HF Vertically-Oriented Moxon Rectangles
A 40-Meter Example

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Over the years, readers have sent me questions concerning the possibility for setting up an HF Moxon Rectangle that is vertically oriented for a lower HF band. The desires have ranged from simply reducing QRM in a specific quadrant to needing a fixed-position wide beamwidth array for various operating conditions: contests, field day, and some types of nets.

A Vertically Oriented Wire Moxon Rectangle

A vertically oriented Moxon rectangle is not feasible for every HF band. 160 and 80 meters would require such tall supporting structures that the physical result would be nearly impossible to handle. Perhaps the lowest band for which a vertically oriented Moxon rectangle might be built is 40 meters, and even on this band, the support requirements are severe. The Moxon rectangle is based on 1/2-wavelength elements, although the ends are bent toward each other. The result is still about 70% the length of a linear dipole, which is considerably longer than a typical full-size monopole on 40. In fact, a 40-meter Moxon rectangle is about 50' from one tail set to the other, and if we vertically orient the array, then that is the top to bottom dimension. We also require some spacing between the bottom of the beam and the ground. We shall discuss the exact amount in the course of describing the antenna.

Supposing that we have the tall redwoods and Douglas firs to use as support posts--or some towers on an otherwise well-equipped antenna farm--a 40-meter vertically oriented Moxon rectangle is feasible within some restrictions. Let's create one by using the calculator on the Moxon rectangle index page. We shall use AWG #12 copper wire and set the design frequency at 7.1 MHz so that the beam will cover the band. **Fig. 1** shows the detailed dimensions.

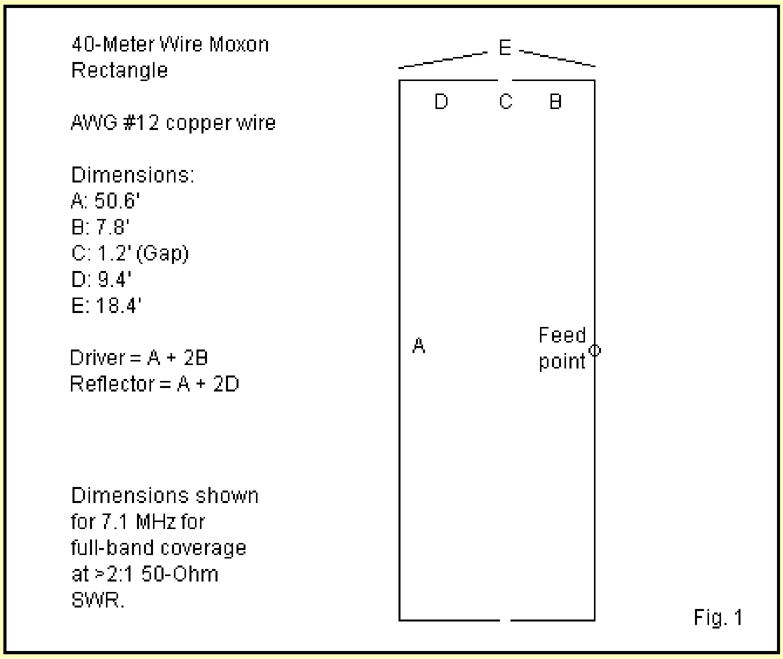


Fig. 1

Since the Moxon rectangle consists of a driver and a reflector, the main forward lobe is outward from the feedpoint. Like all 2-element driver-reflector beams, the gain is highest at the low end of the band and tapers off as we increase frequency. The design program places the highest front-to-back ratio at the design frequency so that the ratio is about the same at the band edges. As well, placing the 50-Ohm resonant impedance (or something very close to it) at the design frequency yields similar SWR values at the band edges. Both the front-to-back ratio and the SWR depart from optimal values more rapidly below the design frequency than above it. Hence, the design frequency is normally about 1/3 the way up the overall operating passband.

