Circular Polarization and OSCAR Communications

OSCAR users are switching to circular polarization to lessen signal fading. Build this low-cost antenna system and hear what you've been missing.

By Bernie Glassmeyer,* W9KDR

Most amateurs use either horizontal or vertical polarization because no other types are needed for terrestrial communication. In space communication certain polarization changes must be accounted for. This may be simply done with a basic understanding of what to expect and how to compensate for it.

Skywave communication involves the use of the mysterious ionosphere to reflect the waves of high-frequency signals. The ionosphere consists of ionized particles that extend from about 30 to 300 miles above the earth. See Fig. 1. Because the particles are in a constant state of flux, the effect on the radio signal passing through the ionosphere is random and ever-changing. Signals to and from a satellite are affected to varying degrees depending on the frequency, time of day, and location of the receiver and transmitter. The major effect is contributed by Faraday rotation, which causes changes in the polarization of electromagnetic waves as they pass through the ionosphere. Frequencies up to approximately 1 GHz (1000 MHz) are subject to Faraday rotation when they traverse the ionosphere. Since the present OSCAR satellites operate in this frequency range, we have an opportunity to observe the phenomenon of Faraday rotation.

Orbital Perspective

To track the satellite we must know its

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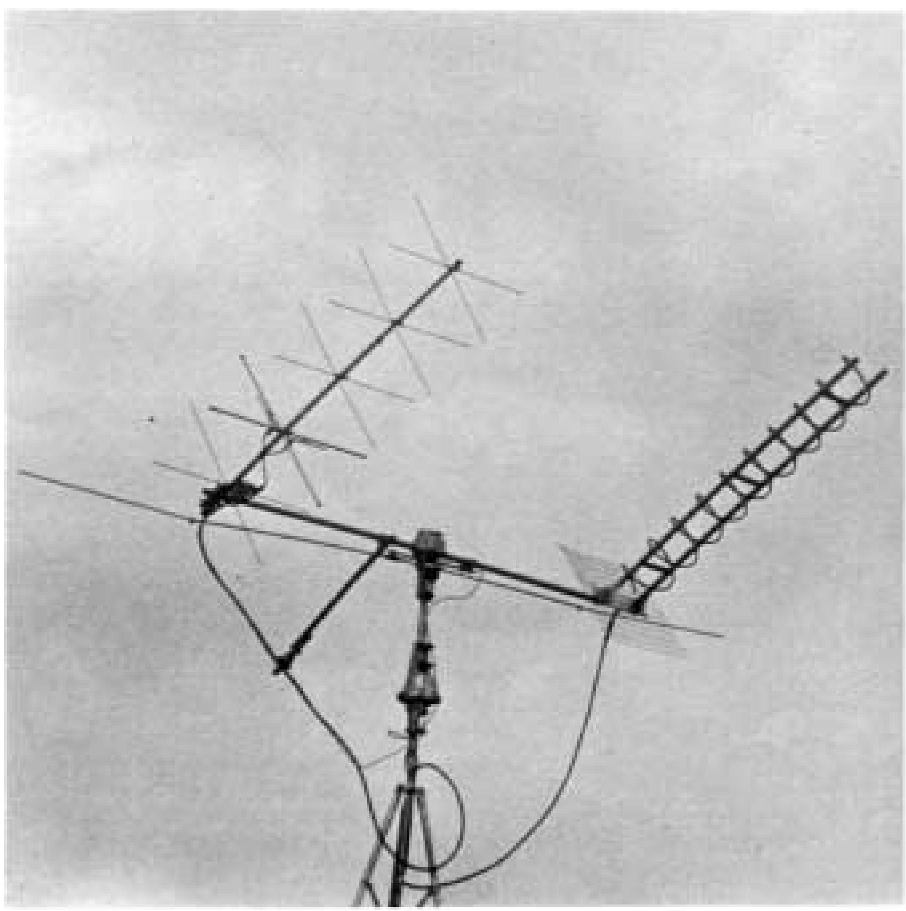


The author's satellite communications antenna system. On the left is a commercially made crossed-dipole Yagi antenna for 2 meters. On the right is a 9-turn 70-cm helical antenna. Note the counterweight mounted on the elevation boom.

