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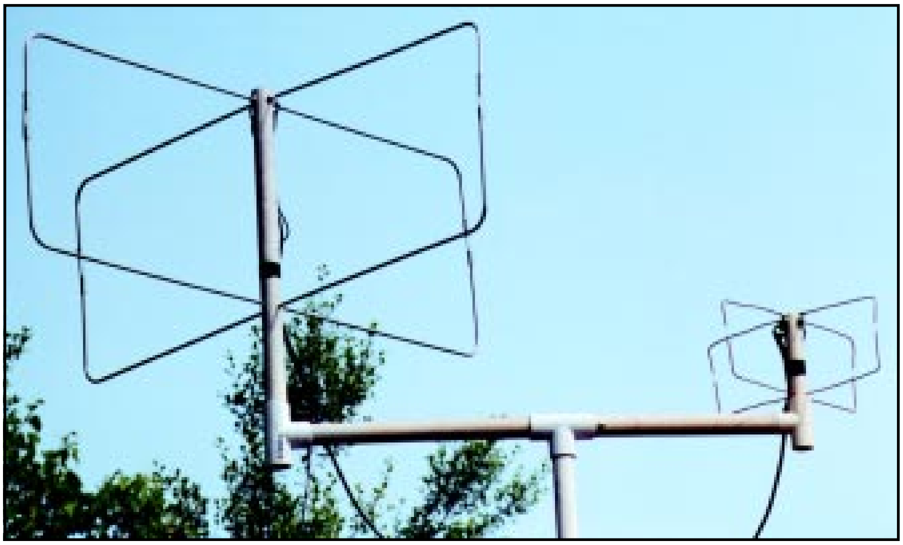
A Simple Fixed Antenna for VHF/UHF Satellite Work

Explore the low-Earth orbiting amateur satellites with this effective antenna system.

When we are just getting interested in amateur satellite operation, the thought of investing in a complex azimuth-elevation rotator system to track satellites across the sky can stop us in our tracks. For starters, we need a simple, reliable, fixed antenna—or set of antennas—to see if we really want to pursue this aspect of Amateur Radio to its limit. We'll look at the basics of fixed antenna satellite work and develop a simple antenna system suited for the home workshop. There will be versions for both 145 and 435 MHz.



Turnstiles and Satellites

For more than decades, many fixed-position satellite antennas for VHF and UHF have used a version of the turnstile. The word "turnstile" actually refers to two different ideas. One is a particular antenna: two crossed dipoles fed 90° out of phase. The other is the principle of obtaining omnidirectional patterns by phasing almost any crossed antennas 90° out of phase. The first idea limits us to a single antenna. The second idea opens the door to adapting many possible antennas to omnidirectional work.

Figure 1 shows one general method of obtaining the 90° phase shift that we need for omnidirectional patterns. Note that the coax center conductor connects to only one of the two crossed elements. A $^{1}/_{4}$-λ section of transmission line that has the same characteristic impedance as the natural feed point impedance of the first antenna element alone connects one element to the next. The opposing ends of the two elements go to the braid at each end of the transmission line. If the elements happen to be dipoles, then a 70 to 75-Ω transmission line is ideal for the phasing line. However, the resulting impedance at the overall antenna feed point will be exactly half the impedance of one element alone. So we will obtain an impedance of about 35 Ω. For the dipole-based turnstile antenna, we'll either have to accept an SWR of about 1.4:1 or we'll have to use a matching section to bring the antenna to 50 Ω. A parallel set of RG-63 $^{1}/_{4}$-λ lines will yield about 43 Ω impedance, about right to bring the 35-Ω antenna impedance to 50 Ω for the main coax feed line. For all such systems, we must remember to account for the velocity factor of the transmission line, which will yield a line length that is shorter than a true quarter wavelength.

The dipole-based turnstile is popular for fixed-position satellite work. Figure 2 shows—on the left—one recommended system that has been in *The ARRL Antenna Book* since the 1970s. For 2 meters, a standard dipole-turnstile sits over a large screen that simulates ground. Spacing the elements from the screen by between $^{1}/_{4}$ and $^{3}/_{8}$ of a wavelength is recommended for the best pattern. For satellite operation, the object is to obtain as close to a dome-like pattern overhead as possible. The most desirable condition is to have the dome extend as far down toward the horizon as possible to let us communicate with satellites as long as possible during a pass.