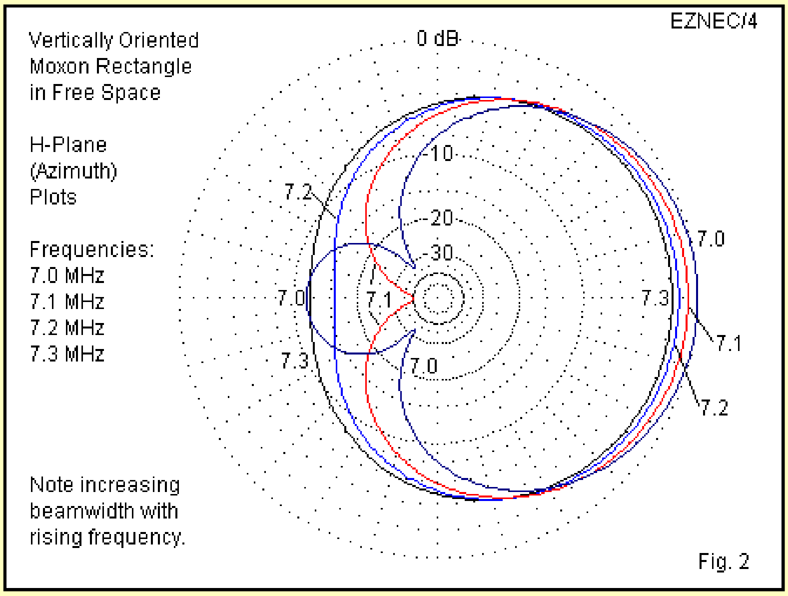


Fig. 2

Fig. 2 illustrates the gain and front-to-back performance across the band by overlaying free-space H-plane patterns for 7.0, 7.1, 7.2, and 7.3 MHz. These patterns correspond to azimuth patterns for a vertically oriented Moxon rectangle placed over ground. Note what happens to the pattern as we move below and above 7.1 MHz, where the front-to-back ratio is highest. The cardioidal pattern deteriorates in different ways as we change frequency in different directions. The following small table summarizes the free-space performance of the array.

Free-Space Performance of a Vertically Oriented AWG #12 Wire Moxon Rectangle in Free-Space

Frequency	**Gain**	**Front-to-Back Ratio**	**E-Plane Beamwidth**
7.0 MHz	**6.34 dBi**	**12.3 dB**	**123 degrees**
7.1	**5.80**	**31.4**	**144**
7.2	**5.22**	**14.2**	**163**
7.3	**4.77**	**10.1**	**179**

The impedance is very close to a resonant 50 Ohms at 7.1 MHz. We can gauge the impedance performance across 40 meters from **Fig. 3**. The graph shows the 50-Ohm SWR performance across the band. The thin-element (wire) version of the array on 40 meters just manages about 2:1 SWR at the band edges. Of course, if you only plan to use a portion of 40 meters, you are free to design the antenna around the frequency you most often use.