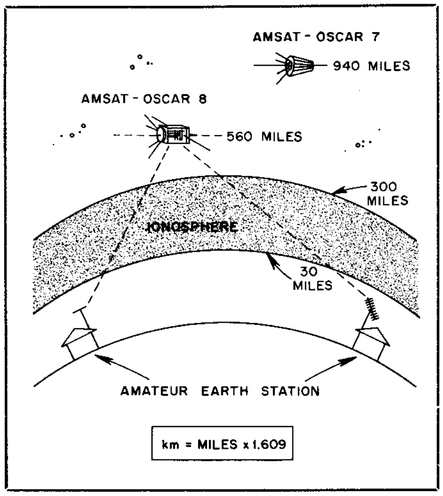


Fig. 1 — Both uplink and downlink signals must pass through the ionosphere to reach the OSCAR satellites. Approximate distances from the earth's surface are shown.

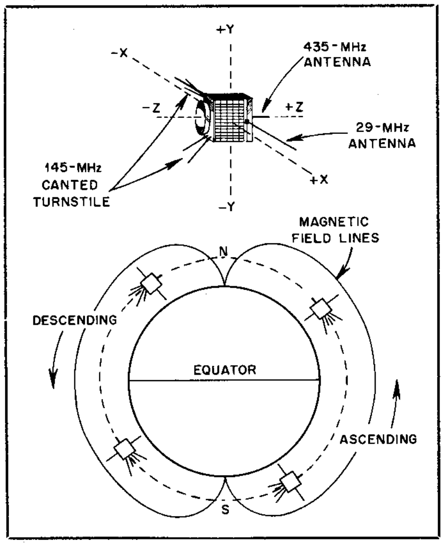


Fig. 2 — The path and orientation of OSCAR 8 as it orbits the earth.

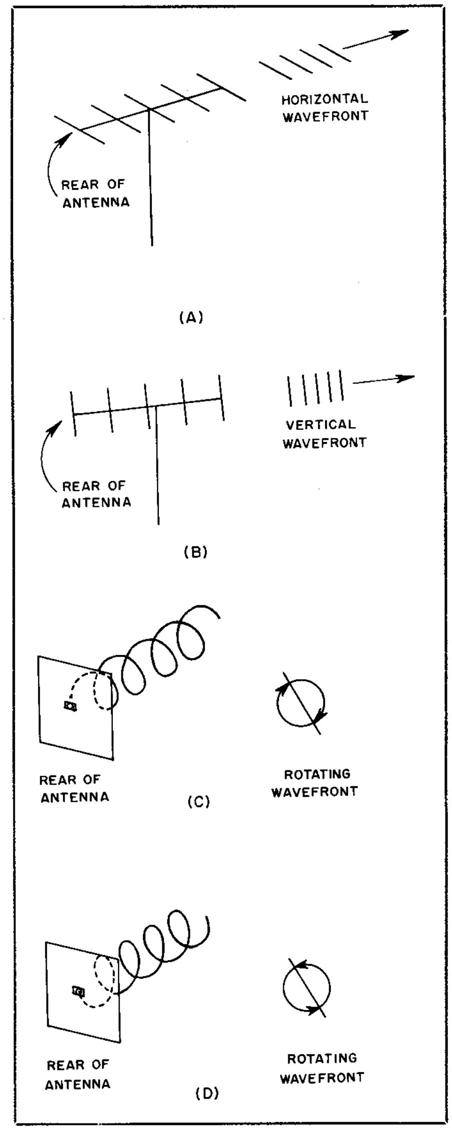


Fig. 3 — Types of polarization. (A) Horizontal polarization. (B) Vertical polarization. (C) Right-hand circular polarization. (D) Left-hand circular polarization.

location relative to our position on earth. This is easy to do using tracking devices available from ARRL hq.[1] and other sources, and the OSCAR operating schedule, published monthly in *QST*. Once the position of the satellite is established, it is time to consider another unknown: spacecraft rotation. A perspective may be gained by studying Fig. 2. The direction of orbit for OSCAR 8 on a south-to-north evening (ascending) pass is indicated by the positive z-axis (top of spacecraft). For a north-to-south morning (descending) pass, the direction of orbit is indicated by the negative z-axis. Therefore, the positive z-axis points in the direction of the earth's geomagnetic north pole, and the negative z-axis points in the direction of the south geomagnetic pole. The north and south geomagnetic poles, distinct from the more familiar geographic poles, define the earth's magnetic field. Because this axis inclines about 12 degrees from the geographic axis, the geomagnetic poles lie 798 miles from the geographic poles. The stabilization system aboard OSCAR 8 consists of four permanent magnets aligned along the z-axis. These magnets allow the spacecraft to remain parallel to the earth's magnetic field.

