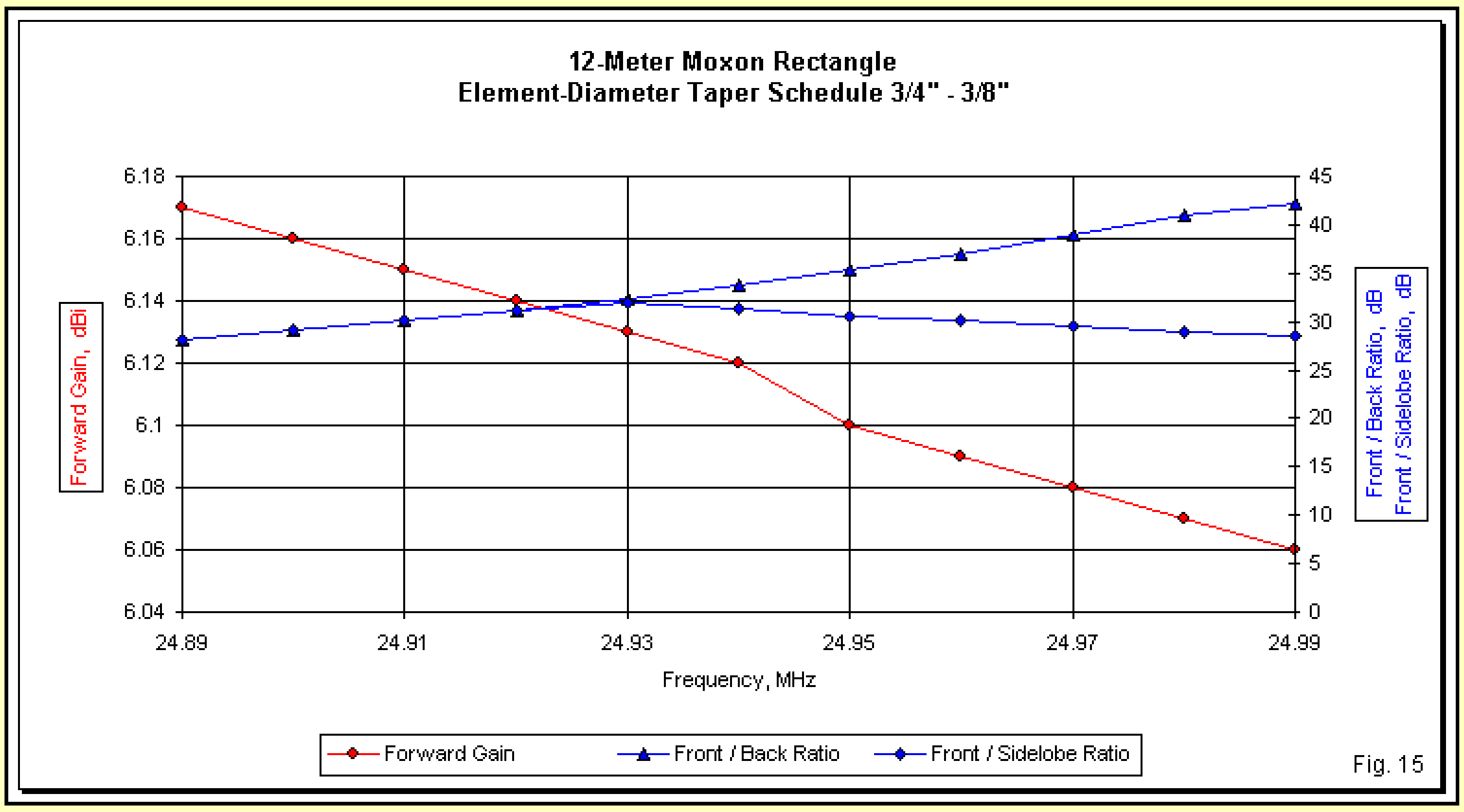


Fig. 15

Moxon Rectangle 12-Meter Performance
See text for dimensions.

Frequency MHz	Free-Space Gain dBi	Front-Back Ratio dB	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
24.89	6.17	28.17	48.5 - j 2.5	1.06
24.94	6.12	33.72	50.4 - j 0.7	1.02
24.99	6.06	42.14	52.4 + j 1.0	1.05

I have included **Fig. 16** solely to make the record complete. All values of resistance, reactance, and 50-Ohm SWR are as close to flat lines as we are likely to find in such graphs.