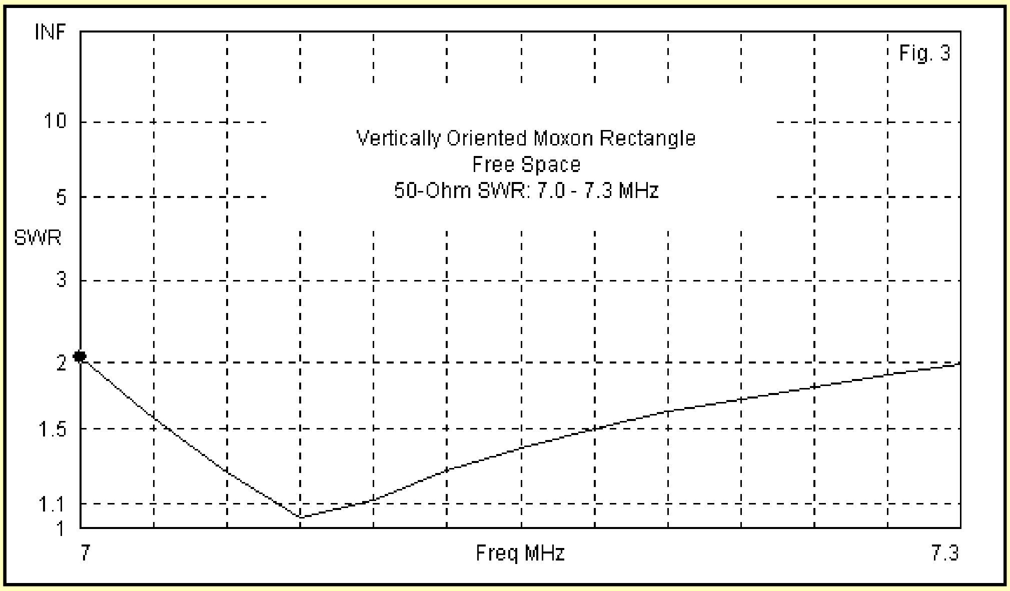


Fig. 3

When we place the antenna over ground, we obtain about the same beamwidth as in a free-space model. The gain progression, with values adjusted for the presence of ground, follows the same progression across the band. However, perhaps the most important facet of behavior over ground involves the elevation pattern of the array. As we move the antenna farther above ground without disturbing the dimensions of the array itself, we obtain different elevation patterns. There is a lowest main lobe. However, even at a modest height above ground, the antenna shows the emergence of a second higher-angle lobe. The higher the antenna, the stronger the higher-angle lobe until as a certain height, it dominates over the lower lobe. Let's consider raising the antenna in approximate 0.05-wavelength increments from 0.15-wavelength up to 0.35-wavelength. At 40 meters, we obtain heights of 21, 28, 35, 42, and 48 feet for the bottom wire, with resulting top heights of 72, 79, 86, 93, and 99 feet. **Fig. 4** shows what happens to the elevation pattern. The table below the figure provides numerical details of the modeled performance.

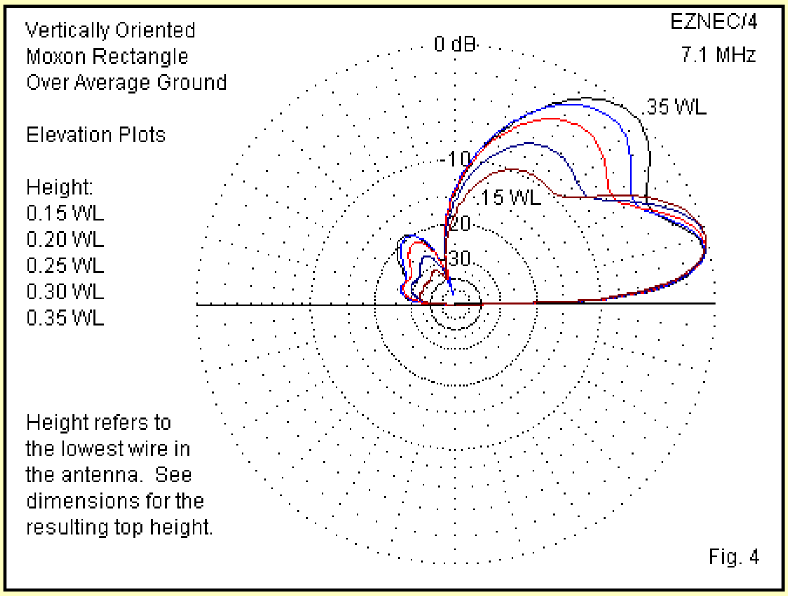


Fig. 4

Modeled Performance at 7.1 MHz of a Vertically Oriented Moxon Rectangle Over Average Ground

Height Wavelengths	Height Feet	Gain dBi	TO Angle degrees	Vertical Beamwidth degrees	Front-to-Back Ratio dB	Horizontal Beamwidth degrees
0.15	21	4.08	16	23	33.5	142
0.2	28	4.03	15	22	30.0	145
0.25	35	3.92	14	21	27.0	147
0.3	42	3.81	13	20	26.0	147
0.35	48	3.74	12	22	27.0	146
		4.13	47	37	19.0	152

First, let's notice that the maximum gain at the TO angle is considerably less than we are used to seeing for the Moxon rectangle when we orient the antenna horizontally. Part of the gain reduction is a function of the much wider beamwidth, and part is a function of placing a vertically polarized antenna close to the ground. For this exercise, a proper comparison antenna is a vertical monopole or a 1/2-wavlength vertical dipole. Its gain would be in the vicinity of 0.3 dB, so the vertically oriented Moxon shows the gain improvement of any 2-element parasitic array with a driver and reflector: almost 4 dB.