The turnstile-and-screen system, while simple, is fairly bulky and prone to wind damage. However, the turnstile loses performance if we omit the screen. One way to reduce the bulk of our antenna is to find an antenna with its own reflector. However, it must have a good pattern for the desired goal of a transmitting and receiving dome in the sky. The dual Moxon rectangle array, shown in outline form on the right of Figure 2, offers some advantages over the traditional turnstile. First, it yields a somewhat better dome-like pattern. Second, it is relatively easy to build and compact to install.

Almost every fixed satellite antenna

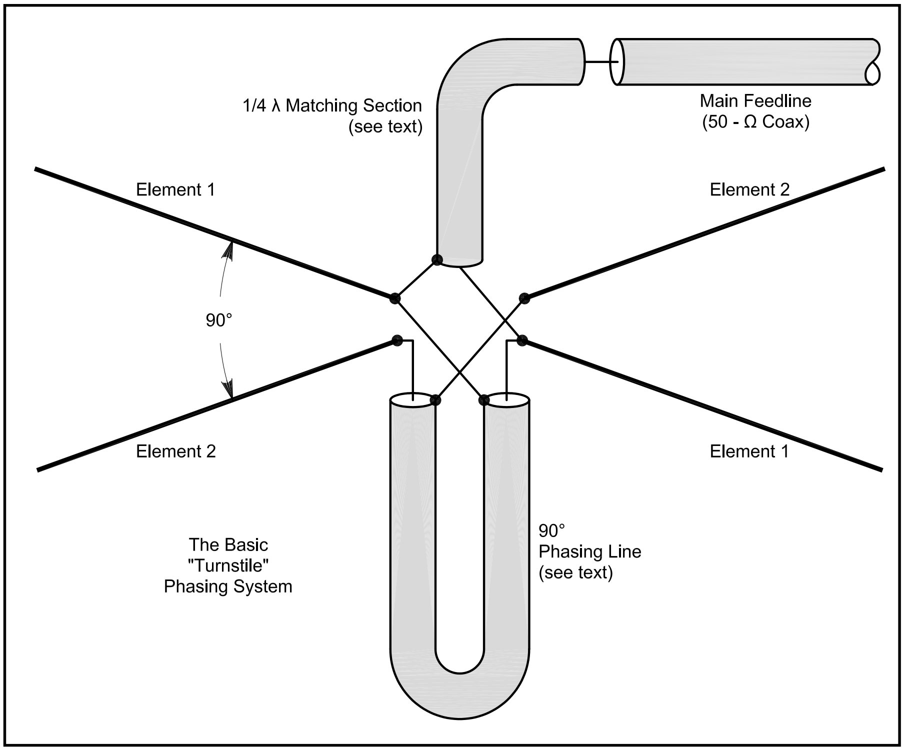


Figure 1—The basic turnstile phasing (and matching) system for any antenna set requiring a 90° phase shift between driven elements in proximity.

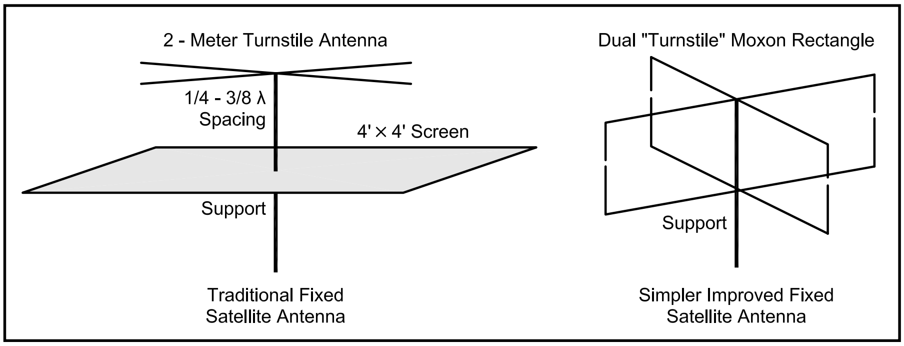


Figure 2—Alternative schemes for fixed-position satellite antennas: the traditional turnstile-and-screen and a pair of "turnstiled" Moxon rectangles.

shows deep nulls at lower angles, and the number of nulls increases as we raise the antenna too high, thus defeating the desire for communications when satellites are at low angles. Figure 3 shows the elevation patterns of a turnstile-and-screen and of a pair of Moxon rectangles when both are 2λ above the ground. A 1λ height will reduce the low angle ripples even more, if that height is feasible. However, the builder always has to balance the effects of height on the pattern against the effects of ground clutter that may block the horizon.

