# Is the V-Yagi a 3-Element Moxon?

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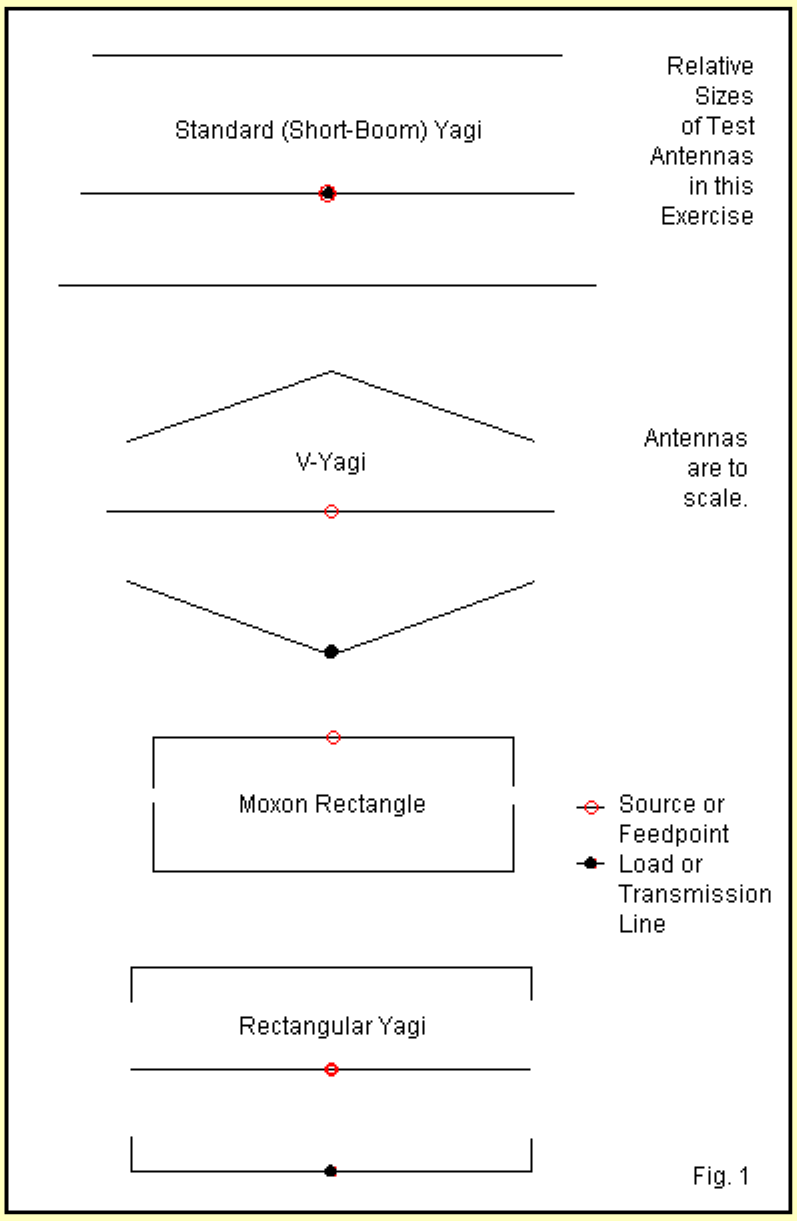
In the exploration of the V-Yagi, we ended with an unanswered question based on the performance and pattern characteristics of the antenna. The pattern and some of the performance curves resemble those associated with the 2-element Moxon rectangle that uses dual coupling--from the parallel elements and from element tip to element tip. However, the Moxon rectangle uses close tip spacing between the driver and reflector. The V-Yagi uses wider spacing between parasitic element tips, with an intervening driver. Hence, the question mark.

We can formulate the question in several ways. Is the V-Yagi a 3-element Moxon rectangle? This question is actually a disguised form of another: Does the V-Yagi derive its patterns and performance curves from dual forms of element coupling? Or, are the V-shaped elements in the V-Yagi sufficient to account for the analogous behaviors between it and the Moxon? An affirmative answer to the latter question would suggest that there may be a critical angle for parasitic elements that produces, at the design frequency, a nearly cardioidal pattern. This result would be consistent with studies of the VK2ABQ square. In that design, which uses the same kind of fold-back elements as the Moxon, we find 2 versions: a narrow-spaced version that forms a squared Moxon and a wide-spaced (or large-gap) version that appears less dependent upon the gap for its characteristics.

The questions posed here have very few practical implications. They do not change the recommended dimensions for the V-Yagi or alter its performance. Instead, the matter simply piques my curiosity. My analytic tools focus on careful modeling of the antenna. However, the calculations performed by the NEC core do not automatically signal the number and types of coupling modes that may be at work with relatively close spaced elements in an array. Rather, the program calculates interactions among all segments as a single large matrix, taking into account the geometric structure of segments, some of which are connected to others and some of which form unconnected wire ends.

However, NEC offers indirect evidence for single or dual element coupling. (Actually, all elements within the inductive or close-in near field range are dual coupled. However, the more parallel the elements and the farther apart, the weaker that end coupling will be until we may almost dismiss it. However, NEC does calculate the end effect of wires and takes this factor into account in the overall calculation of the interactive matrix.) We need to devise a strategy that will allow us to distinguish between patterns that result from Vee'd parasitic elements and those that emerge from dual coupling.

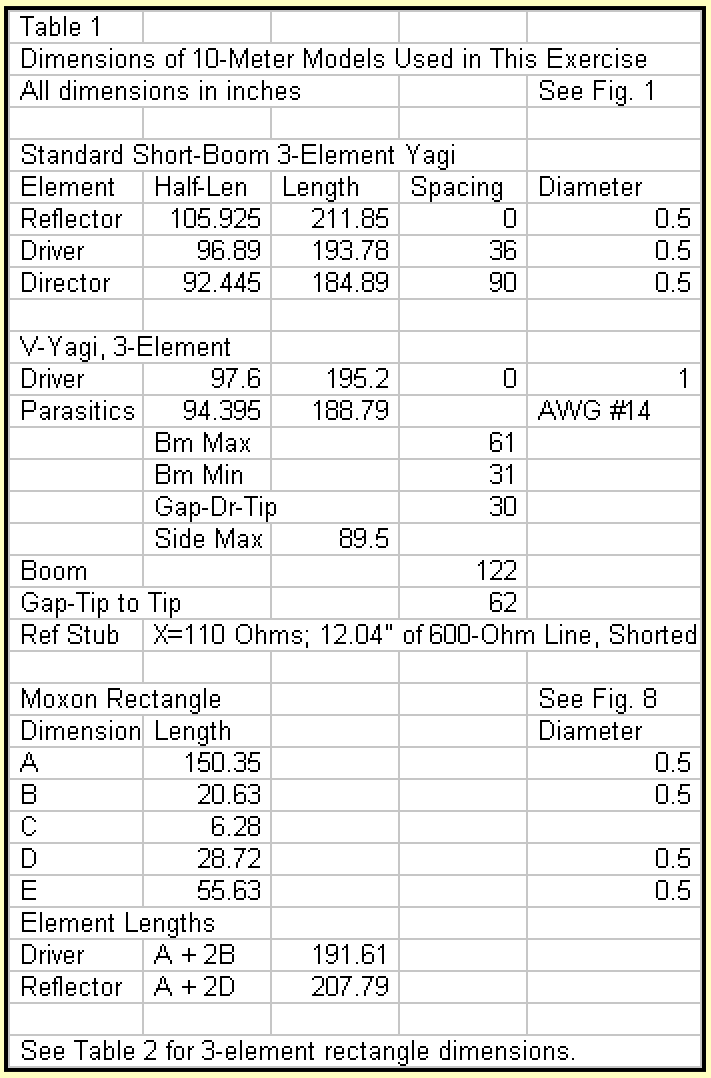
We can obtain the necessary clues if we pay close attention to the patterns and performance curves of a series of antennas. **Fig. 1** shows the sequence that we shall use. All antennas in the series are scaled to each other, relative to the models that we shall examine. In fact, all of the models will use the 10-meter amateur band (28.0 to 29.0 MHz) as the test arena. Except for the V-Yagi, all models will use 0.5" diameter elements. The V-Yagi model will use a 1" driver with AWG #14 parasitic elements. (The diameter of AWG #14 wire is 0.0641".) The first antenna is a short-boom standard-design Yagi. Its patterns and performance curves will form a reference against which we can compare the results from other models.



The second antenna is the V-Yagi. We shall be interested in examining the details of how the pattern and performance curves differ from those of a standard Yagi. Then we may compare the data for both antennas against a model of a Moxon rectangle to see if we may find points of similarity and of difference. However, this comparison alone will not provide us with sufficient information to be decisive about our initial question.

If there is dual coupling between the parasitic elements of a V-Yagi, we ought to be able to enhance that phenomenon by creating a rectangular version of the antenna, shown at the bottom of **Fig. 1**. The sketch of the rectangle is incomplete, since it shows a shortened driver. We may bring the driver to resonance by adding symmetrical extensions at right angles to the driver. We shall look at 2 variations on this process to see if they have any significant affect the antenna performance.

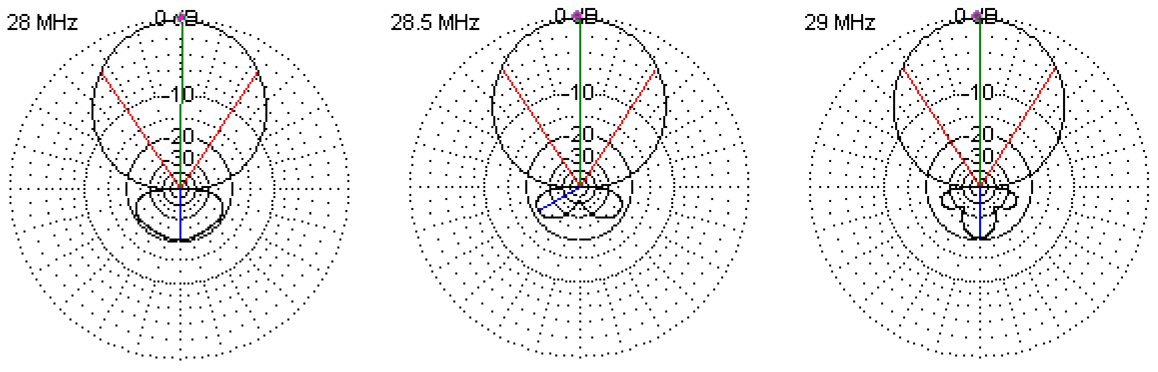
The sum of these maneuvers should provide us with sufficient information to determine whether or not the V-Yagi obtains its Moxon-esque patterns and performance curves solely from the parasitic Vee element shapes or also from coupling between element tips. **Table 1** provides the dimensions for most of our test models. I shall explain any special designations in the course of working with each antenna.