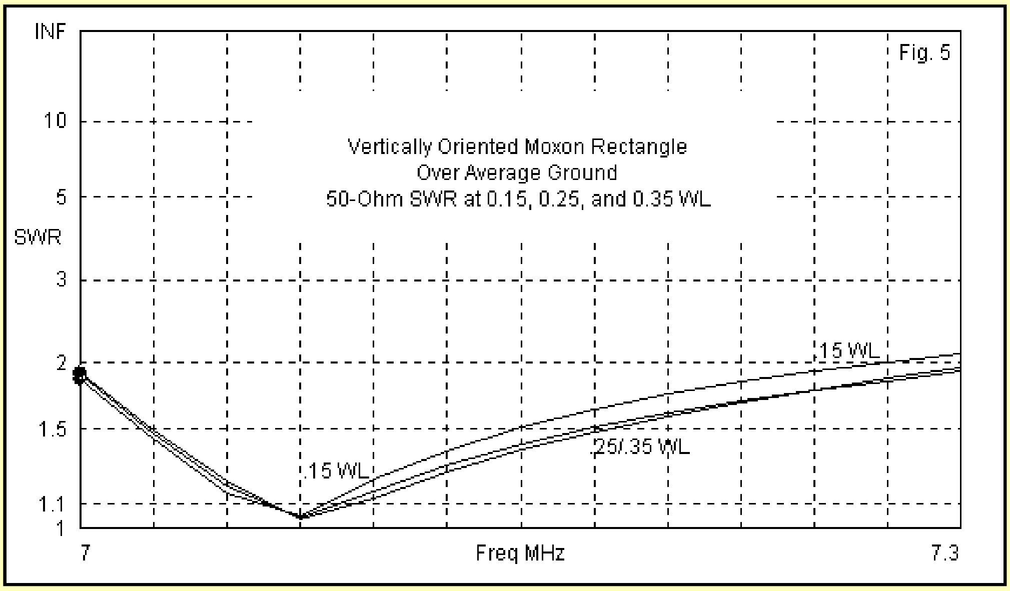
Second, let's also notice that the main lobe gain decreases slightly as we elevated the antenna above ground, despite the slowly dropping value for the TO angle, the elevation angle of maximum radiation. The reason for the slow decrease in maximum forward gain is the relatively rapid growth of the higher-angle second lobe. It uses energy that, for each new height increase, would have gone into the main lobe. At the highest level for the antenna bottom wire, the higher-angle lobe becomes stronger than the lower lobe, as shown in the table by the double entry.

For maximum reduction of high-angle QRN and other noise, a lower installation height is indicated by the modeled performance. The smaller the upper lobe, the less sensitive the antenna will be to RF from high-angle skip--which includes most of the lightning noise from beyond ground-wave distances. Since the vertical beamwidth is so wide, there would be no noticeable difference in DX signal strength for any of the listed installation heights. However, the lower level antenna would often produce a better signal-to-noise ratio.

However, DX communications is not the only operating mode. Many operators are interested in more general communications and in net operations. Many contacts have a range of 1000 miles or less. For such operators, the growth of the higher angle lobe can enhance the higher skip angle of signals from closer sources, despite the higher noise levels. Indeed, for some net operations, the highest installation level shown might well be the best of the lot. In effect, the double lobe forms a wall of radiation or receiver sensitivity with less than a half S-unit difference for any angle from below 12 degrees to well above 47 degrees.

Installation height, then, becomes a compromise between what is desirable relative to the signal sources involved in the communications and what is physically feasible for supporting and maintaining the antenna.

Like most vertical antennas, the Moxon rectangle, when vertically oriented, does not change its impedance very much over a wide range of heights above ground. The sample 50-Ohm SWR graphs in **Fig. 5** cover the lowest, highest, and middle heights of the ones used to produce the elevation patterns, and they show too little variation to need comment.