The elevation patterns show the considerably smoother pattern dome of the Moxon pair over the traditional turnstile. The middle of the turnstile dome has nearly 2 dB less gain than its peaks, while the top valleys are nearly 3 dB lower than the peaks. The peaks and valleys can make the difference between successful communications and broken-up transmissions. So, for the purpose of obtaining a good dome, the Moxon pair may be superior.

A reasonable suggestion offered to me was simply to add reflectors to a standard dipole turnstile and possibly obtain the same freedom from a grid or screen structure. Figure 4 shows the limitation of that solution. The result of placing reflectors behind the dipole turnstile is a pair of crossed 2-element Yagi beams fed 90° out of phase. The pattern is indeed circular and stronger than that of the Moxon pair. However, the beamwidth is reduced to only 56° at the half-power points. The antenna would make an excellent starter for a tracking AZ-EL rotator system, but it does not have the beamwidth for good fixed-position service.

The Moxon pair, with lower but smoother gain across the sky dome, offers the fixed-antenna user the chance to build a successful beginning satellite antenna. The pattern will be circular within under a 0.2-dB difference for 145.5 to 146.5 MHz, and within 0.5 dB for the entire 2-meter band. Since satellite work is concentrated in the 145.8 to 146.0 MHz region, the broadbanded antenna will prove fairly easy to build with success. A 435.6 MHz version, designed to cover the 435 to 436.2 MHz region of satellite activity will have an even larger bandwidth.

Like the dipole-based turnstile, the Moxons will be fed 90° out of phase with a 1/4-λ phasing line of 50-Ω coaxial cable. The drivers will be connected just as shown in Figure 1. Since the natural feedpoint impedance of a single Moxon rectangle of the design used here is 50 Ω, the pair will show a 25-Ω feed-point impedance. Paralleled 1/4-λ sections of 70- to 75-Ω coaxial cable will transform the low impedance to a good match for the main 50-Ω coaxial line to the rig. In short, we have "turnstiled" the Moxon rectangles into a reasonable fixed-position satellite antenna.

Building the Moxon Pairs

The Moxon rectangle is a modification of the reflector-driver Yagi parasitic beam. However, instead of using linear elements, the driver and reflector are bent back toward each other. The coupling between the ends of the elements combined with the coupling between parallel sections of the elements combine to produce a pattern with a broad beamwidth. By carefully selecting the dimensions, we can obtain both good performance (meaning adequate gain and an excellent front-to-back ratio) and a 50-Ω feed point impedance.[1]

In fact, a single Moxon rectangle might be used on each band for reasonably adequate satellite service. When pointed straight up, the Moxon rectangle pattern is a very broad oval, although not a circle. The oval pattern also gives the Moxon another advantage over dipoles in a turnstile configuration. If the phasing-line between dipoles is not accurately cut, the normal turnstile near-circle pattern degrades into an oval fairly quickly be-

[1] See "Having a Field Day with the Moxon Rectangle," *QST*, June, 2000, pp 38-42, for further details on the operation of the Moxon rectangle, along with the references in the notes to that article. Also included in the notes is the source for a program to calculate the dimensions for a 50-Ω Moxon rectangle for any HF or VHF frequency using only the design frequency and the element diameter as inputs.