The OSCAR 8 spacecraft currently makes one 360-degree rotation about its z-axis every five minutes. The 2-meter antennas (four canted turnstiles) mounted on the negative z-axis (bottom of the spacecraft) and the 10-meter dipole mounted on the x axis both rotate on the z-axis. Result: additional polarization rotation and fading.

Circular Polarization

Now that we have some idea of the orbital mechanics of the spacecraft, let's take a look at the types of polarization used in space communications. The two most likely polarization candidates are right-hand circular polarization (RHCP) and left-hand circular polarization (LHCP). To understand these two forms, we must choose one of the two conventions of circular polarization theory. One theory is the 1942 classic physics definition; the other is the definition of the Institute of Electrical and Electronics Engineers (IEEE). Arguments lasting to the wee hours of the night have occurred between these two schools of thought. I chose the IEEE convention, since all recent work done in the field uses it. Let's accept it and proceed. The IEEE convention is taken from a viewpoint at the rear of the antenna looking in the direction of travel of the wavefront, as shown in Fig. 3. As we look in that direction, an RHCP wave will turn *clockwise*. An LHCP wave will turn *counter-clockwise*.

Most vhf operators know that vertical and horizontal polarization are not compatible; about 20 dB of signal strength is lost when the transmitting station uses one polarization and the receiving station uses the other. But circular polarization can be used with vertical and horizontal polarization, and any form in between.

Because of Faraday and satellite rotation, the polarization of the rf energy from space is indeterminate. Observing the intense fading of a received signal such as the 435.095-MHz beacon from the OSCAR 8 spacecraft has changed the thinking of many recent OSCAR converts who would rather switch than fight Faraday rotation. If you tune in the beacon and get QSB (fading of the received signal), that's it — polarization rotation — unpredictable and ever-changing. Regardless of the polarization at the spacecraft or earth station antenna, whether uplink or downlink, when the signal passes through the ionosphere its polarity is changed. Sometimes the rotation is as much as 180 degrees in a five-minute period, as on 10 meters. By switching to circular polarization, it is possible to change a marginal signal to "solid copy," and gain the hands-on experience you will need to become proficient in space communications.

The best possible system would be switchable RHCP and LHCP on both the uplink and downlink frequencies. Both RHCP and LHCP are useful because the effects of Faraday rotation may be so severe that the polarization sense may actually become reversed!

Assembling such an antenna system is not difficult. Fig. 4 shows four Yagi antennas, a pair for 144 MHz and a pair for 432 MHz. Note how each antenna is mounted at a right angle to its counter-

[1] A simple tracking device, the OSCARLOCATOR, is available from ARRL.