A Reversible-Direction Vertically Oriented Moxon Rectangle

I took a long look at horizontally oriented Moxon Rectangles in "Having a Field Day with the Moxon Rectangle," *QST* (June, 2000, pages 38-42). The article was reprinted in *Simple and Fun Antennas for Hams*, pp. 12-19 to 12-24. I note this reprint, because the entire volume is a potpourri of interesting ideas that may be useful to newer antenna builders. However, in the present context, the key element in the article is the possibility of using the Moxon rectangle as a reversible-direction beam. That use was feasible when the antenna was horizontal, and it is equally feasible when the antenna is vertically oriented.

The key is to use 2 identical elements, each with the dimensions of a driver in the original design. When we wish to convert one of those elements into a reflector, we can load the reflector to make it electrically longer. The load will consist of a length of transmission line set up to form a shorted stub. Since the transmission line will be the same kind of stock that we use for the main feedline, we can set up a switching system for a stub from each element. In one switch position, line 1 becomes simply part of the feedline to the driver and line 2 to the other element is shorted to provide inductive loading. In the other switch position, the line from element 2 becomes part of the feedline, and the line from element 1 becomes a stub.

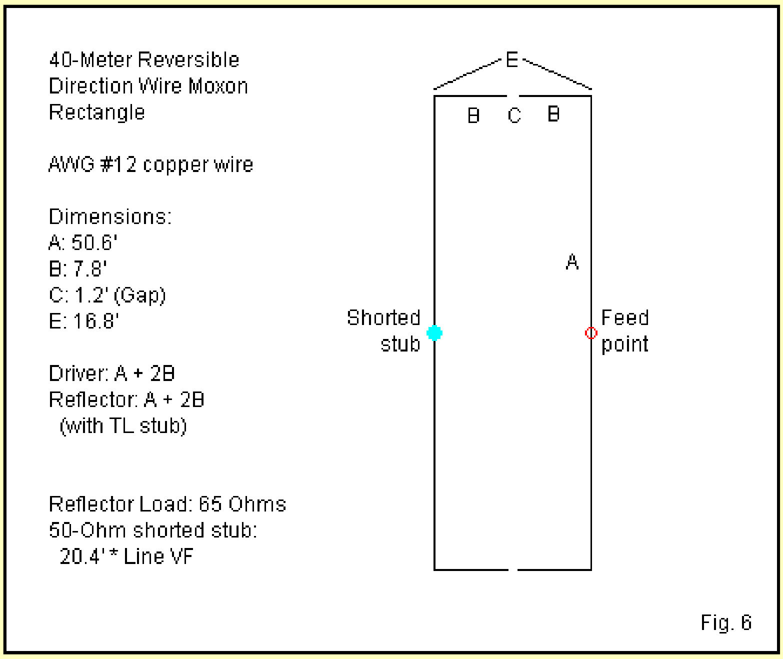
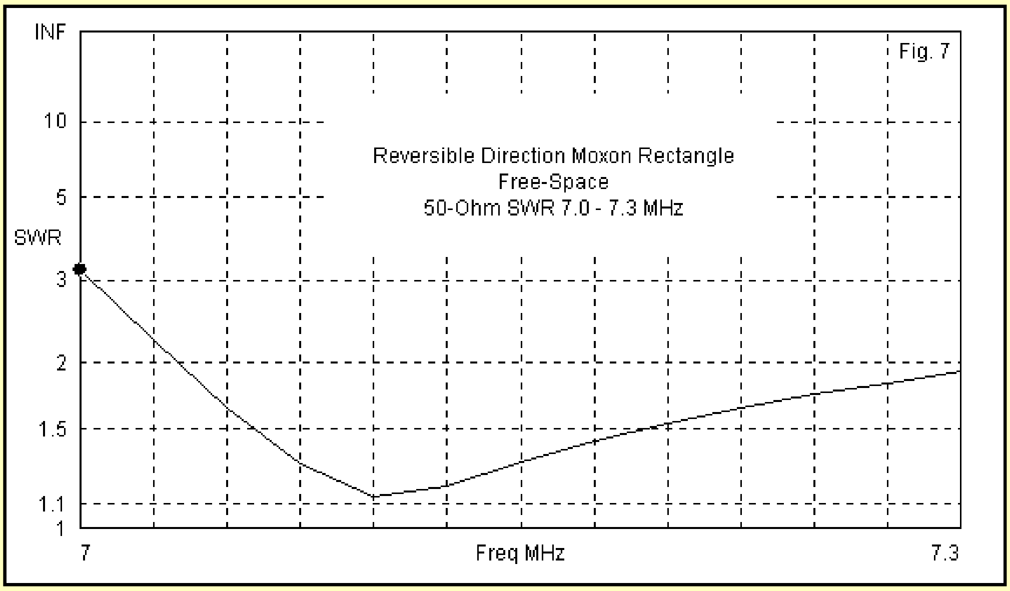