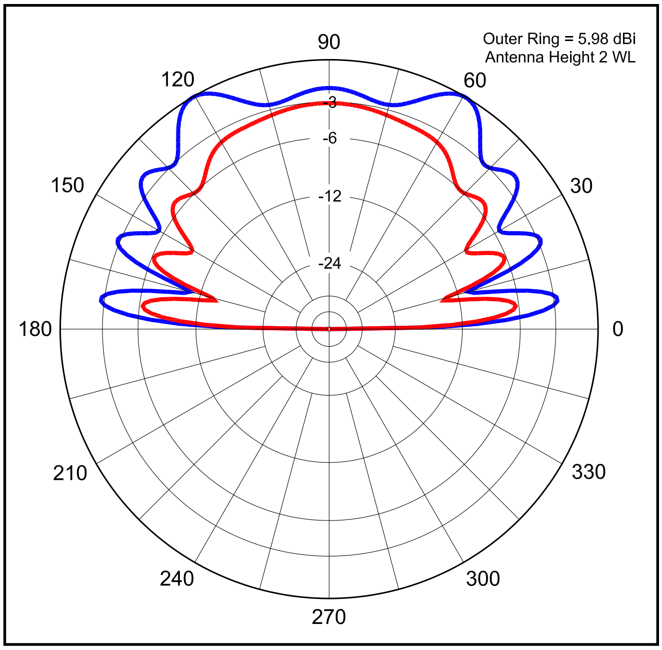


Figure 3—A comparison of elevation patterns for the turnstile-and-screen system (with $^3/_8\lambda$ wavelength spacing, shown in blue) and a Moxon pair (shown in red), both at 2λ height.

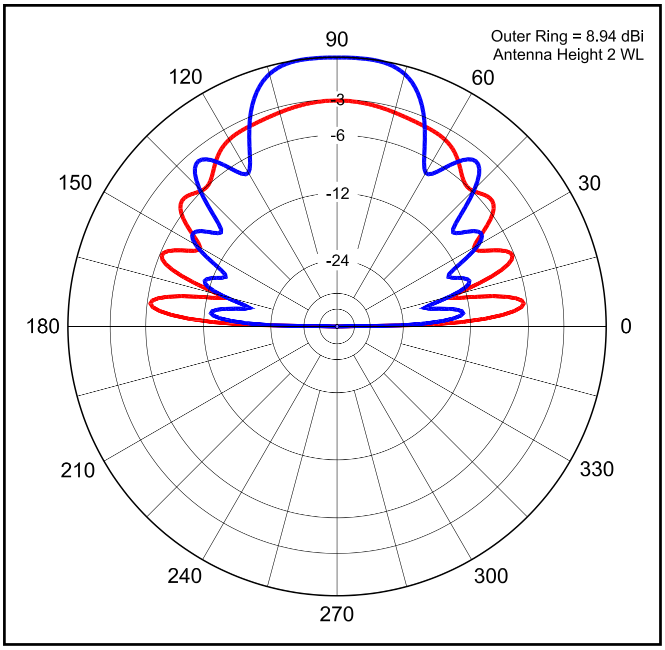


Figure 4—A comparison of elevation patterns for 2-element turnstiles (crossed 2-element Yagis, shown in blue) and a Moxon pair (shown in red), both at 2λ height.

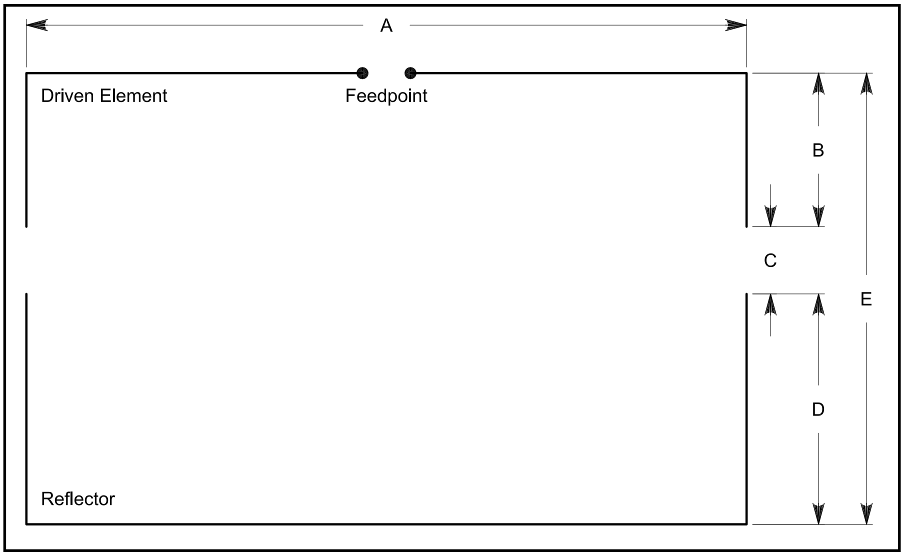


Figure 5—The basic dimensions of a Moxon rectangle. Two identical rectangles are required for each "turnstiled" pair.

Table 1
Dimensions for Moxon Rectangles for Satellite Use

Two are required for each antenna. The phase-line is 50-Ω coaxial cable and the matching line is parallel sections of 75-Ω coaxial cable. Low power cables less than 0.15 inches in outer diameter were used in the prototypes. See Figure 5 for letter references. All dimensions are in inches.