| | | | | |
|---|---|---|---|---|
| Table 1 | | | | |
| Dimensions of 10-Meter Models Used in This Exercise | | | | |
| All dimensions in inches | | | | See Fig. 1 |
| | | | | |
| Standard Short-Boom 3-Element Yagi | | | | |
| Element | Half-Len | Length | Spacing | Diameter |
| Reflector | 105.925 | 211.85 | 0 | 0.5 |
| Driver | 96.89 | 193.78 | 36 | 0.5 |
| Director | 92.445 | 184.89 | 90 | 0.5 |
| | | | | |
| V-Yagi, 3-Element | | | | |
| Driver | 97.6 | 195.2 | 0 | 1 |
| Parasitics | 94.395 | 188.79 | | AWG #14 |
| | Bm Max | | 61 | |
| | Bm Min | | 31 | |
| | Gap-Dr-Tip | | 30 | |
| | Side Max | 89.5 | | |
| Boom | | | 122 | |
| Gap-Tip to Tip | | | 62 | |
| Ref Stub | X=110 Ohms; 12.04" of 600-Ohm Line, Shorted | | | |
| | | | | |
| Moxon Rectangle | | | | See Fig. 8 |
| Dimension | Length | | | Diameter |
| A | 150.35 | | | 0.5 |
| B | 20.63 | | | 0.5 |
| C | 6.28 | | | |
| D | 28.72 | | | 0.5 |
| E | 55.63 | | | 0.5 |
| Element Lengths | | | | |
| Driver | A + 2B | 191.61 | | |
| Reflector | A + 2D | 207.79 | | |
| | | | | |
| See Table 2 for 3-element rectangle dimensions. | | | | |

**The Standard Yagi**

Standard 3-element Yagis come in a variety of boom lengths and element layouts. The 10-meter version used here is a short-boom model with a 90" spacing between the reflector and the director (with the standard 0.5" diameter elements). For added gain, we can increase the boom length by up to 50% with only a small reduction in the 2:1 SWR passband. However, the short-boom model perhaps most closely corresponds to the V-Yagi and other models. The native driver impedance is close to 25 Ohms, so I have equipped the model with a beta match to yield 50-Ohm SWR curves, which appear for all other models in the series. In general, the operating passband of an antenna does not change significantly when we add a well designed impedance-matching network. As well, such networks have no effect upon the pattern shape, the forward gain, or the rear lobes of the array.



Free-Space Azimuth Patterns of a Standard 3-Element Short-Boom Yagi

Fig. 2

**Fig. 2** shows the free-space azimuth or E-plane patterns of the antenna at the band edges (28.0 and 29.0 MHz) and at the design frequency (28.5 MHz). The design selects element length and spacing values to yield at least a 20-dB 180-degree front-to-back ratio at each band edge. Perhaps the most important pattern feature to notice is the side nulls at 90 degrees off the main forward heading of the pattern. Because the elements are parallel to each other and because each element has negligible end radiation, the radiation far field goes to virtually zero at right angles to the boom in a free-space context. (Over ground, the nulls become shallower as we bring the antenna closer to ground.)

Since the patterns do not show the relative gain values, the following small table of spot values will fill the blanks. The table shows excessive decimal places in values, but you may truncate the values wherever you please.

**Spot Free-Space Performance of the Short-Boom Standard Yagi**

| **Frequency** | **28.0** | **28.5** | **29.0** |
|---|---|---|---|
| **Gain dBi** | **7.08** | **7.12** | **7.36** |
| **180-Deg. Front-to-Back Ratio dB** | **20.74** | **41.84** | **20.59** |
| **Beamwidth degrees** | **66.8** | **66.6** | **65.6** |
| **Feedpoint Resistance Ohms** | **79.78** | **53.98** | **30.54** |
| **Feedpoint Reactance Ohms** | **6.89** | **0.12** | **-1.41** |
| **50-Ohn SWR** | **1.615** | **1.080** | **1.639** |

We can enhance the spot values by performing a frequency sweep at 0.1-MHz intervals. The result will be a better sense of how values progress from one end of the band to the other. **Fig. 3** shows the curves for forward gain and front-to-back ratios. The line labeled front/back ratio gives the 180-degree values, while the line labeled front/side ratio provides the worst-case front-to-back ratio (since the short-boom array has no forward sidelobes). Note that the worst-case front-to-back ratio does not change very much over the entire 3.5% bandwidth

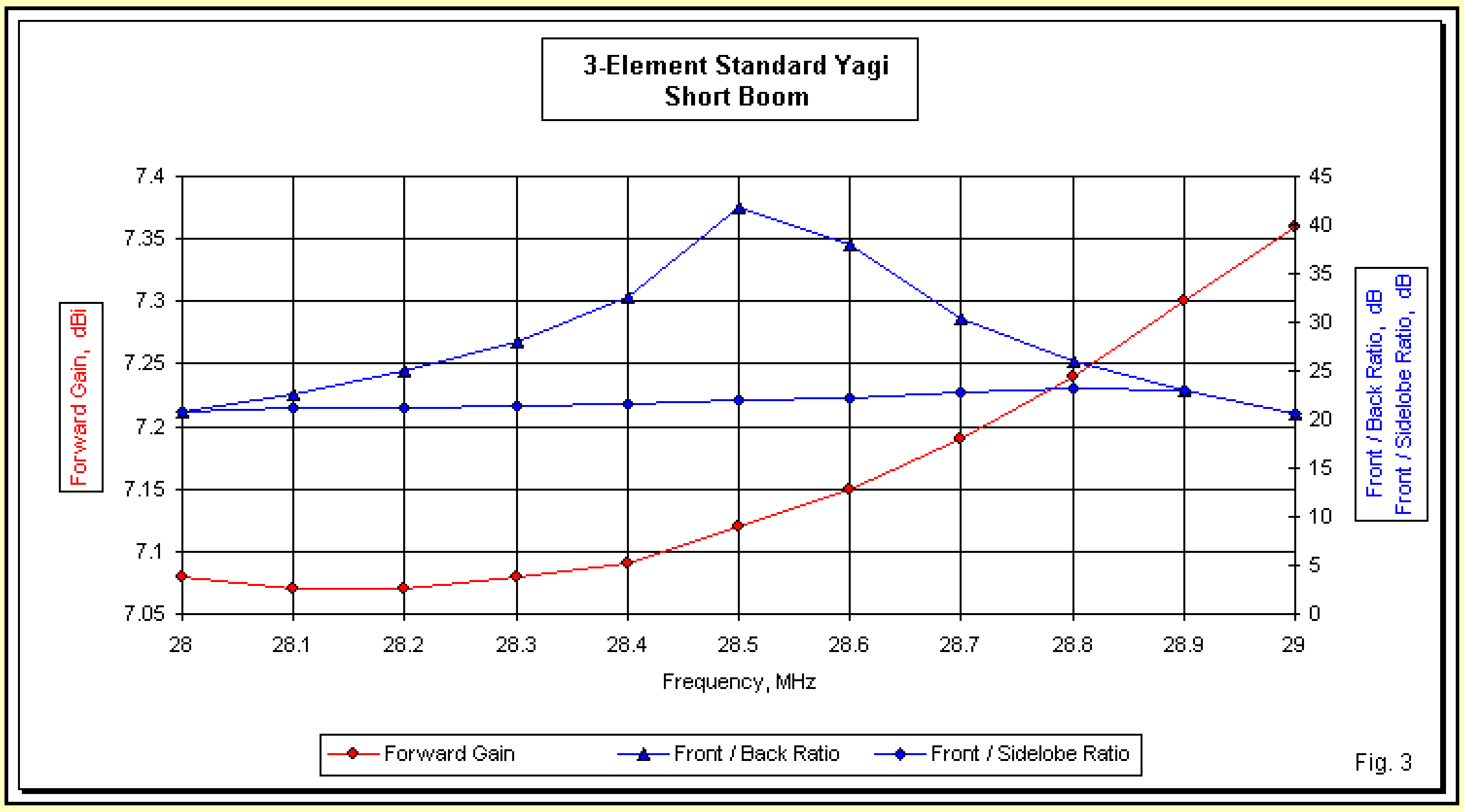


Fig. 3

What the spot chart does not show us is the fact that, at the low end of this wide passband, the gain actually dips as frequency increases befor entering the steady rise in value that we ordinarily associate with Yagis having 1 or more directors. The dip is operationally insignificant but will be interesting as a reference when we compare other array performance curves with this one. The position of the 180-degree front-to-back ratio values tells us that the peak value occurs just above the design frequency.