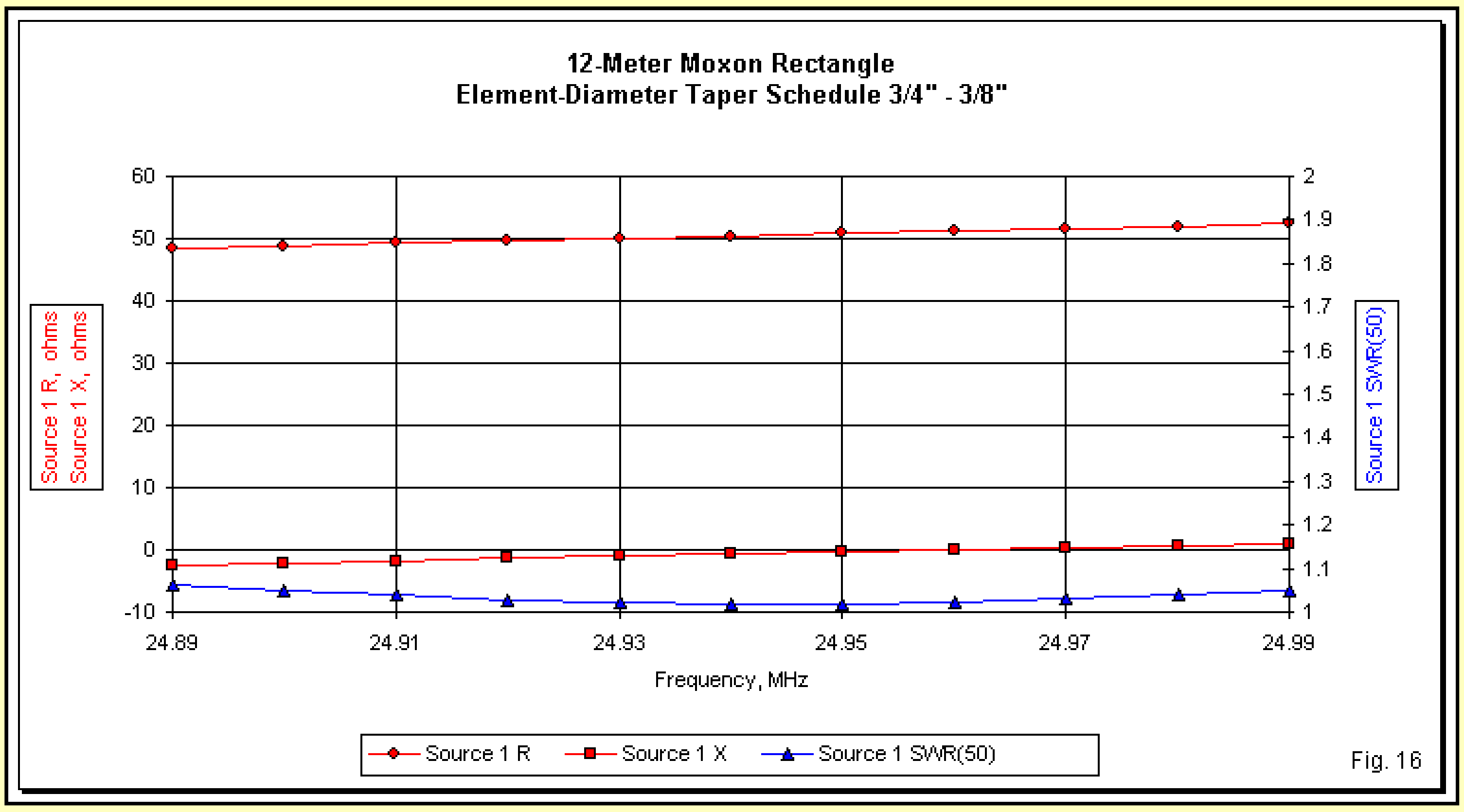
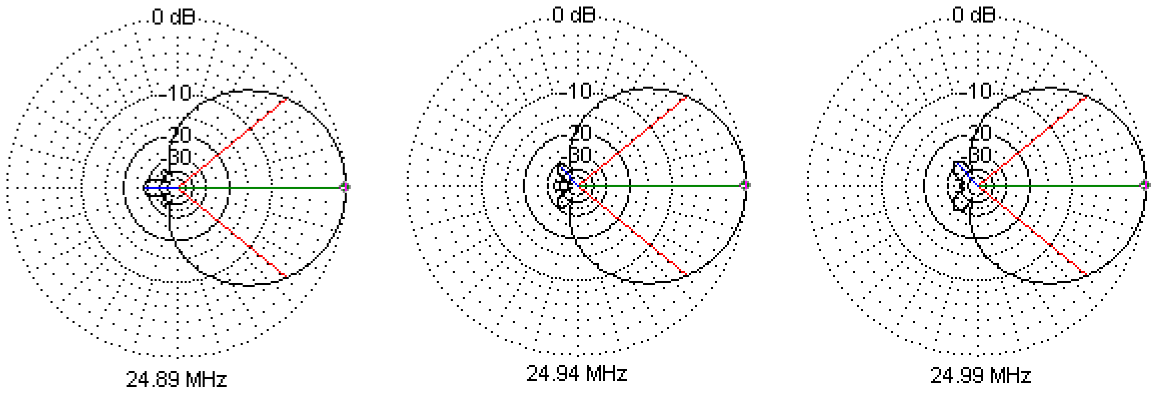