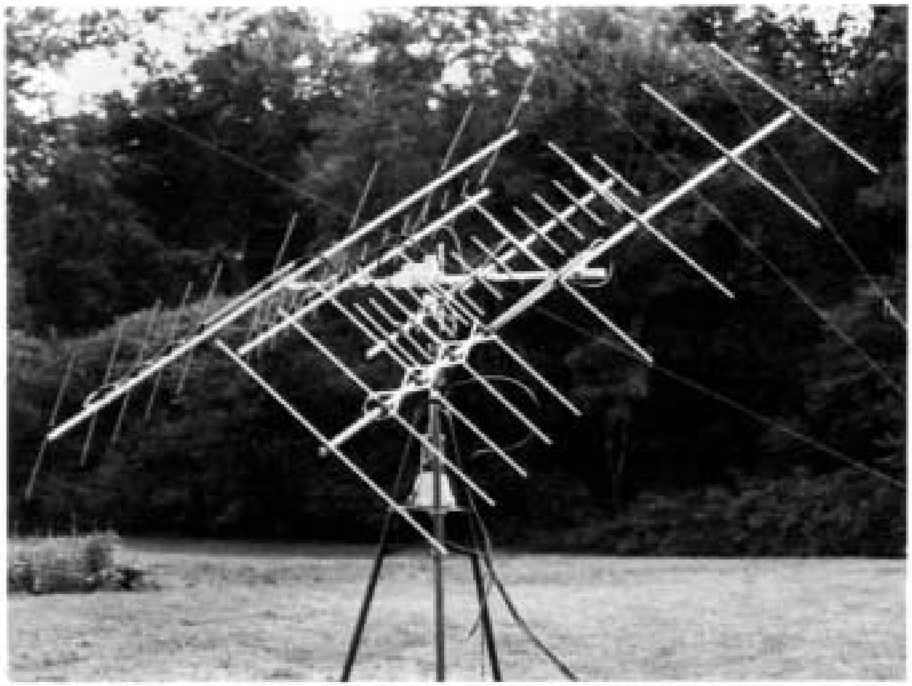


Fig. 4 — An OSCAR array, built by W1VD and assembled from KLM log-periodic Yagis (featured in the 1980 ARRL *Handbook*, page 14-8).

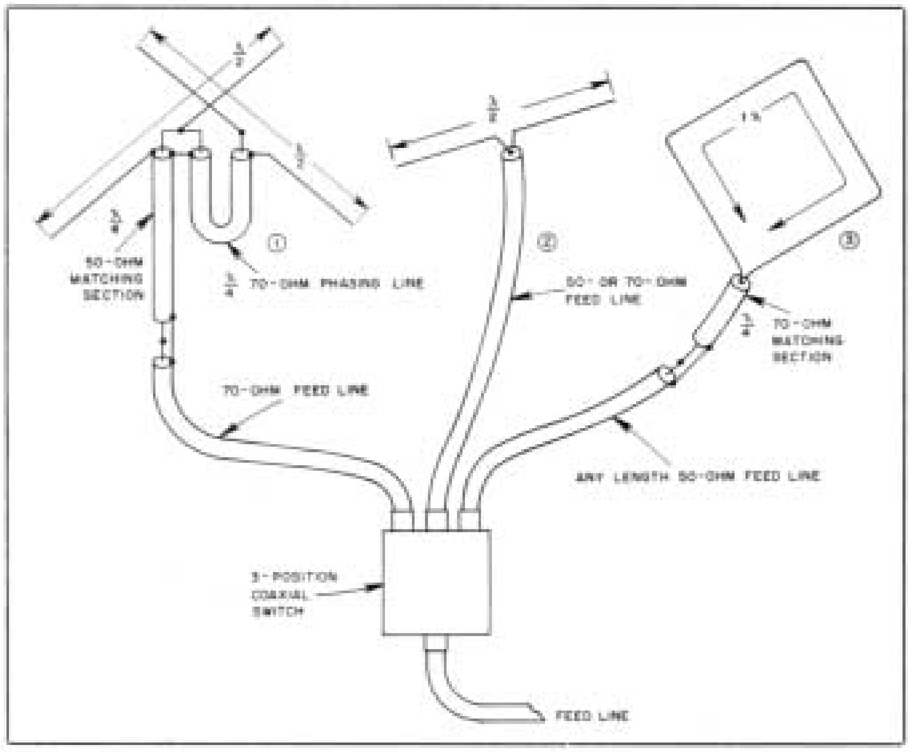


Fig. 5 — Any one of three 10-meter antennas — a turnstile (1), rotary dipole (2), or horizontal loop (3) — may be selected for OSCAR downlink reception.

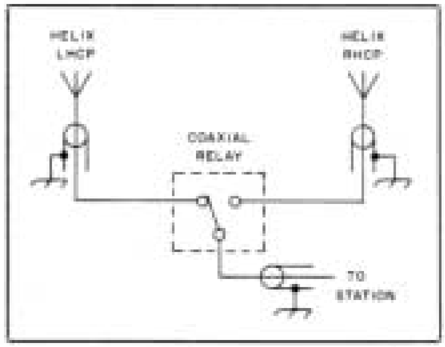
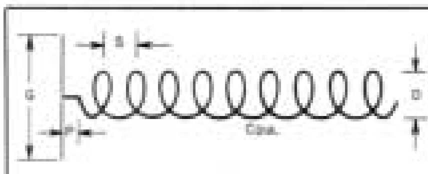


Fig. 6 — A switchable-sense antenna system for satellite communications.