Dimension	*145.9 MHz*	*435.6 MHz*
A	29.05	9.72
B	3.81	1.25
C	1.40	0.49
D	5.59	1.88
E (B + C + D)	10.80	3.62
$^1/_4$ wavelength	20.22	6.77
0.66 velocity factor phasing and matching lines	13.35	4.47

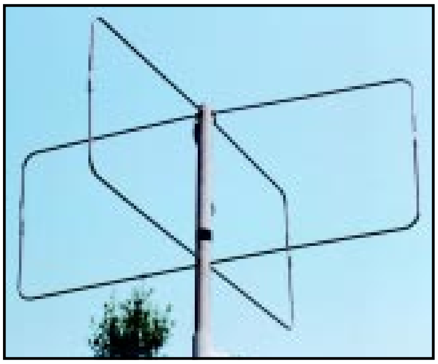
cause the initial single dipole pattern is a figure 8. The single Moxon oval pattern allows both dimensional inaccuracies and phasing-line inaccuracies of considerable amounts before degrading from a nearly perfect circle.

Figure 5 shows the critical dimensions for a Moxon rectangle. The lettered references are keys to the dimensions in Table 1. The design frequencies for the two satellite antenna pairs are 145.9 MHz and 435.5 MHz, the centers of the satellite activity on these two bands. The 2-meter Moxon prototype uses $^3/_{16}$-inch diameter rod, while the 435 MHz version uses #12 AWG wire with a nominal 0.0808-inch diameter. (Single Moxons built to these dimensions would cover all of 2-meters and about 12 MHz of the 432 MHz band.) Going one small step up or down in element diameter will still produce a usable antenna, but major diameter changes will require that the dimensions be recalculated.

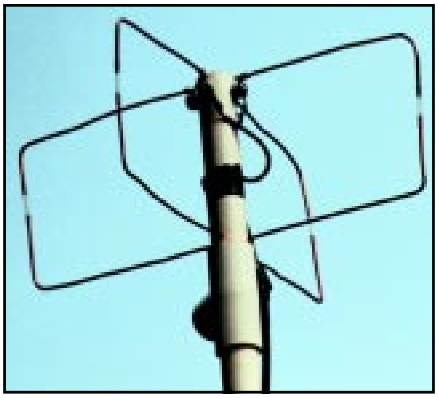
The reflectors are constructed from a single piece of wire or rod. I use a small tubing bender to create the corners. The rounding of the corners creates a slight excess of wire for the overall dimensions in the table. I normally arrange the curve so that the excess is split between the side-to-side dimension (A) and the reflector tail (D). Practicing on some scrap house wire may make the task go well the first time with the actual aluminum rod. The total reflector length should be A + (2 × D).

The driver consists of two pieces, since we'll split the element at its center for the feeding and phasing system. I usually make the pieces a bit longer before bending and trim them to size afterwards. The total length of the driver, including the open area for connections, should be A + (2 × B).

Perhaps the most critical dimension is



A close-up view of the 145.9 MHz rectangle pair.



The 435-MHz Moxons.

the gap, C. I have found nylon tubing, available at hardware depots, to be very good to keep the rod ends aligned and correctly spaced. When everything has been tested and found correct, a little super-glue on the tubing ends and aluminum stands up to a lot of wind. I usually nick the aluminum just a little to let the glue settle in and lock the junction. For the UHF version, a short length of heat-shrink tubing provides a lock for the size of the gap and the alignment of the element tails.

It is one thing to make a single Moxon and another to make a working crossed pair. Figure 6 shows the general scheme that I used for the prototypes, using CPVC. (Standard schedule 40 or thinner PVC or fiberglass tubing can also be used.) The support stock is $^{3}/_{4}$ inch nominal. The reflectors go into slots at the bottom of the tube and are locked in two ways. Whether or not the two reflectors make contact at their center points makes no difference to performance, so I ran a very small sheet screw through both 2-meter reflectors to keep their relative positions firm. I soldered the centers of the 435-MHz reflectors. Then I added a coupling to the bottom of the CPVC to support the double reflector assembly and to connect the boom to a support mast. Cementing or pressure fitting the cap is a user option.