Fig. 16

The very small changes in the patterns in **Fig. 17** show how truly narrow the 12-meter band is. The rear lobe changes are visually noticeable, but operationally, it is unlikely that even the best ears could tell the difference in the suppression of rearward QRM across the band. Indeed, normal construction variations are likely to move the peak front-to-back ratio to a slightly different frequency than the one shown in the graphs and tables.



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

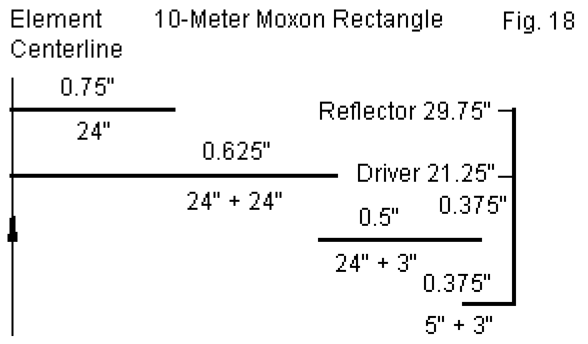
Fig. 17

10 Meters

If we define 10 meters in terms of the first MHz of the total band, we still obtain the widest of the upper HF amateur bands at 3.5%. Many Yagis (especially the 10-meter sections of tri-band designs) manage to cover only the first 800 kHz with under 2:1 50-Ohm SWR. However, the Moxon rectangle easily covers the entire first MHz if we can accept the normal gain reduction across the passband. As the smallest of our rectangles (12.8' by 4.6'), the array has plenty of strength with 3/4" tubing at the center and 3/8" tail sections. **Fig. 18** shows the element taper schedule corresponding to the tabular values below the figure.

10-Meter Moxon Rectangle

Fig. 18



Taper Schedule
Diameter above line
Tube Length below line
First number = exposed length
Second Number = overlap (insertion) length

A Comparison of the Dimensions of a Tapered Element Diameter Moxon and a Uniform-Diameter Moxon
10 Meters (28.35 MHz) See text for element diameter tapering schedule. Uniform diameter = 0.5"

Dimension	Tapered Model	Uniform Model
A	154"	150.08"
B	21.25"	20.59"
C	4"	6.27"
D	29.75"	28.67"
E	55"	55.53"

Half-Element Diameter Taper Schedule
The difference between the exposed length and the total length is the amount of the smaller diameter tube inserted into the larger tube. Trim about 1/4" from the largest diameter tube at the centerline of the driver element for the gap required for feedline connections. All dimensions are in inches.

Diameter	Exposed Length	Total Length	Element Length
0.75"	24	24	24
0.625"	24	28	48
0.5"	24	27	72
0.375"	5 *	8 *	77 *

* Add length of either driver or reflector tail to the length of the 0.375" diameter tube.

Because the 10-meter band is so wide, the gain decreases by about 0.9 dB from one end of the band to the other, as shown in **Fig. 19**. As well the front-to-back values at the band edges are between 16 and 17 dB. Still, these values a 5 to 6 dB higher than we might obtain with a wide-band 2-element reflector-driver Yagi, and a wide-band Yagi would have larger dimensions in both directions (side-to-side and front-to-back).