C_{DIA} = .017 λ conductor diameter.

$D = \frac{\lambda}{3}$ diameter OD.

G = 0.8 λ or greater.
N = number of turns = 9.
P = 0.12 λ space from reflector to start of first turn.

$S = \frac{\lambda}{4}$ space between turns center to center.

λ = wavelength in free space.

$\lambda(\text{inches}) = \frac{11,810}{f\,(\text{MHz})}$

Fig. 7 — A 70-cm, 9-turn helix, with formulas for determining the critical dimensions. For a 430-MHz design frequency, C_{DIA} = 0.47 inch, D = 9.16 inches, G = 22.0 inches, P = 3.3 inches and S = 6.9 inches (mm = inches × 25.4).

part. This is an effective means to generate circular polarization. Fig. 5 illustrates a scheme that a Mode A user might employ to recover maximum signal from the 10-meter downlink.

A Switchable-Sense Helical Antenna

A helical antenna is another effective means to generate circular polarization. Constructing a set of helix antennas for the 70-cm band is very easy. One antenna wound for RHCP, the other LHCP, a uhf spdt antenna switch or relay, and some good hardline is all that is needed to complete the system. Such a setup is shown in Fig. 6. Only readily available, inexpensive materials are used for construction, and the most comforting part is that the dimensions are not critical. Fig. 7 shows the helix formulas and dimensions. This broadband beauty, with a 1.8-to-1 bandwidth ratio, is ideal for a high-gain, broad-beamwidth satellite-tracking antenna. With this switchable antenna system and 50 to 100 watts of rf output, you should have a respectable signal on the new Phase III satellite.

A close-up detail of the complicated portion of the helix is shown in Fig. 8. A good starting point for construction is the reflector, made of heavy wire mesh. This type of wire mesh is used in most uhf TV "bow tie" antennas. Hardware or wire companies can supply this material in four-foot widths. It is no. 14-gauge galvanized steel and sells at approximately $1.60 per foot. To build two antennas you will need a piece of mesh two by four feet. Trim the mesh so that no sharp ends stick out, or you may end up with a four-sided porcupine.

The next step is to make the reflector mounting plates and boom brackets.

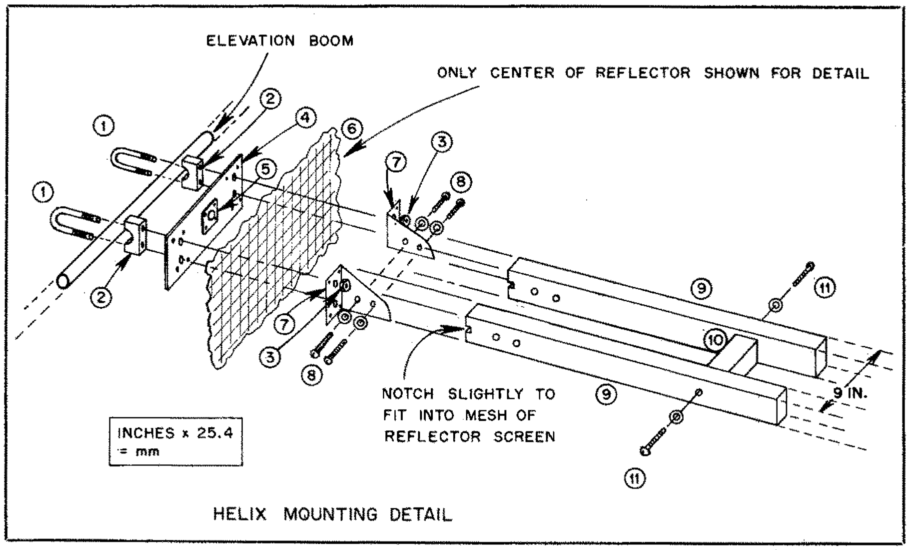


Fig. 8 — The details of the helix-mounting arrangement. See Table 1 for a number-keyed parts list.