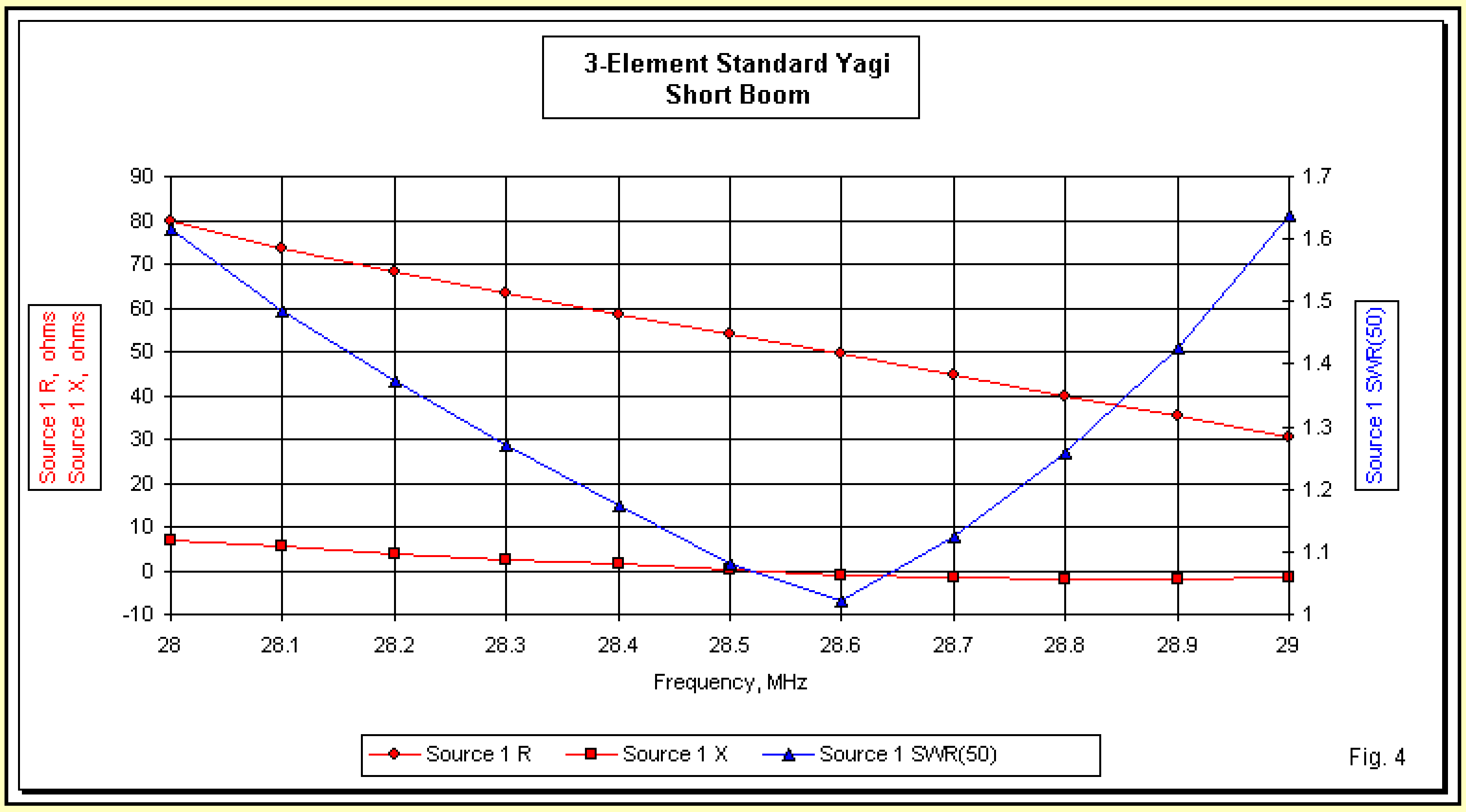


Fig. 4

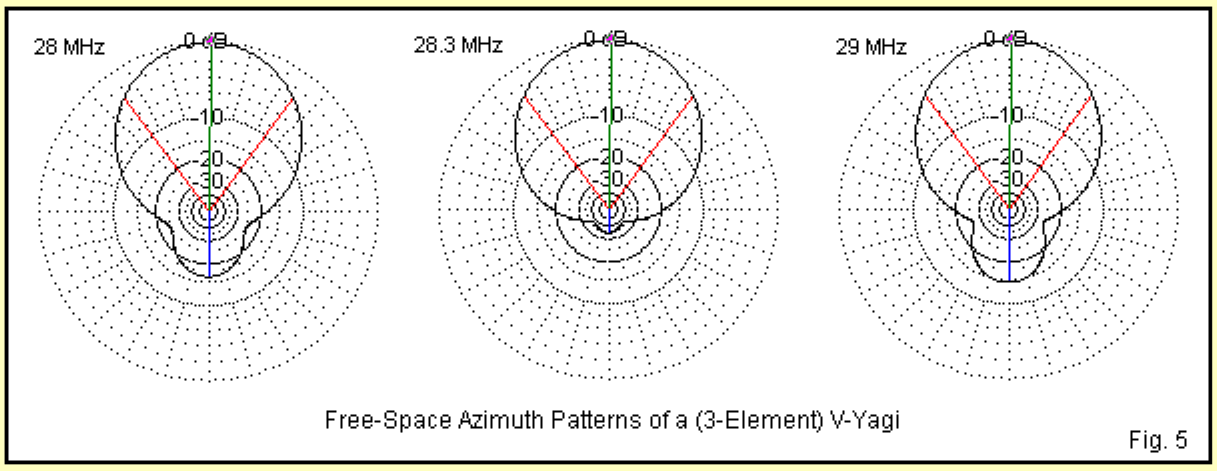
The chart of feedpoint resistance, reactance, and 50-Ohm SWR in **Fig.4** shows the reverse characteristic created by the use of a matching network at the feedpoint. Without the network, the 25-Ohm lines would have shown a rising feedpoint resistance across the band, with a reactance that began as capacitive at 28.0 MHz and ended as inductive at 29.0 MHz. Like the curves that result from the presence of a matching network, the progressions of resistance and reactance would have been nearly linear. Since in either case, I would have set the array dimensions for roughly comparable SWR values at each end of the band, the SWR curve would also have shown a reverse characteristic, rising more rapidly below the design frequency than above it.

The data on the standard-design 3-element Yagi give us a fair catalog of array characteristics to use as we proceed through the comparisons. As well, they serve as a useful review of what to expect from a well-designed 3-element short-boom Yagi.

### The V-Yagi

As shown in **Table 1**, I have selected a simplified model of the V-Yagi for this exercise. Rather than using a tapered-diameter driver, I have set the diameter at 1" with AWG #14 wire parasitic elements. The total boom length from one parasitic center to the other is 122". The total side-to-side dimension of the array is slightly smaller than for the standard-design Yagi, since we load the reflector with an inductive reactance of 110 Ohms (a 12.04" shorted stub of 600-Ohm line). Nevertheless, despite the fatter diameter of the driver relative to the same element in the standard-design Yagi, it is slightly longer.

Perhaps the most intriguing aspect of V-Yagi performance are the free-space azimuth (or E-plane) patterns. They appear in **Fig. 5**, showing the band edge shapes and the shape for the design frequency. In order to yield comparable front-to-back values at the band edges, the design frequency is 28.3 MHz. At the design frequency, the front-to-back ratio is very high, since the 180-degree and worst-case values are identical. As the rear pattern degrades away from the design frequency, the rear lobes grow in a manner quite unlike those of the standard-design Yagi.



Free-Space Azimuth Patterns of a (3-Element) V-Yagi

Fig. 5

In addition to the differences in the rear lobe growth in the V-Yagi, the array shows its side nulls at an angle (with respect to the main forward lobe) that is not 90 degrees. In fact, the side nulls occur at about 120 degrees off the main heading. One consequence of this feature is a wider beamwidth than we find in a standard design. In the following table of spot values, compare the beamwidth values to those for the standard Yagi presented earlier. The V-Yagi beamwidth is 6 to 7 degrees wider.

**Spot Free-Space Performance of the V-Yagi**

| **Frequency** | **28.0** | **28.3** | **29.0** |
|---|---|---|---|
| **Gain dBi** | **7.05** | **6.91** | **6.92** |
| **180-Deg. Front-to-Back Ratio dB** | **16.35** | **34.00** | **14.42** |
| **Beamwidth degrees** | **72.8** | **73.2** | **72.2** |
| **Feedpoint Resistance Ohms** | **37.95** | **42.43** | **31.69** |
| **Feedpoint Reactance Ohms** | **3.29** | **4.29** | **16.98** |
| **50-Ohn SWR** | **1.331** | **1.208** | **1.855** |

When we examine the arrays over the full passband, the V-Yagi performance does not fully match the performance of the standard short-boom 3-element Yagi with respect either to gain or to front-to-back ratio. However, for the present investigation, we are less concerned with this fact than with a comparison of the performance curves. **Fig. 6** presents the gain and front-to-back ratio curves for the V-Yagi for comparison with **Fig. 3**.

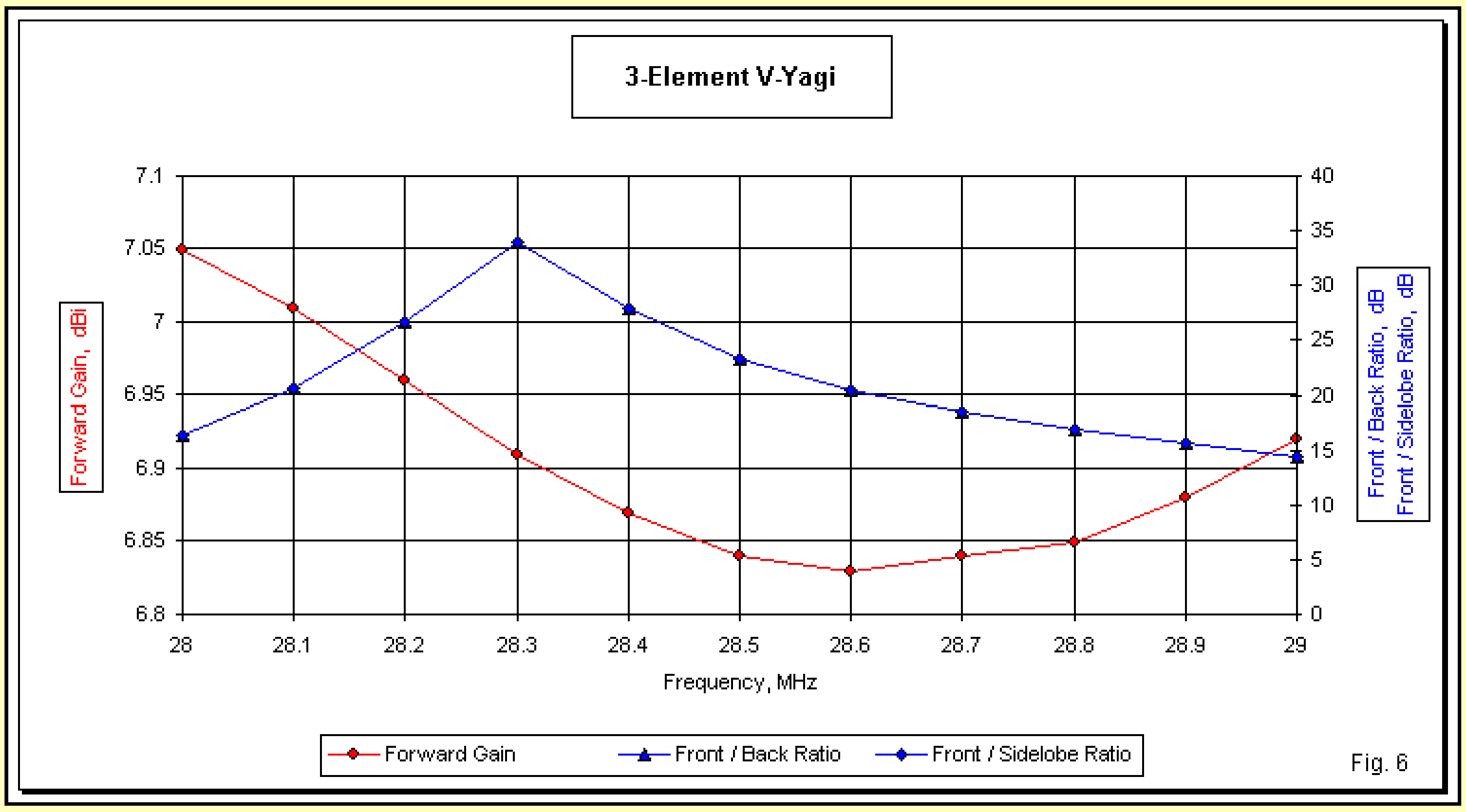


Fig. 6

Partly because V-Yagi construction calls for wire parasitic elements, the front-to-back curves do not hold up at the band edges to the level achieved by the short-boom standard Yagi. However, the 180-degree and the worst-case front-to-back ratios are the same throughout the passband. The gain curve is especially interesting. It shows a decreasing value as we move upward from the low end of the passband, followed by an upward swing at the top of the passband. The reduction in forward gain with increasing frequency resembles in a more dramatic--if not drastic--way the curve for the short-boom standard Yagi. The gain curve is not directly dependent upon the front-to-back ratio, since the front-to-back peak and the gain null occur at significantly different frequencies within the passband. More directly related to the gain curve are the values for the beamwidth: the higher the gain, the narrower the beamwidth. The amounts are small, but the phenomenon exists.