10-Meter Moxon Rectangle
Element-Diameter Taper Schedule 3/4" - 3/8"

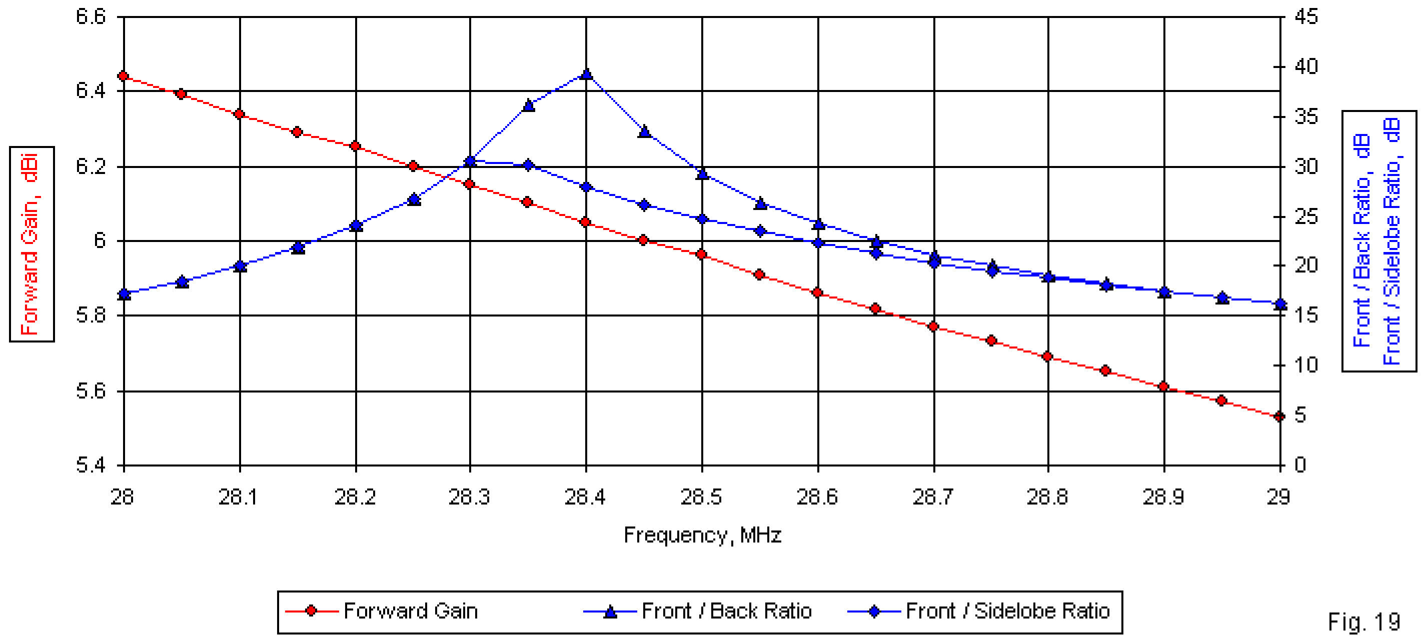


Fig. 19

Moxon Rectangle 10-Meter Performance
See text for dimensions.

Frequency MHz	Free-Space Gain dBi	Front-Back Ratio dB	Feedpoint Impedance R +/- jX Ohms	50-Ohm SWR
28.0	6.44	17.18	38.6 - j13.6	1.49
28.35	6.10	36.07	50.6 + j 1.7	1.04
29.0	5.53	16.18	68.6 + j13.4	1.47

As shown by the performance table and the curve in **Fig. 20**, the Moxon rectangle with the selected element taper schedule still manages to show less than 1.5:1 50-Ohm SWR across the band. Of course, cable losses at 10 meters begin to show themselves, so the SWR values recorded at the transmitter end of the feedline will be slightly less.