Table 1

Parts list for the helix mounting detail shown in Fig. 8.

Piece No.	*Description*	*Comments*
1	U bolt, TV type	Use to bolt antenna to elevation boom
2	U bolt spacer	As above
3	U bolt nut with lock washer	As above
4	Reflector mounting plate (see Fig. 9)	Rivet through reflector to boom brackets
5	Coaxial receptacle, N type	Rivet to mounting plate
6	1- x 2-in. heavy gauge wire mesh	Reflector, cut approx. 22 in. square
7	Helix boom-to-reflector brackets	Rivet through reflector to mounting plate
8	No. 8-32 bolts with nuts and washers	Bolt boom brackets to boom
9	Boom, approx. 1- x 1-in. tomato stake, 6 feet long	
10	Boom spacer, 1- x 1-in. tomato stake	Bolt to boom; cut to give 9-in. spacing
11	No. 8 wood screws with washers	Attach spacers to boom (three places)

Notes: 1) Mount reflector mounting plate to boom brackets observing 9-inch clearance for boom.
2) Wire mesh may be bent to provide clearance for U bolts.
3) When positioning the reflector mounting plate, try to center the coaxial receptacle in the wire-mesh screen.

Follow the dimensions shown in Fig. 9. Heavy aluminum material is recommended; 0.060 inches (1.5 mm) is the minimum recommended thickness. Thicker material will be more difficult to bend, but two bends of 45 degrees spaced about 1/4 inch (6.4 mm) apart will work fine for the brackets in this case. The measurements shown are for TV-type 1-3/4 inch (44.5-mm) U-bolt clamps. If you use another size, change the dimensions to suit. Drill the four holes in the reflector mounting plate and mount the coax receptacle, using pop rivets or nuts and bolts. It is advisable to check clearance between the coax receptacle and the elevation boom before final assembly. The thickness of the U-bolt spacers will affect this clearance. Mount a short piece of pipe, the same size as the elevation boom you will be using, to the U bolts, wire mesh reflector, reflector mounting plate and boom brackets, as shown in Fig. 8. Position the plate in the center of the wire mesh reflector. It will be necessary to bend some of the mesh to clear the U bolts. Loosely tighten the U bolts so the plate can be adjusted to fit the mesh.

The wood boom assembly shown in Fig. 8 is two six-foot lengths of tomato stake joined together in three places. Mount one spacer in the center and the other spacers one foot in from each end. Position the notched ends of the boom to fit into the mesh. When the correct alignment is obtained, clamp the assembly together and drill holes for rivets or bolts through the reflector mounting plate, brackets and wood boom assembly. When drilling the boom holes, place the reflector flat on the floor and use a square so the boom is perpendicular to the reflector. Mark the boom through the holes in the boom bracket. When the assembly is complete, give the wood boom a coat of marine varnish.

The most unusual aspect of this antenna is its use of coaxial cable for the helix conductor. It is readily available, inexpensive, light in weight, and easy to shape into the coil required for the helix. Nine turns will require about 22 feet (6.71 m), but allow 25 feet (7.62 mm) and trim off the excess. The author used an FM-8 type of coaxial cable, but any type may be used that is near the 1/2-inch (12.7-mm) diameter required, and has a center conductor and shield that can be soldered together. Strip about four inches (102 mm) at one end of the cable down to the center conductor, but leave enough braid to solder to the center conductor. This will become an electrical short. The exposed center conductor should be measured 3.3 inches (84 mm) from the short and the excess cut off. This is the dimension P in Fig. 7. Wind the 25-foot length of coax in a coil about 10 inches (254 mm) in