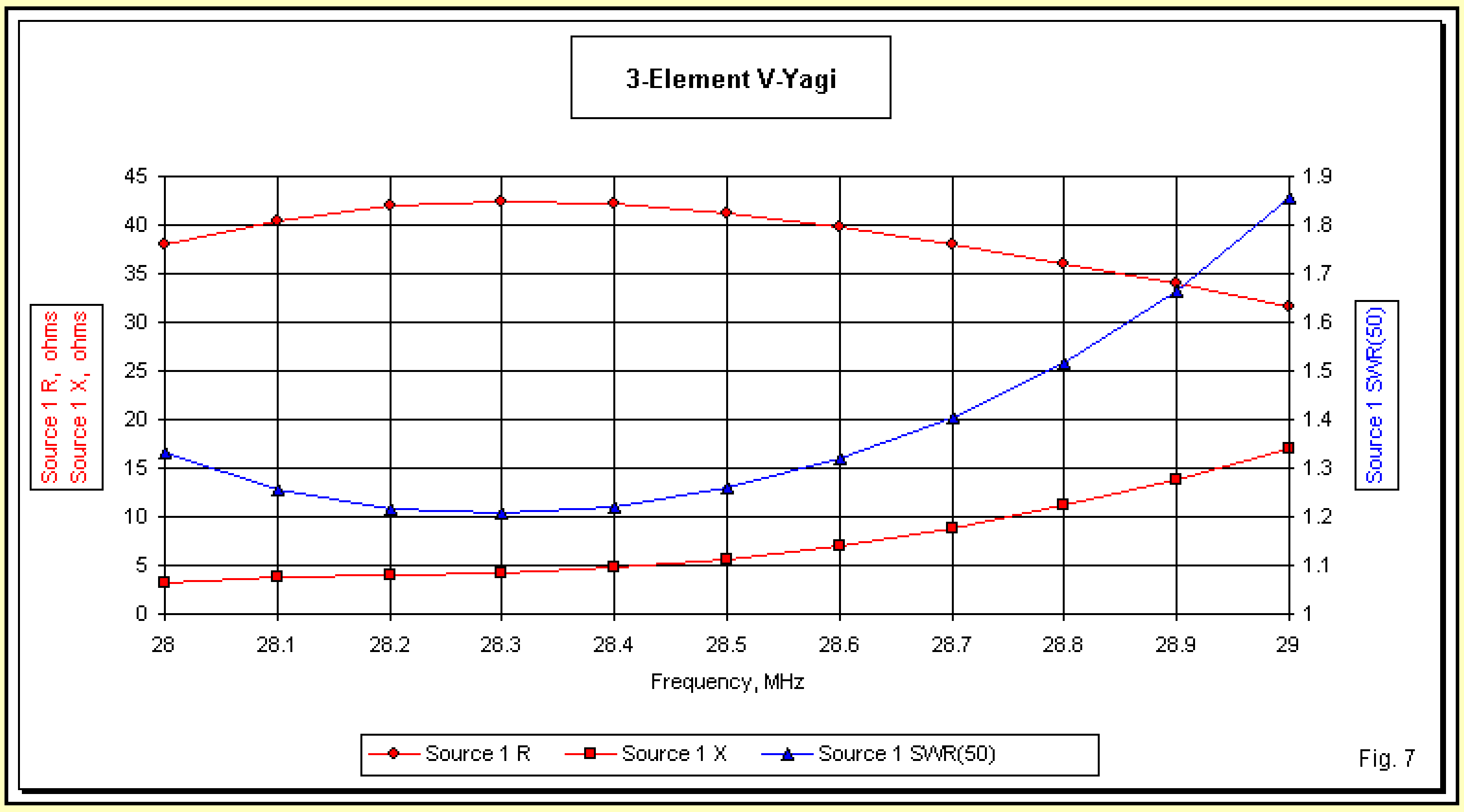


Fig. 7

**Fig. 7** shows the resistance, reactance, and direct 50-Ohm SWR of the V-Yagi from 28.0 to 29.0 MHz. Compare the curves to **Fig. 4**. The standard Yagi shows nearly linear resistance and reactance curves. Without the matching network, these curves would show the opposite slope, but retain their near linearity. In contrast, the V-Yagi resistance curve shows its highest value at the design frequency, with lower values away from that frequency (28.3 MHz). As well, the reactance curve is not close to linear. The SWR shows a relatively high value (although still below 2:1) at the top end of the band, because I resonated the array at the design frequency. However, in the V-Yagi, the resonant driver frequency requires only a slight adjustment of the driver length and is almost independent of the dimensions for the parasitic elements. Therefore, we might easily adjust the driver for equal SWR values at both band edges. We may also perform this adjustment on the standard Yagi. Its modeled length is not inherently resonant, but set for the application of a beta match. Resonating the driver of that array would make it fit for a 1/4-wavelength matching section instead of the beta match stub.

## The Moxon Rectangle

The question that we posed in the beginning--whether a V-Yagi exhibits dual coupling--requires that we add a Moxon rectangle to our list of examinees. The Moxon rectangle clearly exhibits both parallel and tip coupling, and so its characteristics become an important for comparison. However, the Moxon is a 2-element driver-reflector array, and we shall have to adjust some of our expectations accordingly.

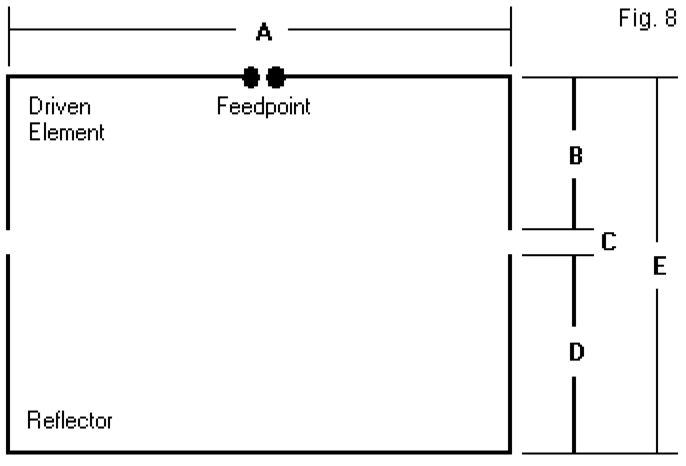
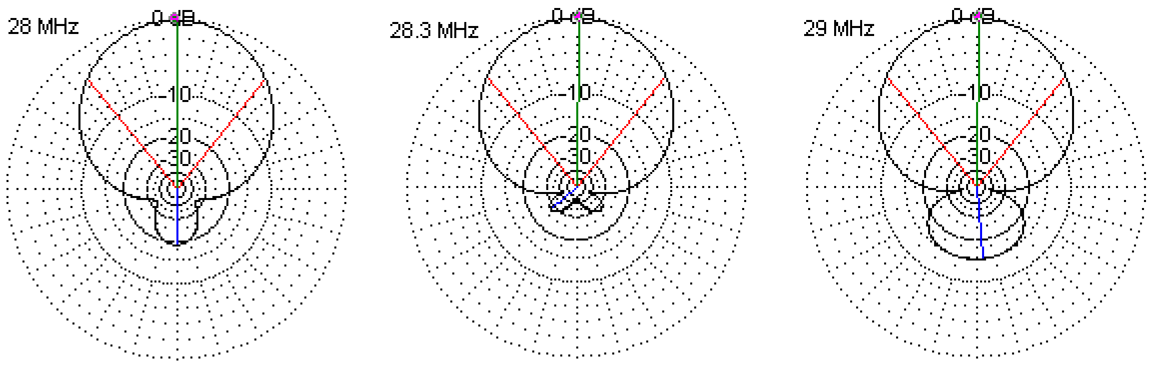


Fig. 8

Outline of and Dimesion Guide to a Moxon Rectangle

**Fig. 8** supplies the dimension designations that correlate to the actual 10-meter dimensions shown in **Table 1**. Note that the overall driver and reflector lengths are approximately normal for a 2-element driver-reflector parasitic array. The key to the Moxon's performance lies in the gap between the tips. As we decrease the element diameter, the required tip gap needed to restore performance grows smaller. As well, the gap is more sensitive to construction variation than any of the length measurements.



Free-Space Azimuth Patterns of a (2-Element) Moxon Rectangle

Fig. 9

Like the V-Yagi, the Moxon requires a design frequency about 1/3 of the way up the operating passband to achieve comparable front-to-back ratios. In this exercise, I lowered the design frequency to match the frequency used for the V-Yagi. For equal front-to-back values at the band edges, a design frequency of about 28.35 MHz or so would have been superior. (Since the array has only 2 elements, the same technique is also necessary to achieve comparable 50-Ohm SWR values at the band edges.) **Fig. 9** shows the patterns for the Moxon model across the passband. As the table of spot performance values shows, the band-edge front-to-back values are comparable to those of the V-Yagi. Because the array has only 2 elements, gain values are lower.

**Spot Free-Space Performance of the Moxon Rectangle**

| **Frequency** | **28.0** | **28.3** | **29.0** |
|---|---|---|---|
| **Gain dBi** | **6.35** | **6.03** | **5.38** |
| **180-Deg. Front-to-Back Ratio dB** | **19.13** | **43.99** | **14.75** |
| **Beamwidth degrees** | **77.4** | **78.0** | **78.6** |
| **Feedpoint Resistance Ohms** | **40.62** | **51.22** | **70.07** |
| **Feedpoint Reactance Ohms** | **-13.73** | **-3.58** | **12.39** |
| **50-Ohn SWR** | **1.443** | **1.078** | **1.486** |

The spot performance checks suggest that the Moxon has both similarities to and differences from the V-Yagi with respect to performance curves. Like the V-Yagi, the Moxon shows a wider beamwidth than standard Yagi designs. At the design frequency, the Moxon beamwidth is actually wider than for the V-Yagi and nearly 12 degrees wider than for a standard 3-element Yagi. **Fig. 10** provides the curves for forward gain and front-to-back ratio for the Moxon. Like any 2-element driver-reflector parasitic array, the Moxon shows a steady decline in gain as we increase the operating frequency. If the curve differs from a standard 2-element Yagi, it is in the nearly linear gain curve across the passband.