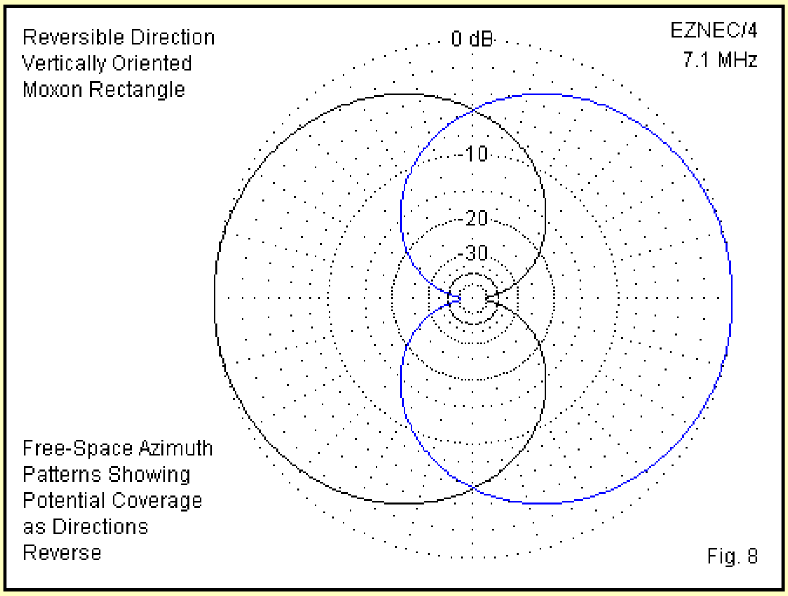
Fig. 6 shows the dimensions for the reversible direction vertically oriented Moxon rectangle. If you compare these dimensions with the one in **Fig. 1**, you will see that we have two drivers and a gap that has not changed its size. However, we do have a load in the form of a shorted transmission line stub. The required reactance to load the reflector is about +j65 Ohms. If 50-Ohm coaxial cable had a velocity factor of 1.0, the required length at 7.1 MHz

to produce the desired Moxon pattern and a near-resonant impedance would be just about 20.4'. The most common velocity factors that we find are 0.66-0.67 for solid dielectric coax versions and about 0.78-0.80 for foam and other special dielectrics. Multiply the velocity factor for the line you actually use times the calculated line length to obtain the physical line length for each stub. Since the velocity factor may vary from one batch of coax to the next, it may pay to actually measure the velocity factor of the line you have. However, the line length is not overly finicky, and you can trim it to the level of perfection you desire.

One effect of compressing the overall width or E-dimension of the Moxon rectangle is to lower the feedpoint impedance from about 52 Ohms down to about 45 Ohms at resonance. The actual value may vary between 40 and 46 Ohms, depending on the precise length of the stub. One consequence is a slight compression of the 50-Ohm SWR curve, as shown in **Fig. 7**. We lose about 35 kHz of the 40-meter band, if we wish to keep the SWR below 2:1. This fact may lead you to re-design the array more closely to one or the other end of the band, depending upon the type of operating that you do. However, except for a number of linear amplifiers, an SWR slightly above 2:1 is not fatal to either your signal or your rig.



With an ability to reverse the beam direction, the vertically oriented Moxon rectangle provides excellent overall coverage, with small decreases (less than 1 S-unit) at right angles to the beam headings. **Fig. 8** overlays patterns for the beam when set for use in each direction to show both the main lobes and the nulls in coverage. While the antenna is not designed to directly complete with a rotatable beam, the coverage is not bad for a fixed set of wires.