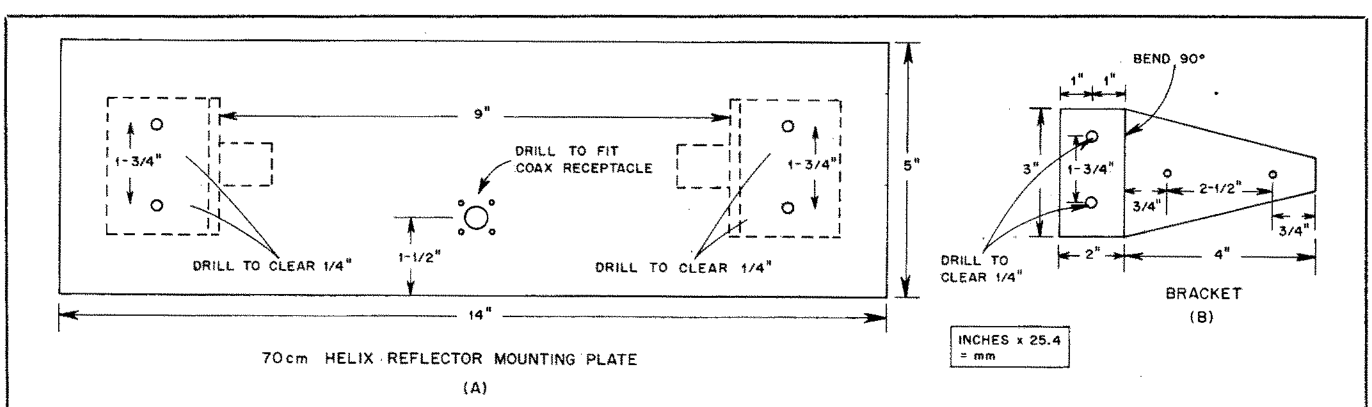


Fig. 9 — (A) The helix reflector mounting plate (part no. 4 in Table 1). (B) The boom brackets (part no. 7 in Table 1).

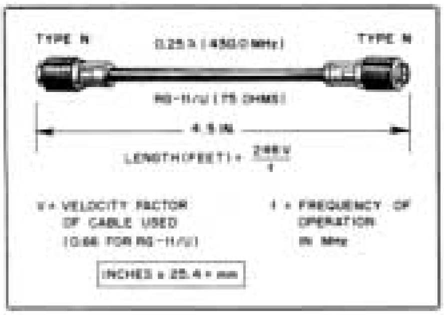
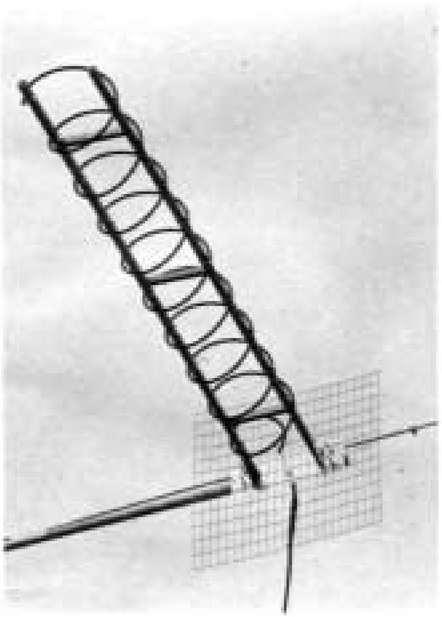


Fig. 10 — A coaxial matching section of 75-ohm cable matches the 140-ohm impedance of the helix to the 52-ohm feed line.



A close-up view of the author's 70-cm helical antenna.

diameter. Check Fig. 3 to determine which way to wind the coil for RHCP or LHCP. Slip the coil over the boom and move the stripped end of the cable toward the coax receptacle, which will become the starting point of the nine turns. Solder the center conductor to the coax receptacle, and start the first turn 3.3 inches (83.8 mm) from the point of connection at the coax receptacle. Tie-wraps are used to fasten the coax to the wood boom. Mark the boom using dimension S in Fig. 7. The first tie-wrap will be only half this distance when it first comes in contact with the boom, then each successive turn on that side of the boom will be spaced by dimension S. Use two tie-wraps so they form an X around the boom and coax. Once the first wrap is secure, wind each turn and fasten the cable one point at a time. Before each turn is tightened, make sure the dimensions are correct. When you reach nine turns, check all dimensions again. Cut the coax at the ninth turn, strip enough of the end to solder a short. The exposed solder connections at each end of the coax conductor may be taped and sprayed or covered with a RTV-type covering to weatherproof them.