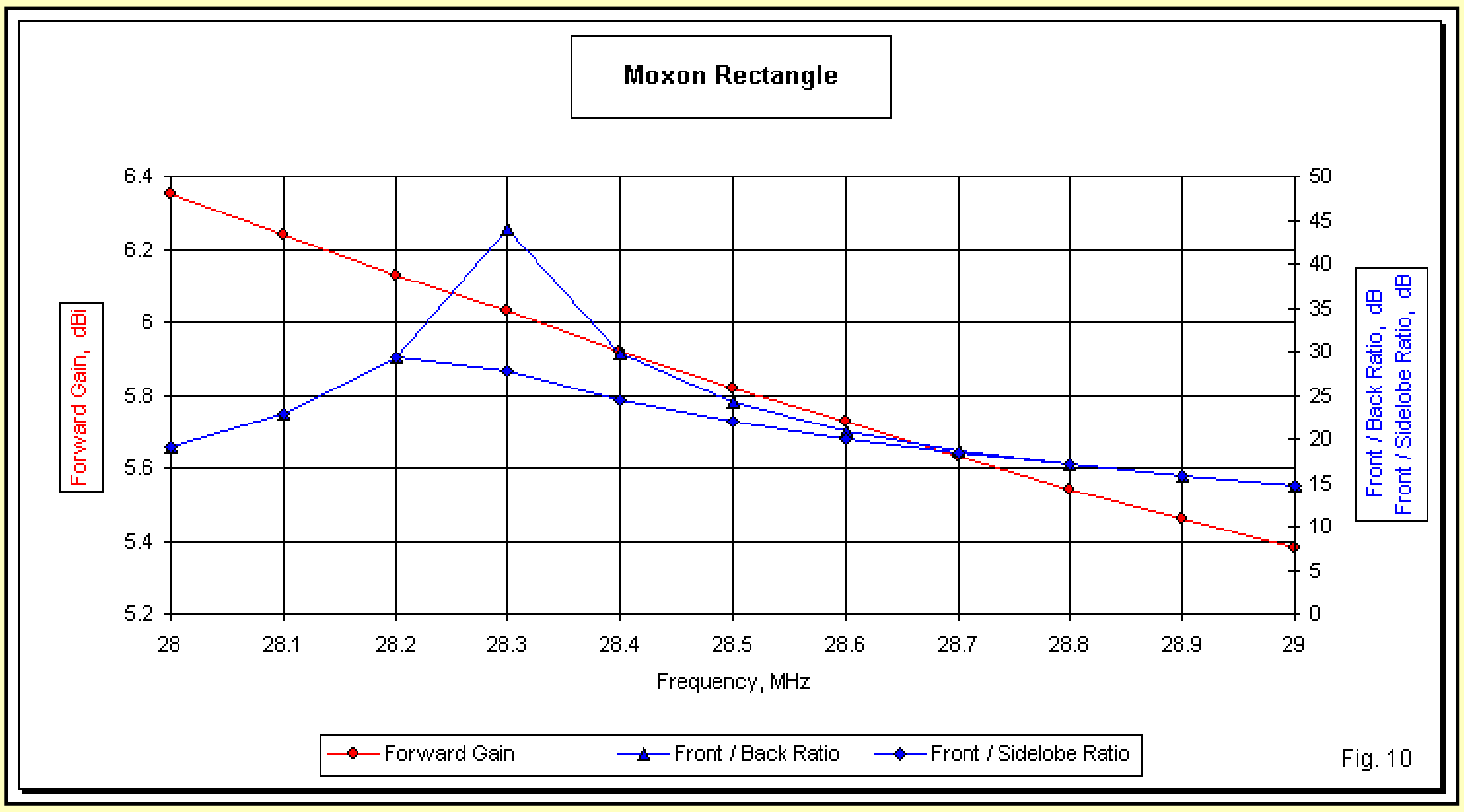


Fig. 10

The front-to-back curves show differences between the 180-degree and the worst-case values in the center region of the passband. The remnant lobes at the design frequency--apparent in **Fig. 9**--show why the worst-case value is lower than the 180-degree value. However, as we move toward the passband edges, the rear lobe becomes a single bulbous affair. Under this condition, the worst-case and the 180-degree front-to-back ratios become identical.

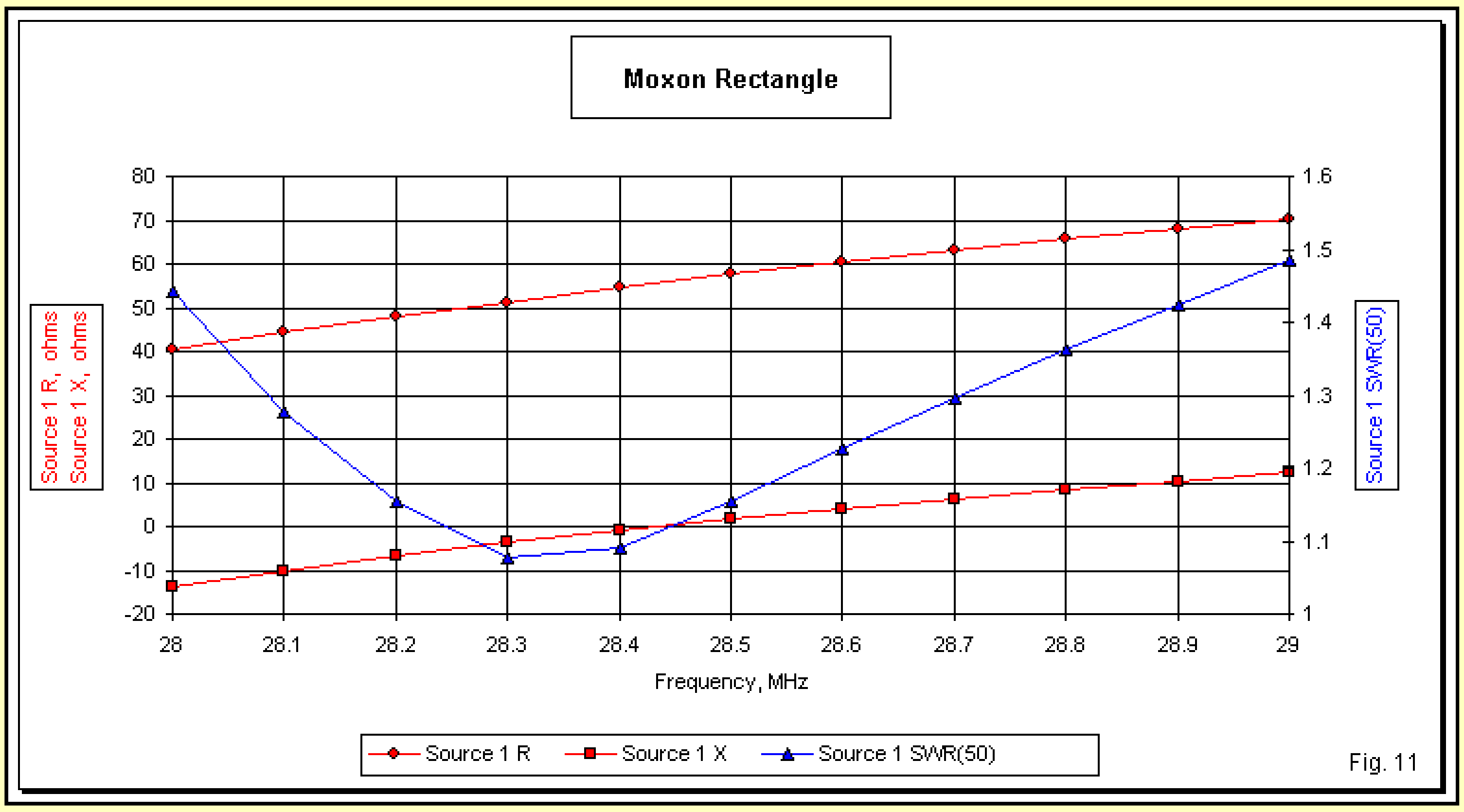


Fig. 11

One of the most useful features of the Moxon rectangle is the slow rise in both resistance and reactance across the 10-meter band, as shown in **Fig. 11**. The result is a wide SWR passband. In this case, the 50-Ohm SWR does not rise to 1.5:1 between 28.0 and 29.0 MHz. Neither the V-Yagi nor the standard 3-element short-boom Yagi can match this performance, although both of these antennas have band-edge SWR values below 2:1.

One feature of the Moxon that is not amenable to graphing concerns the phase angle of the current on the tip segment of each element. By increasing the number of model segments per element, we can obtain rough values that are useful for first-order comparisons. Ideally, we would like to know the current phase angle as close to the tip as feasible, but initially, we may use 40-50 segments per element to arrive at a general indication of what is happening. The exercise requires that we take the difference in current phase angle between the center segment of each element and the phase angle of the tip segment. Since the tip region is an area of high rates of change in both current and voltage, we cannot expect exactitude from the model. However, we may find something that is suggestive.

In a standard 2-element Yagi using a driver and a reflector, with 51 segments per element, the sum of the phase angle changes for the two elements (relative to values at the element centers) is about 5 degrees. In a similarly segmented Moxon rectangle, the sum of the phase-angle changes is over 15 degrees. The equivalent sum (for 3 elements) in a V-Yagi with similar segmentation is under 6 degrees. The numbers, while far from definitive, strongly suggest that the V-Yagi does not have significant levels of tip-to-tip coupling. The corollary to this tentative conclusion is that the V-Yagi patterns are functions almost exclusively of the Vee geometry and not of element end coupling.

The question that remains is whether we can devise a more definitive test.

**The 3-Element Rectangle**

One potential route to confirming our initial very tentative conclusion is to re-form the V-Yagi into a rectangle. In rectangular form, the end coupling--if any--will be enhanced by the fact that the parasitic elements will face each other, tip to tip. As well, the parts of the parasitic elements not within the facing tails will be truly parallel to each other. Several experimental models suggest that the minimum side-to-side dimension for the rectangle is about 160", 10" wider than the Moxon rectangle. The 160" size allows for a direct 50-Ohm feedpoint.

Since the driver length is almost wholly independent of the mutual performance of the parasitic elements, we may allow it a full length or we may use various means of shortening it. Inductive loading tends to lower the feedpoint impedance. However, end hats sustain the feedpoint impedance better than any other means of reducing the side-to-side dimension of the driver. We shall need to reduce the driver by a total of nearly 40" or about 20" per end. If we add to the driver ends a pair of extensions at right angles to the driver, and if we make them about 12.8" long (each), the driver will approach resonance at the design frequency.