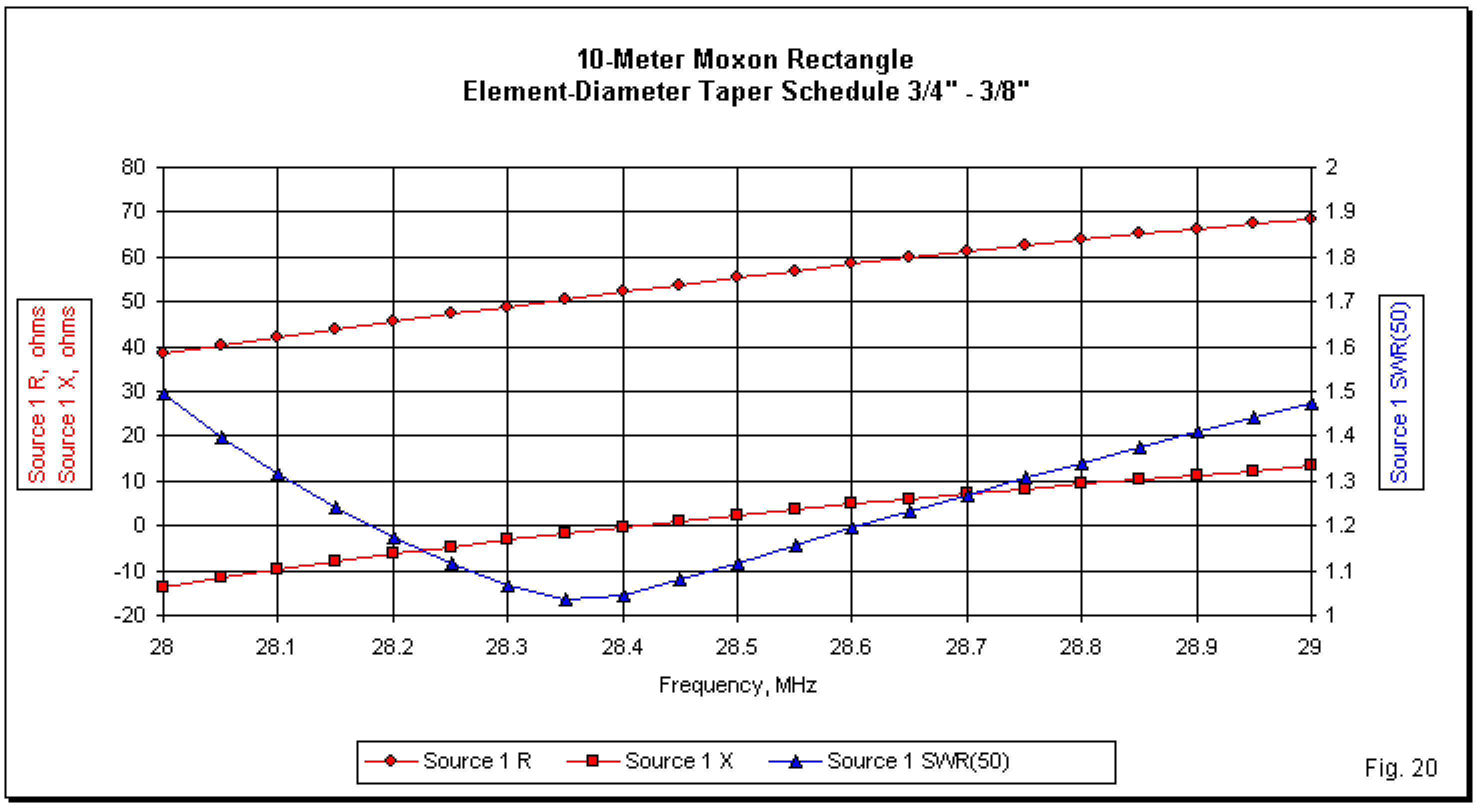
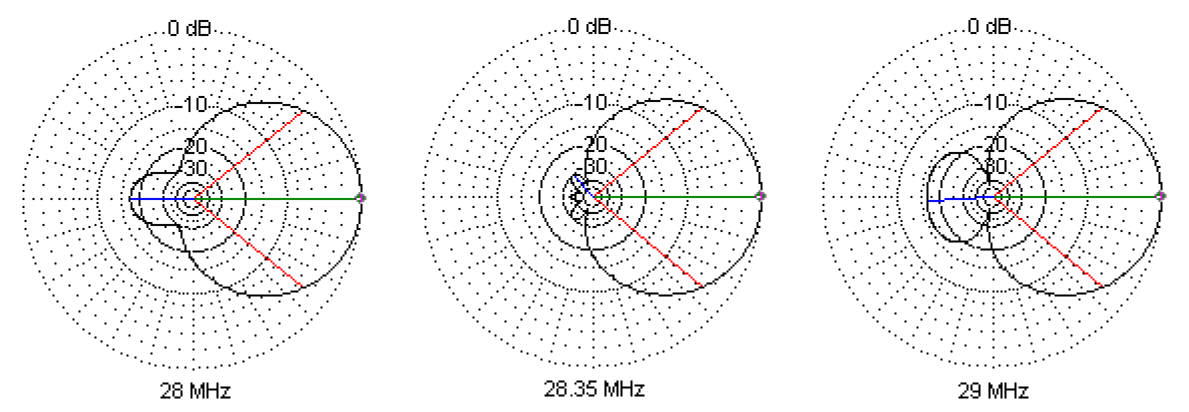

10-Meter Moxon Rectangle
Element-Diameter Taper Schedule 3/4" - 3/8"

Fig. 20

Even under wide-band conditions, such as those on 10 meters, the rearward lobes remain well behaved. Except for the peak value of 180-degree front-to-back ratio, where we find two lobes symmetrically arranged on each side of the centerline, the rearward radiation forms a single lobe. As shown in the patterns in **Fig. 21**, the rearward pattern is relatively straight-sided below the design frequency. Above the design frequency, the pattern shows a a single bulbous lobe.