The coaxial 75-ohm quarter-wavelength matching section shown in Fig. 10 is connected in series with the feed line at the antenna feed point. The formula for determining the correct impedance value for a coaxial quarter-wave matching transformer is

$$Z_0 = \sqrt{Z_s Z_r}$$

where

Z_0 = desired transformer impedance
Z_s = transmission-line impedance
Z_r = antenna impedance

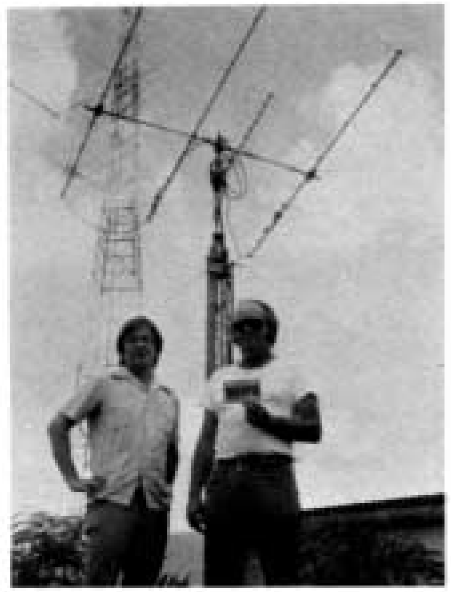
The impedance of the helix is approximately 140 ohms. To match the 52-ohm transmission line, a transformer of 85.3 ohms is required. The 75-ohm cable used here is close enough to this value for a good match. The transformer should be connected directly to the female connector mounted on the reflector mounting plate. Use a double-female adapter to connect the feed line to the matching transformer. Wrap the connectors with plastic electrical tape, then spray with an acrylic resin for waterproofing.

To mount these antennas on an elevation boom, a counterbalance is required. The best way to do this is to mount an arm about two feet (610 mm) long to the elevation boom, at some point that is clear of the rotator, mast and other antennas. Point the arm away from the direction the helices are pointing in, and add weight to the end of the arm until balance is found.

Do not run long lengths of coax to this antenna, unless you use hardline. Even short runs of good RG-8/U coax are quite lossy: 50 feet of foam RG-8/U at 430 MHz has a loss of 2 dB. There are other options if you must make long runs and can't use hardline. Some amateurs mount the converters, transverters, amplifiers and filters at the antenna. This could be done with the helix antenna very easily; the units could be mounted behind the reflector, which will also add counterbalance. If this approach is used, check local electrical codes before running any power lines to the antenna.

Many theoretically minded amateurs will argue that polarization sense does not change as the signal passes through the ionosphere. So far, only a few active OSCAR 8 Mode J users have discovered that it pays to switch polarization sense. With one RHCP, one LHCP helix and a remote uhf spdt switch, you will be able to determine for yourself if this phenomenon exists. With active satellites equipped for 70-cm transmission and reception orbiting the earth every day, we only need point our antennas skyward to enjoy and learn from the exciting world of satellite communications. QST

Strays



These two OSCAR DXpeditioners, Herb Schoenbohm, KV4FZ, of Christiansted, Virgin Islands, and Bud Ansley, W6VPH, of Pasedena, California, have put many new spots in the Caribbean on the air for OSCAR DXers. This photograph was taken at the KV4FZ antenna farm.

"HAMFEST CALENDAR" RULES AND REGS

☐ *QST* will list your hamfest in its monthly "Hamfest Calendar," free of charge. There are certain guidelines, however.

Hamfests will be listed only once. Sponsors may specify the issue in which the announcement should appear. Normally, if the event will occur before the 10th of the month, we recommend listing it in the previous month's issue. The deadline for *receipt* of hamfest information is the 15th of the second month preceding publication. In other words, if an event is August 5, the announcement should be in the July issue, and will need to arrive in Newington by the 15th of May at the very latest. For an August 19 event, the sponsor could choose either the July issue, with the May 15 deadline, or the August issue, with a June 15 deadline.

We will acknowledge all information received at Hq. for "Hamfest Calendar" with a postcard stating the date of publication. If you do not receive an acknowledgement within two weeks, your letter may not have arrived at Hq., so please send us a duplicate copy.

Oh, yes, "Hamfest Calendar" is separate from the hamfest section of the Ham Ads. See the first page of the Ham Ads section in this issue for more information. — *Marge Tenney, WB1FSN*