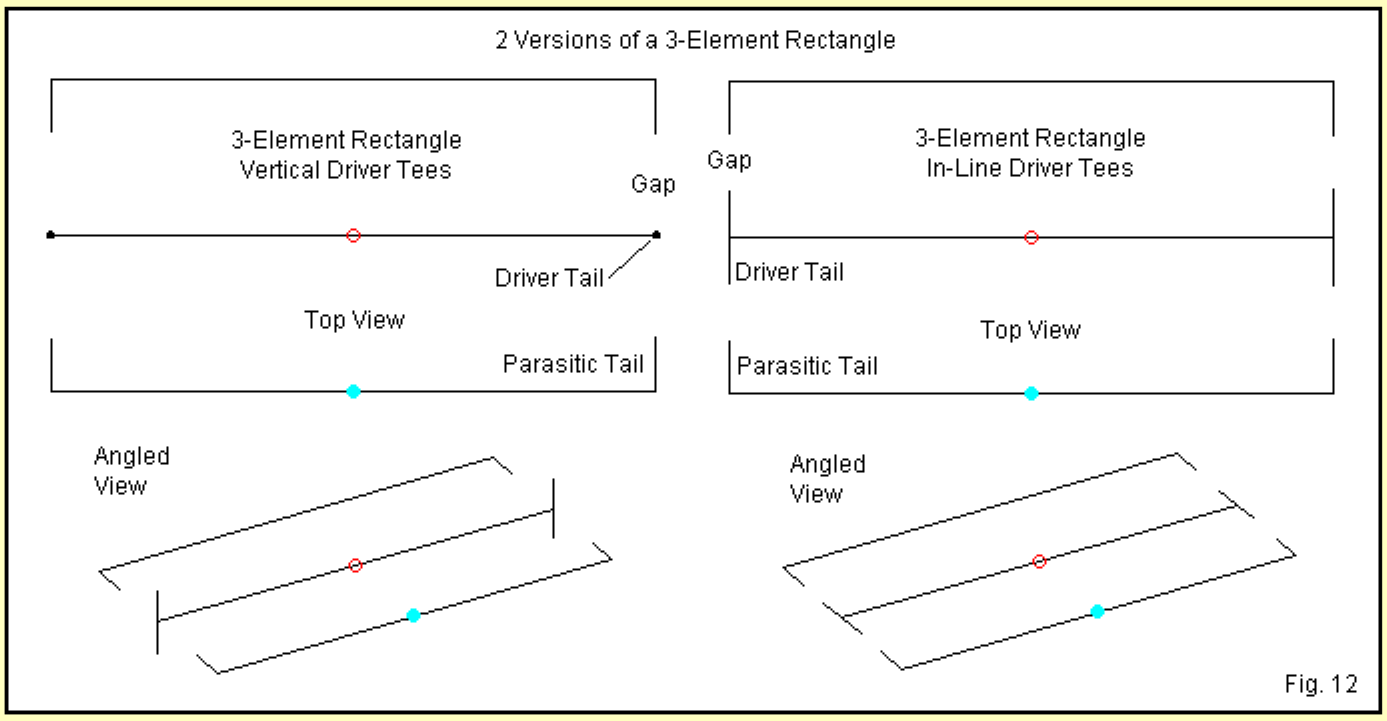
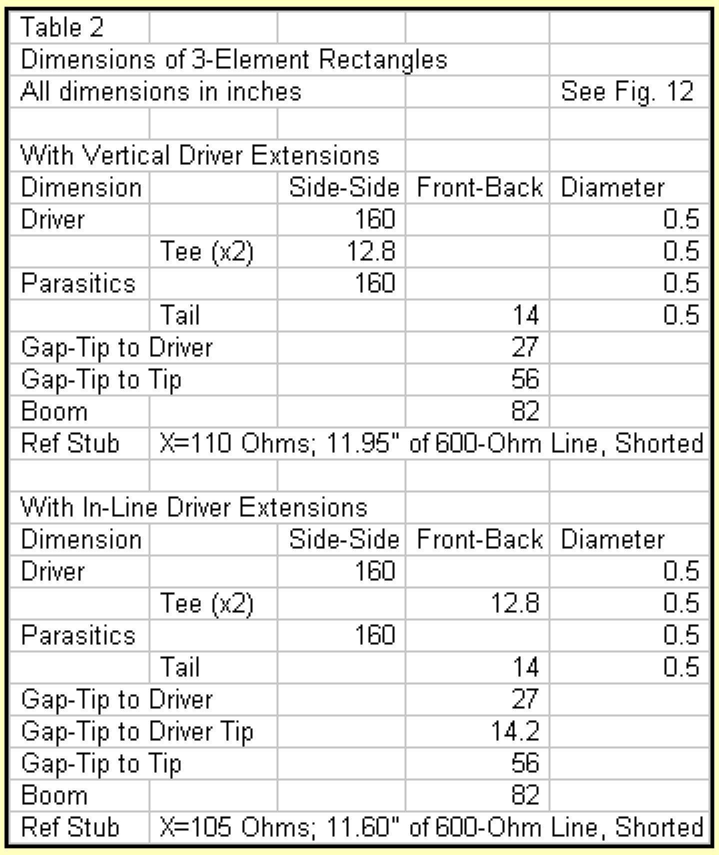


Fig. 12

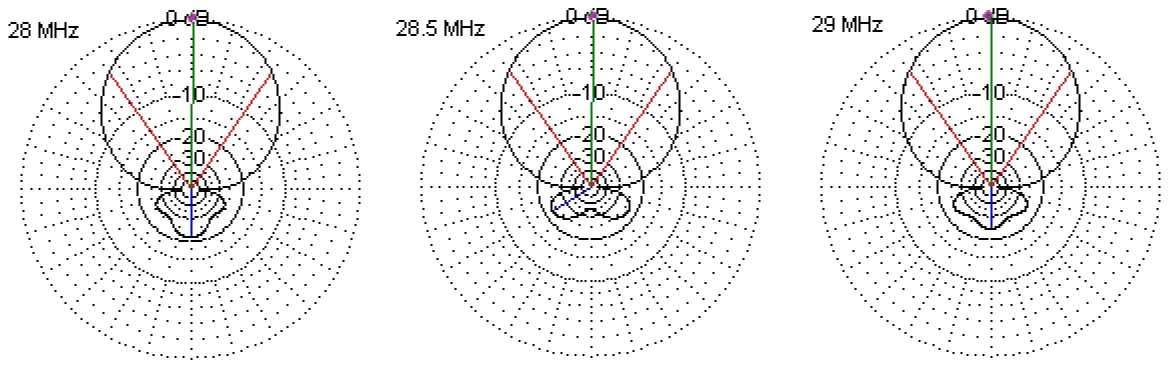
The next step in the design process is to decide on the direction of the Tee's driver ends. Essentially, we have a choice between placing them vertically or placing them in line with the parasitic element tails. In fact, a fairer test of the possibility of end coupling between parasitic elements is to use both orientations in successive tests. **Fig. 12** shows outline sketches of the two driver orientations. If there are significant performance differences between the two versions of the driver, then there will be some disruption of tip-to-tip coupling in at least one of the cases. Our initial clue to the results of this experiment appears in **Table 2**. Note that the only difference in the dimensions of the two antenna models is in the 5-Ohm difference in the required loading reactance of the 600-Ohm shorted stub on the reflector.



| | | | | |
|---|---|---|---|---|
| Table 2 | | | | |
| Dimensions of 3-Element Rectangles | | | | |
| All dimensions in inches | | | | See Fig. 12 |
| | | | | |
| With Vertical Driver Extensions | | | | |
| Dimension | | Side-Side | Front-Back | Diameter |
| Driver | | 160 | | 0.5 |
| | Tee (x2) | 12.8 | | 0.5 |
| Parasitics | | 160 | | 0.5 |
| | Tail | | 14 | 0.5 |
| Gap-Tip to Driver | | | 27 | |
| Gap-Tip to Tip | | | 56 | |
| Boom | | | 82 | |
| Ref Stub | X=110 Ohms; 11.95" of 600-Ohm Line, Shorted | | | |
| | | | | |
| With In-Line Driver Extensions | | | | |
| Dimension | | Side-Side | Front-Back | Diameter |
| Driver | | 160 | | 0.5 |
| | Tee (x2) | | 12.8 | 0.5 |
| Parasitics | | 160 | | 0.5 |
| | Tail | | 14 | 0.5 |
| Gap-Tip to Driver | | | 27 | |
| Gap-Tip to Driver Tip | | | 14.2 | |
| Gap-Tip to Tip | | | 56 | |
| Boom | | | 82 | |
| Ref Stub | X=105 Ohms; 11.60" of 600-Ohm Line, Shorted | | | |

Relative to the V-Yagi, the 3-element rectangle is 20% shorter side-to-side, a function of shortening the driver. As well, the boom length from the center of the reflector to the center of the director is 82", 40" shorter than the required boom for the V-Yagi. Not all of the reduction comes from converting the Vee parasitic elements into rectangular form. The tip of each parasitic element is 4" closer to the driver in the rectangle than in the V-Yagi. This adjustment is necessary to produce a near-50-Ohm feedpoint impedance. Since none of the elements has an unusual geometry and these are only test models--not intended for actual construction--all elements are 0.5" in diameter.

*The Vertical-T Driver 3-Element Rectangle*: The rectangularized version of the V-Yagi performs in a manner that is comparable to the V-Yagi. The fatter parasitic elements of the rectangle give it better front-to-back and SWR performance across the passband than the AWG #14 parasitic elements of the V-Yagi. **Fig. 13** provides a view of the band-edge and design-frequency free-space azimuth or E-plane patterns for the version of the antenna using vertically oriented driver Tees.



Free-Space Azimuth Patterns of a 3-Element Rectangle
Driver Shortened with Vertical Tees

Fig. 13

The most notable aspect of the azimuth patterns is the position of the side nulls. They occur at 90-degree angle relative to the main forward heading of the beam. In general--as shown in the spot performance data in the table--the beamwidth averages about 3 degrees wider than for the standard 3-element short-boom Yagi.

**Spot Free-Space Performance of the 3-Element Yagi Rectangle with Vertical Driver Tees**

| **Frequency** | **28.0** | **28.5** | **29.0** |
|---|---|---|---|
| **Gain dBi** | **6.95** | **6.77** | **6.89** |
| **180-Deg. Front-to-Back Ratio dB** | **21.41** | **35.00** | **23.94** |
| **Beamwidth degrees** | **69.6** | **69.8** | **69.2** |
| **Feedpoint Resistance Ohms** | **40.41** | **41.65** | **32.96** |
| **Feedpoint Reactance Ohms** | **-4.98** | **-2.57** | **6.69** |
| **50-Ohn SWR** | **1.271** | **1.211** | **1.564** |

As shown in **Fig. 14**, the worst-case front-to-back ratio is nearly constant across the passband, despite the peak in the 180-degree figure. The band-edge values are 5 to 9 dB better than the corresponding V-Yagi values. So far, we have seen that the 3-element rectangle with vertical Tees has a normal Yagi pattern with better front-to-back values than the V-Yagi. What the V-Yagi and the first of our 3-element rectangles share is the progression of gain values across the first MHz of 10 meters. Both beams show a deep curve with the lowest gain value near the center of the passband. (See **Fig. 6** to compare gain curves.)