The feed point assemblies are attached to solder lugs. The phasing line is routed down one side of the support, while the matching section line is run down the other. Electrical tape holds them in place. For worse weather, the tape may be over-sealed with butylate or other coatings. Likewise, the exposed ends of the coax sections and the contacts themselves should be sealed from the weather. The details can be seen—as built for the experimental prototypes in one of the photos—before sealing, since lumps of butylate or other coatings tend to obscure interesting details.

The overall assembly of the two antennas appears in the second photograph. The PVC from the support **T**s can go to a center Tee that also holds the main support for the two antennas. A series of adapters, made from miscellaneous PVC parts to fit over a standard length of TV mast. Alternatively, the antennas can be separately mounted about 10 feet apart. The 10-foot height of the assembly has proven adequate for general satellite reception, although I live almost at the peak of a hill.

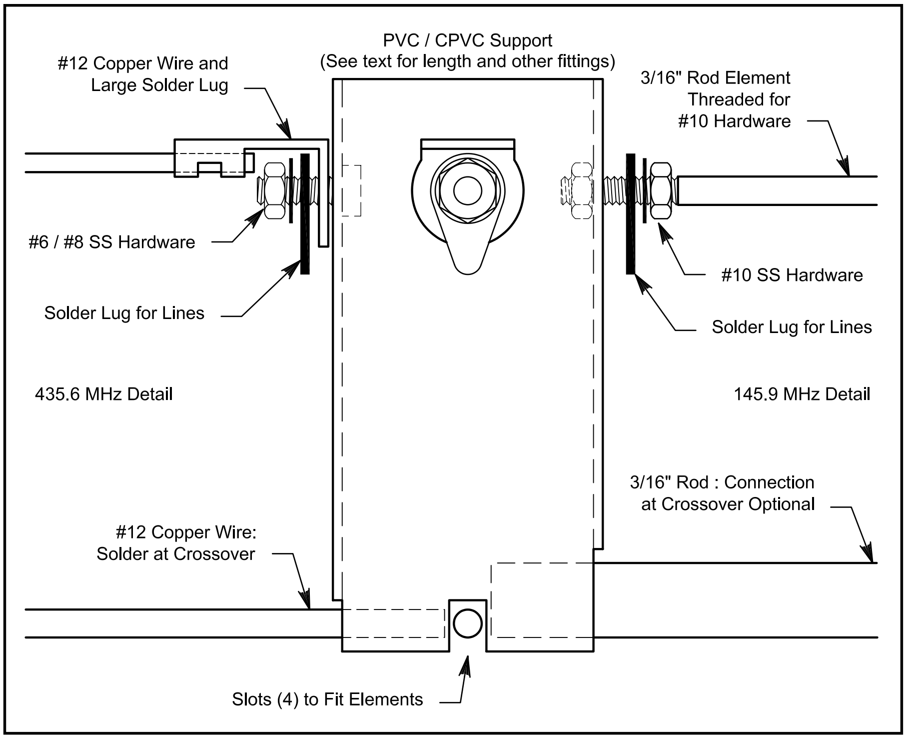


Figure 6—Some construction details for the Moxon pairs constructed as prototypes.

The antennas can be mounted on the same mast. However, for similar sky-dome patterns, they should each be the same number of wavelengths above ground. For example, if the 2-meter antenna is about two wavelengths up at about 14 feet or so, then the bottom of the 435-MHz antenna should be only about 4.5 feet above the ground. Placing the higher-frequency antenna below the 2-meter assembly will create some small irregularities in the desired dome pattern, but not serious enough to affect general operation.

There is no useful adjustment to these antennas except for making the gap between the drivers and reflectors as accurate as possible. Turnstile antennas show a very broad SWR curve. Across 2 meters, for example, the highest SWR is under 1.1:1. However, serious errors in the phasing line length can result in distortions to the desired circular pattern. There is no substitute for checking the lengths of the phasing line and the matching section several times before cutting. The correct length is from one junction to the next, including the portions of exposed cable interior.

These two little antennas will not compete with tracking AZ-EL rotating systems for horizon-to-horizon satellite activity. For satellite work, however, power is not always the problem (except for using too much) and modern receiver front-ends have enough sensitivity to make communication easy. So when the satellite reaches an angle of about 30° above the horizon, these antennas will give a very reasonable account of themselves. When you become so addicted to satellite communication that you invest in the complete tracking system, these antennas can be used as back-ups while parts of the complex system are down for maintenance!

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