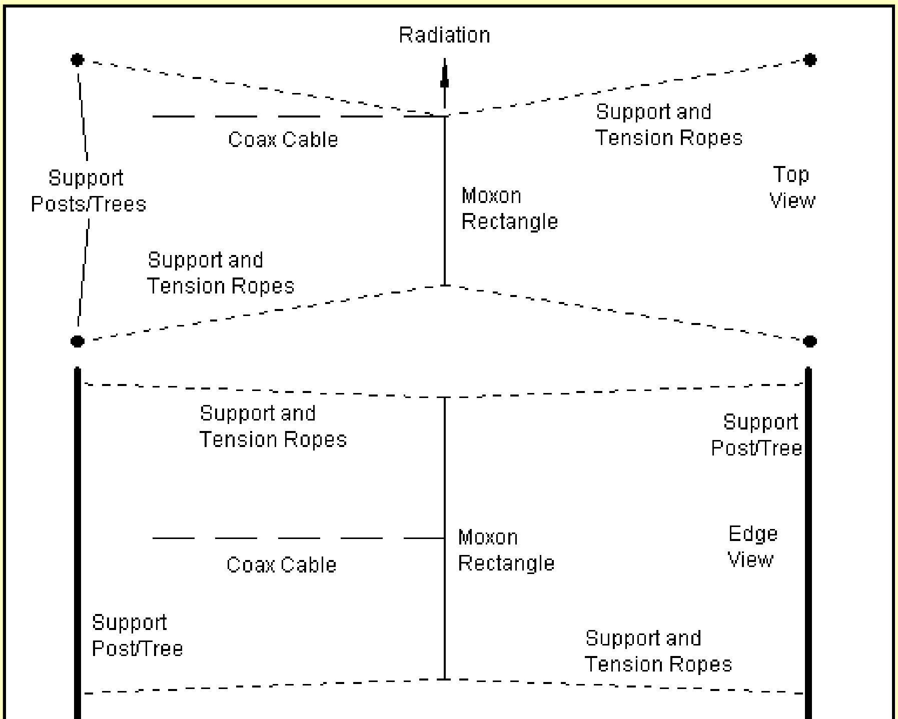
The reversible-direction vertically oriented Moxon is just one of many possibilities. If you happen to have more real estate and tall supports than money, you might even consider a Y formed from 3 different Moxon rectangles. With the backs or reflectors separated by perhaps 1/4 wavelength, the antennas will show almost no interaction due to the high front-to-back ratios. The beamwidth of the vertically oriented Moxon rectangle is wide enough to allow full horizon coverage with just 3 beams.

At the design frequency, the Moxon rectangle has good gain. However, its true benefit to operation lies in the exceptional front-to-back ratio. It achieves in a parasitic array front-to-back ratios that are rarely seen outside the realm of phased arrays. A single Moxon rectangle requires no attention to interconnecting line phase angles, since the arrays geometry provides the current magnitude and phase angle on the rear element to achieve the high level of silence from the rear.

Installation

In the beginning, I noted that a vertically oriented Moxon rectangle is feasible within a set of restrictions. One of those restrictions is the height of the array overall and above ground, and we have examined the effects of various heights on performance. For many operators, the antenna is simply not physically feasible. However, antennas designed for 30 or 20 meters are more feasible. The elevation pattern effects are a function of the bottom height of the array as measured in fractions of a wavelength, so when scaling the antenna for other bands, be certain to scale the bottom height as well in order to tailor the performance to your needs.

Most of the supports for a vertically oriented Moxon rectangle will be vertical, and that fact presents us with another restriction. Keep any conductive or even semi-conductive vertical support (or other object) as far away as possible from the antenna. The goal is to avoid to the degree possible any unwanted coupling that would alter the antenna's performance. **Fig. 9** shows one sort (out of many) of support system that meets this need. The support posts are well-spaced from the array itself, and there is no vertical structure directly ahead of the antenna. If the antenna is a reversible direction version, then the free-area requirement includes both directions from the antenna. However, a single direction array has less critical requirements behind the reflector.



General Layout of a Vertically Oriented
Moxon Rectangle for 40 Meters

Fig. 9

The system shown in the sketch uses ropes that perform two functions. First, they support the wire structure at both the top and bottom. Second, they provide a degree of tension to hold the array in place. The exact tension will be a function of the wire and rope used. Since the gap between the 2 sets of tails needs support, it is usually wise to use a rope or sizable twine and to tape the wires to the rope that goes from front-to-back. In that way, the wire is only slightly stressed, but the front-to-back ropes take up the major stress in the system.