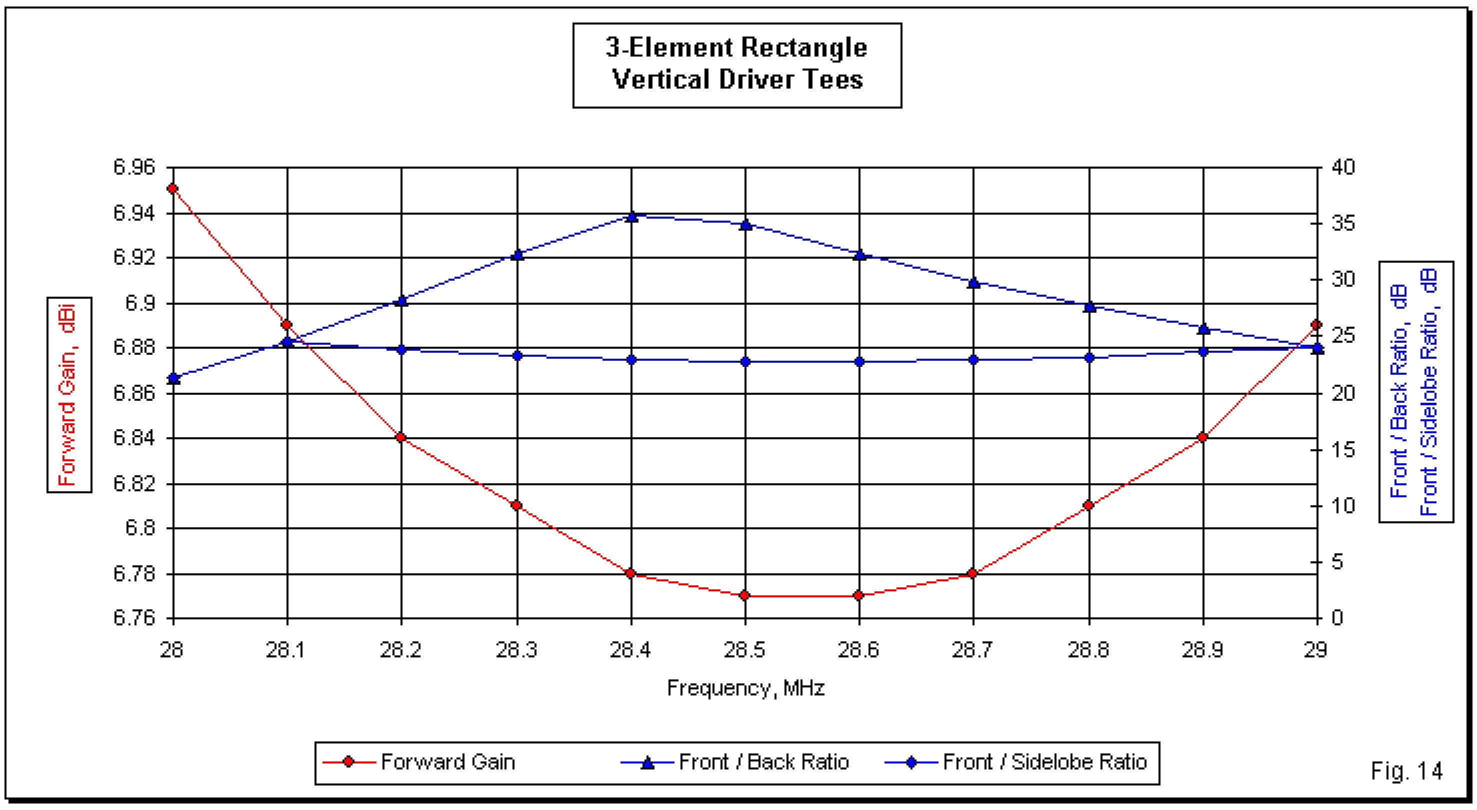


Fig. 14

Because the driver length is relatively independent of other array performance characteristics (within limits, of course), the selection of an operating point is within designer control. **Fig. 15** shows the characteristics for the current model. The peak resistance occurs close to 28.3 MHz, with the actual resonant point at about 28.7 MHz. In contrast, the listed design frequency is 28.5 MHz since the 180-degree front-to-back peak occurs between 28.4 and 28.5 MHz. Overall, the 3-element rectangle has a wider SWR bandwidth than the V-Yagi and the standard-design 3-element short-boom Yagi.

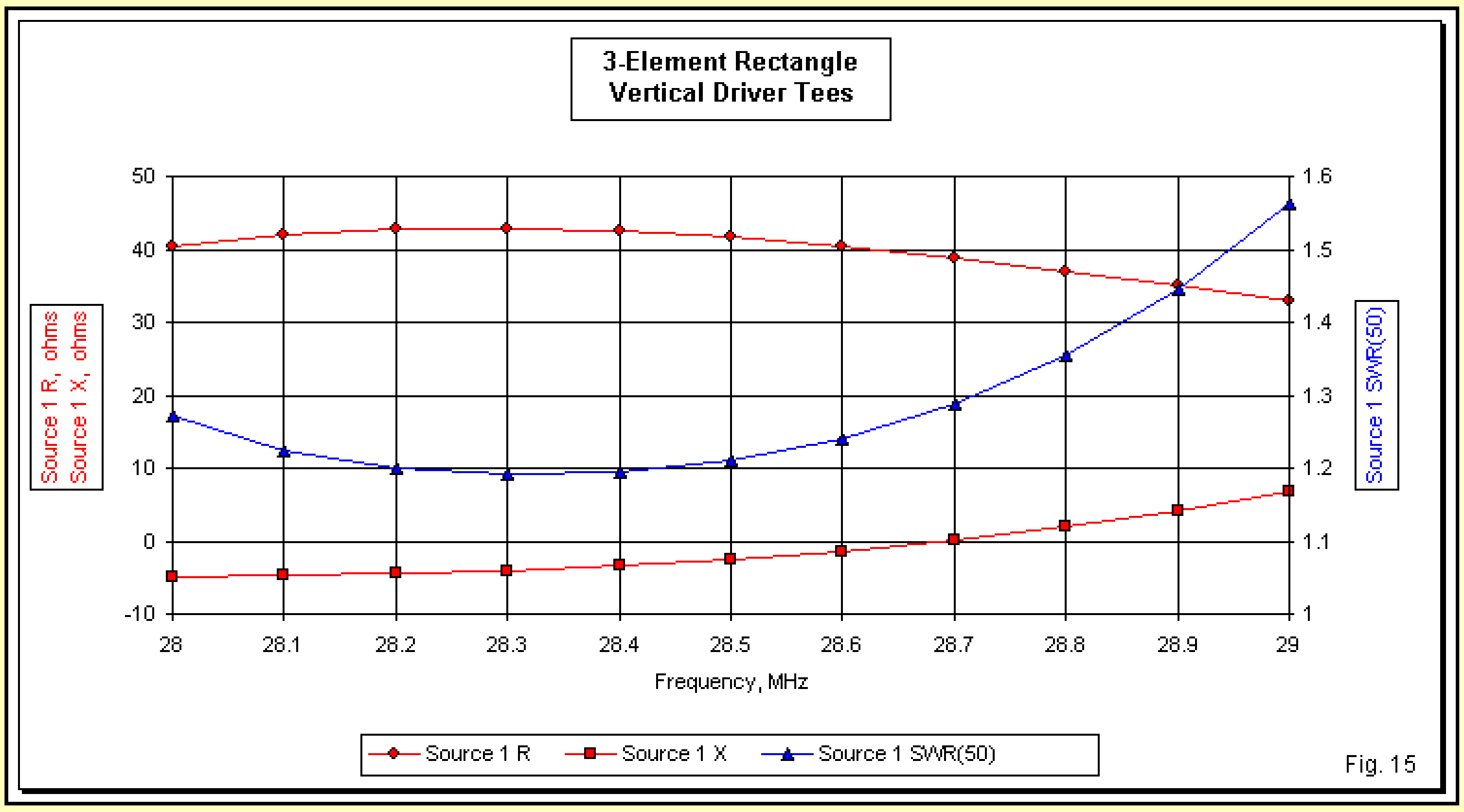
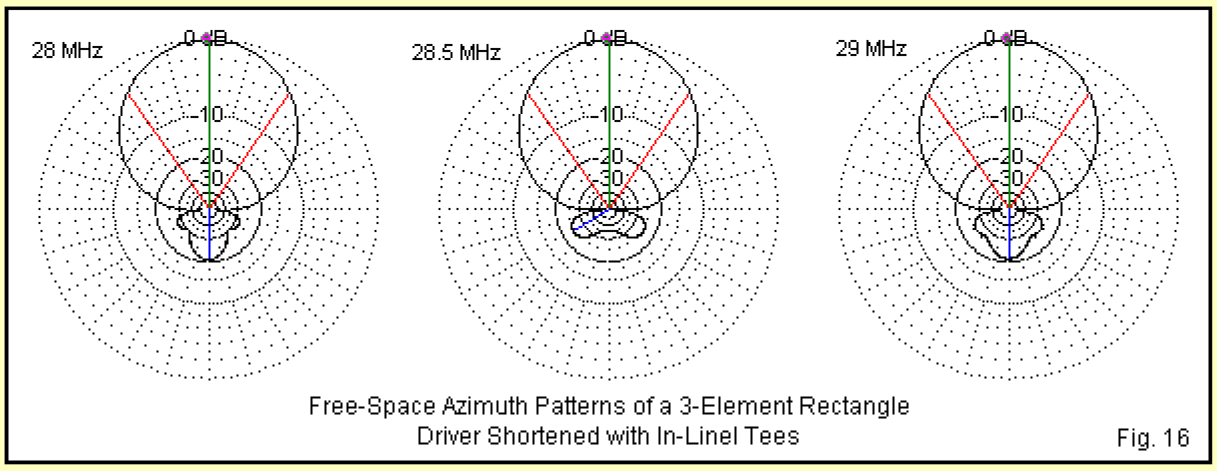


Fig. 15

With vertically oriented driver Tee extensions, the 3-element rectangle produces patterns very similar to those of the full-size short-boom Yagi with which we started this exploration. Although the bent parasitic elements produce a gain curve like the one associated with the V-Yagi, in all other respects the array operates like a standard-design Yagi, with gain reductions that are commensurate with the slightly shorter boom length (82" vs. 90" for the short-boom design). With the driver Tees vertical, the array shows no signs of tip-to-tip coupling.

*The In-Line-Tee Driver 3-Element Rectangle*: The alternative arragement for the driver Tees is to place them in line with the tails of the parasitic elements. As **Table 2** showed, the revision produces no changes in the physical dimensions of the 3-element rectangle. In fact, the only difference is a 5-Ohm reduction in the reflector loading to center the performance within the passband. **Fig. 16** shows the free-space azimuth or E-plane patterns of the resulting array.



Free-Space Azimuth Patterns of a 3-Element Rectangle
Driver Shortened with In-Linel Tees

Fig. 16

There is little, if anything, to distinguish the patterns in **Fig. 16** from those in **Fig. 13**. Even with the driver tails in line with the parasitic tails, the array shows azimuth patterns that are the norm for standard-design Yagis. However, compare the pattern for 28 MHz with the one in **Fig. 2** for the standard design Yagi. With the rectangle, the rear lobes resemble those that we ordinarily find above the design frequency rather than below it. The rectangle appears to find the peak of its front-to-back performance in the center of the design region in which the 3-element Yagi shows a 3-lobe rearward pattern. In many designs, the peak rearward performance occurs to one or the other side of the 3-lobe rearward design region.

**Spot Free-Space Performance of the 3-Element Yagi Rectangle with In-Line Driver Tees**

| **Frequency** | **28.0** | **28.5** | **29.0** |
|---|---|---|---|
| **Gain dBi** | **7.03** | **6.85** | **6.98** |
| **180-Deg. Front-to-Back Ratio dB** | **20.89** | **34.32** | **21.19** |
| **Beamwidth degrees** | **69.6** | **69.8** | **69.2** |
| **Feedpoint Resistance Ohms** | **39.21** | **40.43** | **31.51** |
| **Feedpoint Reactance Ohms** | **-2.23** | **-0.03** | **9.75** |
| **50-Ohn SWR** | **1.282** | **1.237** | **1.693** |

As the table of spot performance characteristics shows, the array does not deviate in any significant way from its performance with the driver Tee vertically oriented. Gain is up marginally and the feedpoint resistance is down marginally. However, as shown in **Fig. 17**, the gain and front-to-back curves show the same progressions of values as in the first rectangle.