28 MHz
28.35 MHz
29 MHz

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

Fig. 21

I have provided complete design data and performance projections for each version of the Moxon rectangle. A complete record of design and performance data across each band of operation is perhaps the only fair way to allow a potential builder or user to evaluate the design to determine if it is one to implement. I could have cited spot values only or, more extremely, peak values. Such data would have given a distorted picture of the true performance potential of the array. For example, citing the peak gain values for each band would have given the impression that performance changes from band to band. As well, citing only peak gain and peak front-to-back values would distort the portrait even further, since these values do not occur at the same frequency. With regard to feedpoint impedance issues, only the curves give the potential user a clear picture of the rates of change of SWR both above and below the design frequency. In these designs, I have no vested interest. Hence, I have no reason not to show all of the data for each band's design, including any performance facts that might count against the use of the Moxon rectangle. (For example, someone interested only in phone operation might wish to redesign one or more of the wide-band designs to favor that portion of the band.)

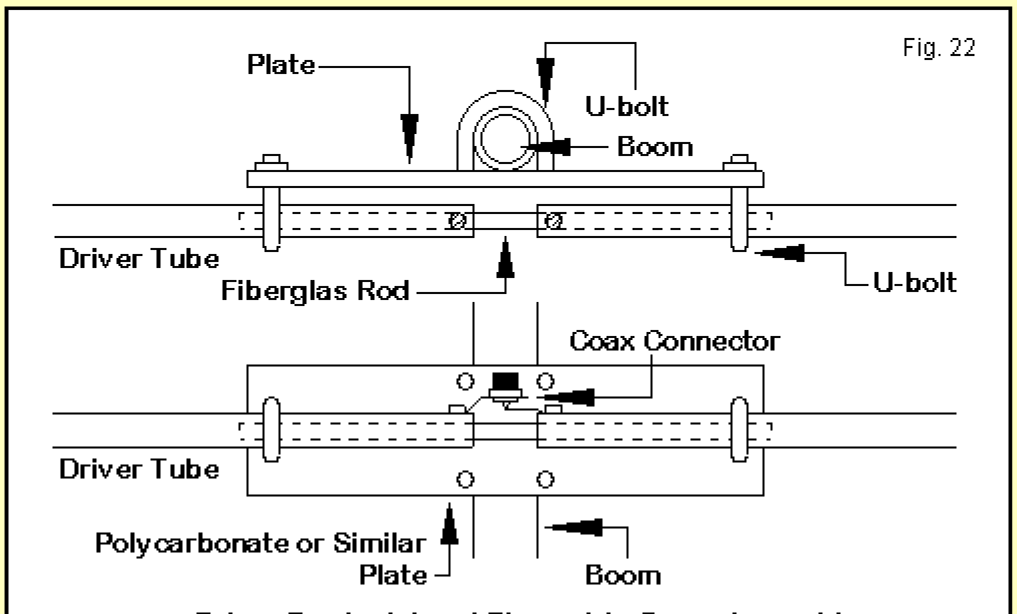
Since I brought attention to the Moxon rectangle back in the early 1990s, numerous versions have been built by various enthusiasts. The arrays range from fixed wire versions for the lower HF range to lightweight wire versions for upper HF to vertically and horizontally polarized versions for a variety of special VHF and UHF applications. More recently, commercially built stepped-diameter rectangles for the upper HF region have appeared. AerialActs of Silver Spring, MD (Craig Roberts, W3CRR) markets a series of Moxon rectangles (called the MaxiMoxon) that employ different taper schedules than the models shown here. The differences in the taper schedule result in a different set of overall dimensions, although they are likely not too far from the values shown in the tables. In addition, there are differences in the preferred construction methods.

Re-design of a Moxon rectangle that employs a stepped-diameter taper schedule is not a task for NEC-2. Because the stepped-diameter correction of NEC-2 implementations does not operate for non-linear elements, the program will not correctly handle the bent Moxon elements. Re-design should use either NEC-4 or a highly corrected version of MININEC 3.13, such as the one sold as Antenna Model. A MININEC implementation must have at least the frequency-drift correctives if it is to handle the 12 and 10- meter designs adequately.