Another restriction is common to many forms of vertically oriented antennas based upon the dipole. The feedline should depart from the feedpoint at right angles to the driver for as far as feasible before changing directions. The goal is once more to prevent unwanted coupling. For horizontal versions of the antenna, we can achieve this goal by bringing the feedline straight back until we reach a centered mast. Then the feedline can proceed downward, supported by the mast.

The vertically oriented array cannot use a vertical mast. In many instances, the feedline must go at right angles to the driver until reaching a suitable support outside the antenna vicinity. Alternatively, for a single direction rectangle, the coax may proceed directly to the rear until it pass the reflector--and then proceed downward. Supporting the coax along its path becomes a major challenge to ingenuity. For all but the highest power levels, RG-8X is a preferred cable for this application because of its lighter weight and its relatively low loss at 40 meters. However, even this cable will load the support structures for the array.

A reversible direction version of the array presents even more challenges. The two lines from the twin drivers must come together at a remote switching box. That box needs support, but in a manner that does not disturb the antenna pattern. We can obtain greater distance from the elements by adding 1/2-wavelength of cable to each line, but at a cost of somewhat higher losses in the stubs. At 40 meters, the losses are small enough to perhaps be acceptable in exchange for placing the switch box beyond the limits of adverse affect on the antenna patterns.

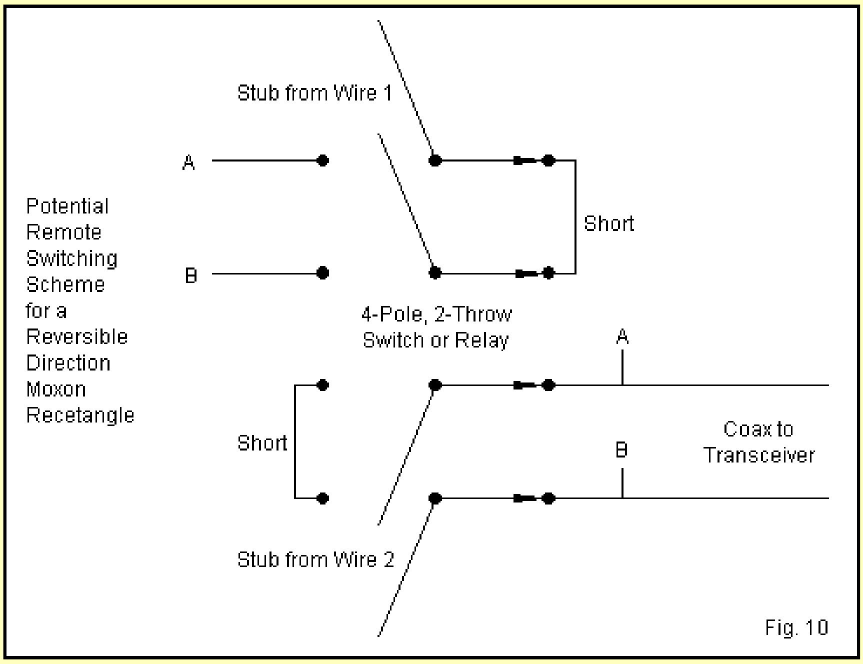


Fig. 10 shows the general principles of the remote switching. The system requires that when one of the lines is used as a shorted stub, both the coax center conductor and braid must be isolated from the other line and from the incoming feedline cable. Hence, the figure shows a 4-pole, 2-throw switch or relay system. Of course, the remote portion of the system must be weather protected, and the remote system requires some form of control voltage line.

The vertically oriented Moxon rectangle is certainly not an array for everyone, and perhaps in the end, not for anyone. However, it does show the performance of the Moxon rectangle when vertically oriented and set up for one of the lower HF bands. Hence, if it serves no other purpose, it provides a comparator for various other types of directional vertical systems, both simple and complex. So even if no one ever builds a vertically oriented Moxon rectangle on 40 through 20 meters, the design exercise will have some use.

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