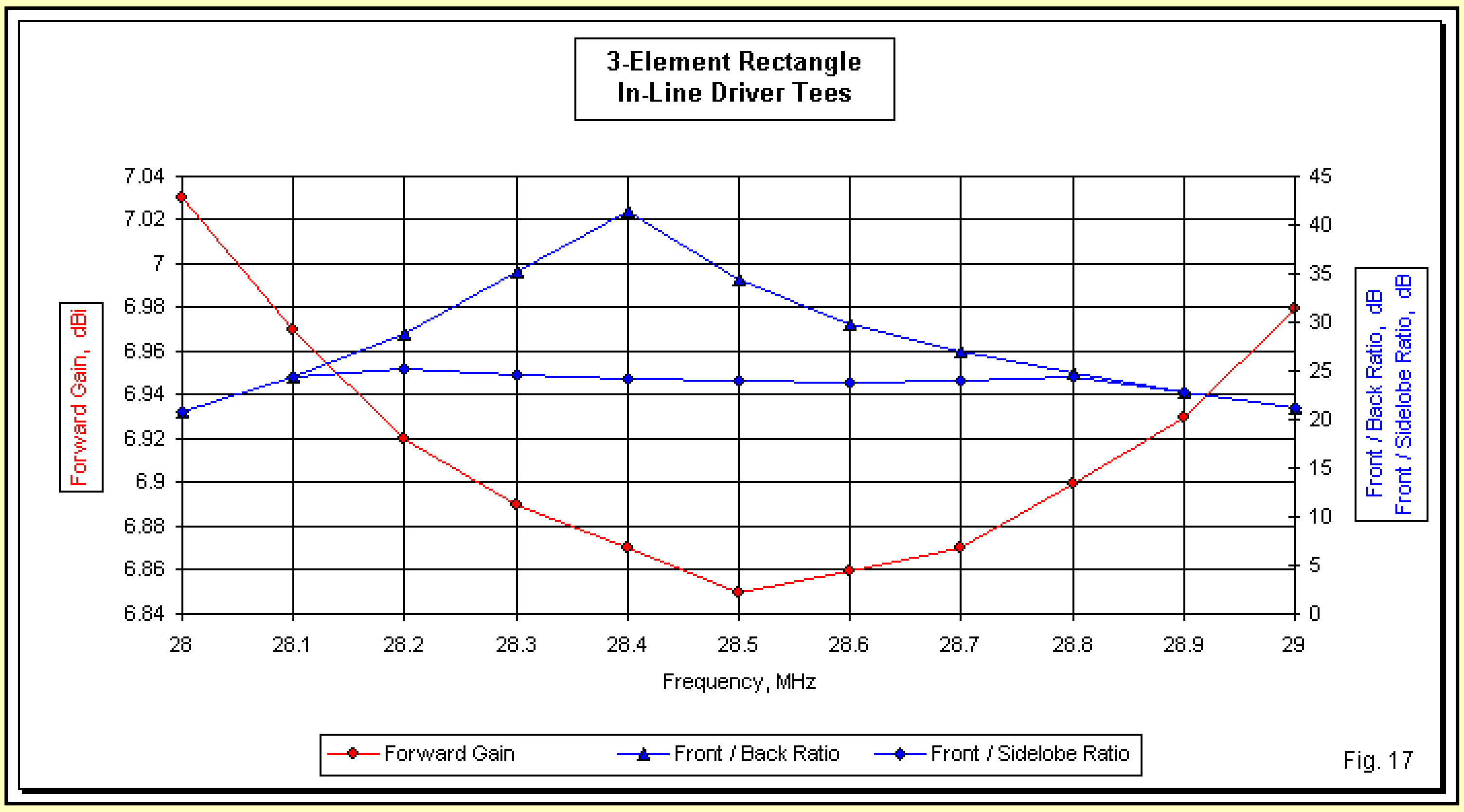


Fig. 17

The resistance, reactance, and 50-Ohm SWR curves in **Fig. 18** tell the same story. The feedpoint resistance peaks at 28.3 MHz, while resonance occurs at 28.6 MHz. The SWR curve is steeper above the center of the band because the in-line driver Tees reduce the average feedpoint resistance by about 1.2 Ohms.

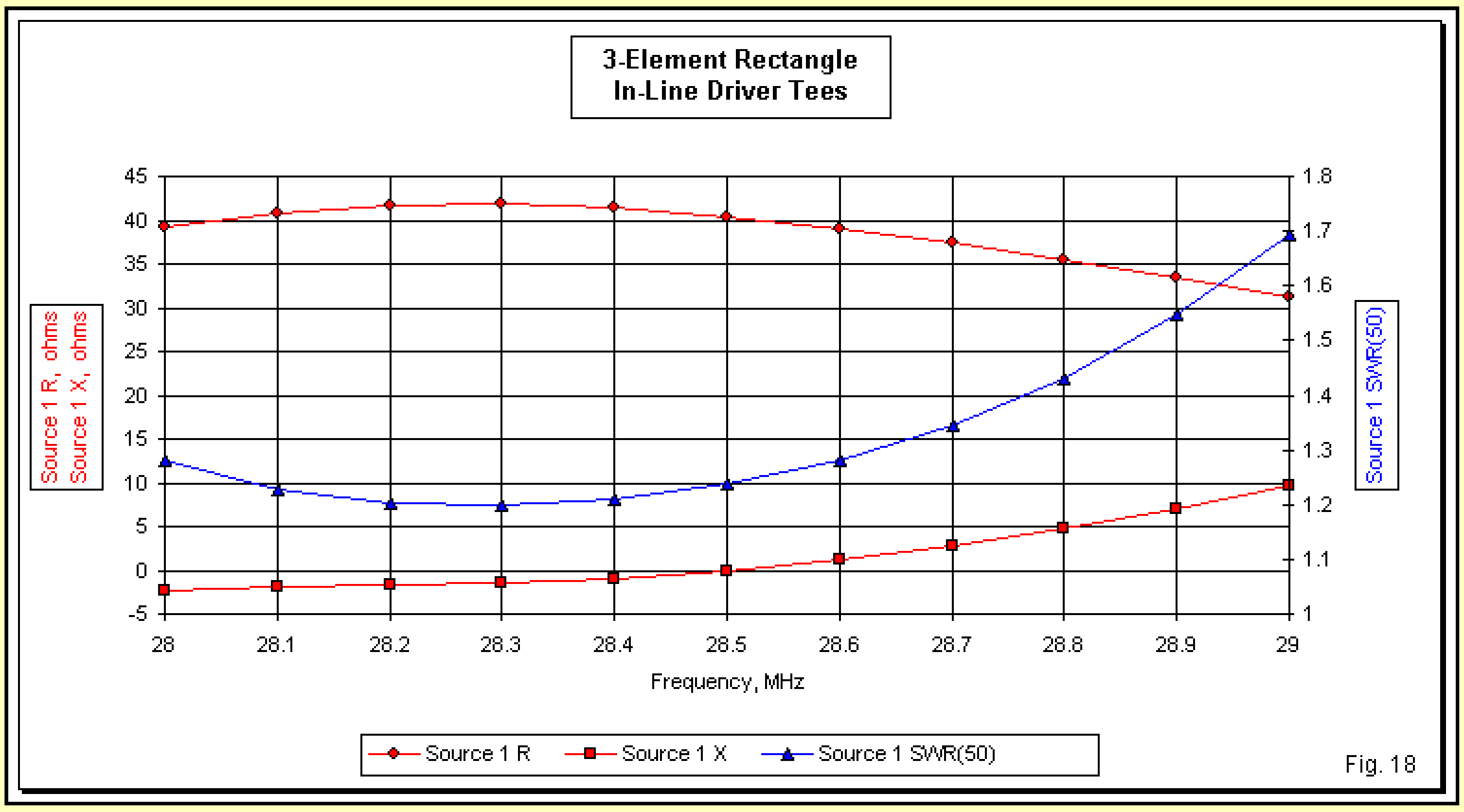


Fig. 18

If there had been significant tip-to-tip coupling between the parasitic elements, moving the driver Tees from a vertical position to an in-line position should have shown significant changes in the performance characteristics of the array. The absence of such changes is fairly conclusive evidence--when combined with the Yagi-normal azimuth patterns--that the level of tip-to-tip coupling is insignificant. If such coupling does not occur with the rectangle, then it also does not occur with the V-Yagi, which places the element ends a total of 8" farther apart.

We may gain a further bit of evidence by comparing the sum of all element phase shifts from element center to element tips for the 3-element Yagis that we have explored. That sum was just under 5.5 Ohms for the V-Yagi. In fact, the standard 3-element short-boom design shows a sum of just under 10.0 Ohms. The corresponding figures for the two rectanglular 3-element Yagis are 10.0 Ohms and 11.4 Ohms for the vertical Tees and the in-line Tees, respectively. In short, the rectangles perform very much like ordinary Yagis.

## Conclusion

We began with a question born of curiosity: does the V-Yagi produce its large beamwidth patterns solely from the Vee shape of its elements or from a combination of element coupling means found in the Moxon rectangle. By comparing a large number of performance facets of a considerable collection of relevant parasitic arrays, we have arrived at a reasonably conclusive answer: the V-Yagi pattern shapes result from the Vee-shape of the parasitic elements. If we create a rectangular 3-element parasitic array, we retain some performance characteristics, such as the gain curve, but others revert to properties we find in standard-design Yagis with similar boom lengths. Curiosity is satisfied, and the survey of different array types has been instructive, especially for performance details that we normally overlook.

So far, I have been unable to create a 3-element parasitic rectangle with closely spaced element tips. Unlike the Moxon rectangle, the 3 elements of a director-based array do not appear amenable to the same treatment as the driver-reflector arrangement of the Moxon rectangle. Indeed, I have not succeeded in finding a driver-director version of the 2-element Moxon rectangle. If a driver-director version of the Moxon does not exist--that is, one in which we may use dual coupling to enhance the overall azimuth pattern--then it is unlikely that any parasitic array with 3 or more elements would succeed. End or element-tip coupling does not have the same effect with a director as with a reflector. In fact, we may achieve a reasonably high front-to-back ratio with a standard (linear-element) driver-director array, if we can handle the low feedpoint impedance and narrow bandwidth. Values up to about a 20-dB front-to-back ratio are possible. Remember that the reason for using the driver-reflector Moxon rectangle is--in part--to achieve higher front-to-back ratios (by 10 dB or more) than are possible with driver-reflector parasitic arrays using linear elements. The Moxon also has a wider passband than 2-element arrays with the same boomlength.

As a consequence, it is unlikely that we shall uncover or even need multi-element versions of the Moxon rectangle. The V-Yagi has its niche among amateur parasitic arrays for two reasons. First, its yields lighter-weight lower-HF beams with good passband coverage. Second, its provides beamwidths similar to those of a Moxon rectangle with about a dB of extra gain. The V-Yagi does not need dual coupling to achieve these results.

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