A Few Construction Notes

Constructing a beam for long-term station use is not a casual task. Building a durable beam does not require a massive shop. Rather, it involves taking pains to ensure that the result is the best possible combination of strength and relatively light weight. Careful planning, careful measurement, and careful fabrication go hand-in-hand-in-hand. Indeed, having a third hand in the shop (in the form of someone willing to help and equally committed to a quality finished product) is extremely helpful. If you work alone, take the trouble to construct jigs from scrap wood around the shop to assist in the drilling and other assembly processes.

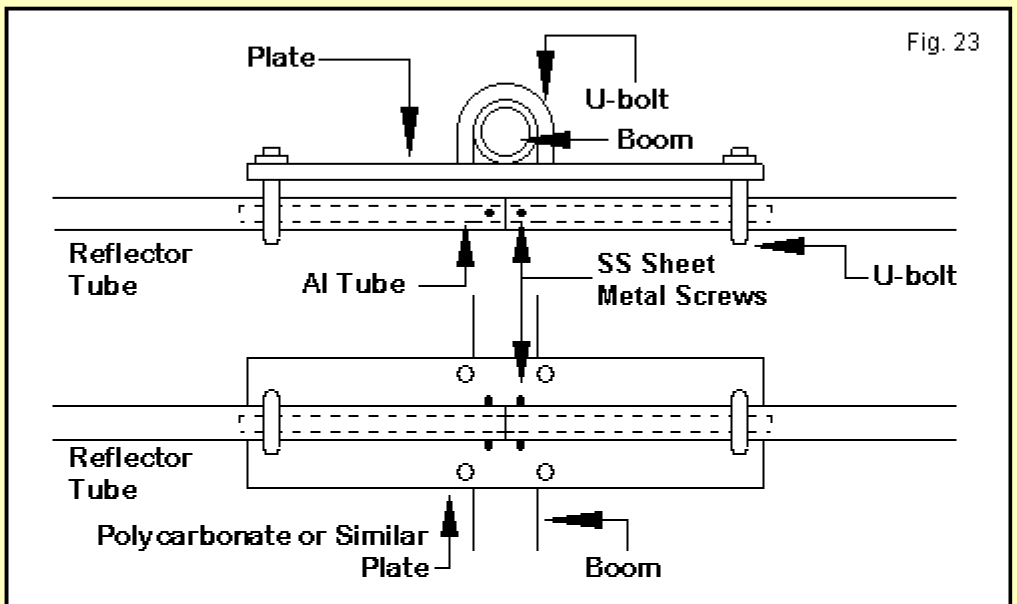
The Moxon rectangle uses a direct 50-Ohm feedpoint, which calls for a split driver to make connections at the element center. At HF, the size of the gap is generally not critical, although the actual gap is in principle simply the distance between the two conductors of the feedline cable. The leads from the cable or from the cable connector are part of the driven element. The element dimensions from end-to-end do not change, so we subtract half the gap size from each half-element in the driver.



Driver Feedpoint and Element-to-Boom Assembly

Modeled designs also presume that all elements are well insulated and isolated from any conductive boom that might provide physical support. A section of 1.25" outside diameter aluminum tubing is probably the most common boom material. Although the assembly is fairly light, a 1/8" wall tube or a nest of 1.25" and 1.125" tubing is necessary to support the wind-induced twisting loads on the entire assembly. The double-tube boom is wise, even for the short 10-meter boom, since it will resist crushing at the boom-to-mast junction. **Fig. 22** shows one method (out of several) for constructing the feedpoint. A polycarbonate or similar plate provides the element isolation and supports the boom U-bolts. Size the plate according to the weight of the elements, using a larger plate for 20 meters and a smaller one for 10. UV protected polycarbonate sheets in 1/4" and 3/8" thicknesses are available from local plastic supply houses in medium to large cities and via the web (for example, McMasters-Carr). If we insert a non-conductive tube or rod into the ends of each element half, we assure element alignment with only 2 U-bolts and also establish an anchor point for the gap and the feedpoint connections. If we also run the inner tube to the gap, then it also provides support that will keep the aluminum elements from crushing as we tighten the U-bolts. The outside diameter of the gap-setting tube should just fit inside the center tube section of the element. For the doubled Moxon element sections, the required rod or tube size would have an outside diameter 1/4" less than the outside diameter of the largest tube in the taper schedule. All hardware is stainless steel to prevent corrosion and to avoid bimetallic electrolysis.

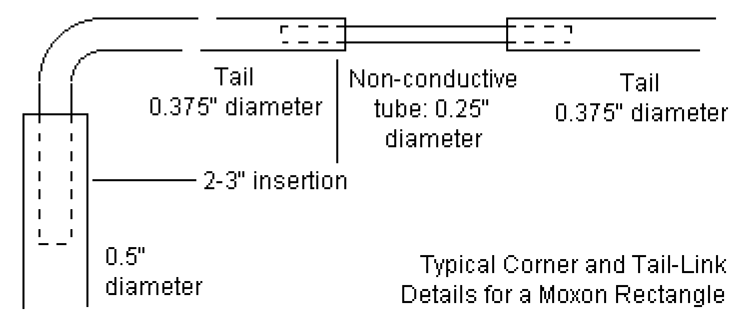
As shown in **Fig. 23**, we may treat the reflector of any Moxon design in a similar manner. In this case, we bring the ends of the tubes together to form a continuous element or we use a single piece of tube to form the center element section. The advantage of using a split section at the reflector center is that we may use an interior piece of aluminum tubing to form the physical and electrical junction of the 2 element halves. Extending the inner tube to the center provides the same insurance against U-bolt crushing that we obtained from the non-conductive tube in the driver elements. The inner tubing should have the same diameter as the non-conductive tube in the driver. If we use a continuous center tube for the largest diameter in the reflector, we may also use separate tubes for the next size, bringing them together at the center of the largest tube. The doubled section should provide sufficient strength to resist U-bolt crushing. U-bolts with solid aluminum saddles are available from sources such as DX Engineering. These U-bolts provide the most secure mounting and also resist element crushing better than U-bolts styled like muffler clamps.



Reflector Element-to-Boom Assembly

The Moxon rectangle 3/8" tail sections must meet several criteria. First, they must turn a corner. Second, they must maintain the gap size, even in the face of winds. Third, they must keep the tail ends aligned. For 3/8" diameter tubing, turning a corner is not difficult. Starting with a tube section that is longer than needed, we can bend one end in the same tubing bender used for small copper tubing. Filling the tube with very fine play sand will further reduce the tendency for crushing during the bending operation, and many builders like to heat the tubing as a further precaution. We can insert the short end into the 0.5" diameter section with the standard 3" insertion overlap. The small curve at the corner will not alter the overall element length enough to cause any noticeable change of performance if we keep the total element length equal to the sum of all of the exposed portions of the sections. **Fig. 24** shows the general scheme.

Fig. 24



The figure also shows a simple way to maintain the gap and to keep the ends aligned. We simply insert a 1/4" non-conductive tube or rod into the tail ends and fasten it with stainless steel sheet metal screws. The tube or rod should be light and should also be UV protected. The result is a physically closed rectangle. Unlike beams with linear elements, the rectangle will not whistle, although you may wish to cap the boom ends. Because the Moxon rectangle in this configuration is subject to racking forces, we likely should reduce the wind load capacity of the elements by a small amount. The structures shown in the taper schedule sketches should handle winds up to about 75 mph.

There are as many variations on physical construction as there are potential element-diameter taper schedules. Therefore, consider these notes as simply a starting point for your own ingenuity.

Conclusion

These notes present usable designs for home built Moxon rectangles for the upper HF range. The Moxon rectangle is--for full performance--essentially a monoband 2-element array with close to the gain of a full size 2-element Yagi but superior front-to-back performance. For wide-band use, the Moxon is shorter than most Yagis and offers a 50-Ohm feedpoint impedance. The Moxon may also be used for yards that do not permit full-length linear elements that a standard Yagi requires.

The Moxon designs shown here employ element-diameter taper schedules that should suffice for winds up to about 75 mph, a condition for long-term home-station use. Due to the effects of the decreasing element diameter, the dimensions for each band differ from those for a uniform-diameter Moxon, and each design requires a custom fit to the selected taper schedule. Hence, each version in the series requires individual design optimizing and individual data graphs and tables. However, the construction of each version differs only in the size of the tubes and the boom-to-element plates. The construction techniques shown are but one set out of many that you might devise.

In the end, the exercise has satisfied my curiosity as to whether a complete line of Moxons might evolve, each with an element taper schedule suited to the beam size for the operating frequency. The answer is yes.

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