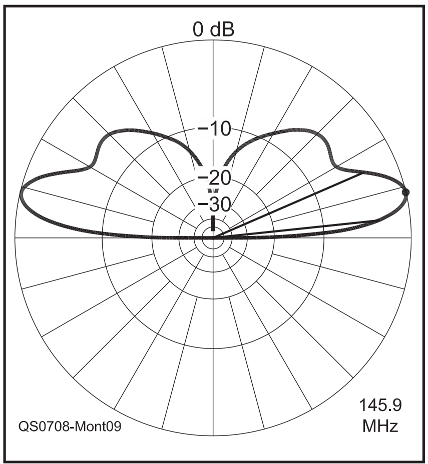

Fig 53 — *EZNEC* elevation radiation pattern of Lindenblad antenna.

PERFORMANCE

The antenna impedance match to 50 Ω was tested using an MFJ-259B SWR meter, which was checked against an external frequency counter and precision 50 Ω load. The antenna provides an excellent match over the entire 2 meter band. This antenna was designed to safely handle any of the currently available VHF transceivers and tested by applying a 200 W signal key down for 9 minutes, then checking the ferrites and cables for temperature rise.

The antenna radiation pattern predicted by the *EZNEC* model is shown in **Fig 53**. This is the elevation plot with the antenna mounted at 6 ft above ground although it can be mounted higher if desired for better coverage to the horizon. As shown in the plot, the pattern favors the lower elevation angles. The –3 dB points are at 5° and 25° with the maximum gain of 4.8 dBic (dB with respect to an isotropic circularly polarized antenna) at around 13°. Most of the satellite pass elevations will be in this range and it is also the elevation at which the satellite provides the best chance for DX contacts. The antenna radiation is right-hand circularly polarized, which will work with virtually any LEO satellite that uses the 2 meter band.

The EZ-Lindenblad antenna has been used for SSB, FM and packet operation on a number of amateur satellites. A portable setup performed well on Field Day, an excellent test of any antenna as it is probably the busiest weekend of the year on the satellites.

6.2 The W3KH Quadrifilar Helix

If your existing VHF omnidirectional antenna coverage is "just okay," this twisted antenna project by Eugene F. Ruperto, W3KH, is probably just what you need! The ever-changing position of LEO satellites presents a problem for the Earth station equipped with a fixed receiving antenna: signal fading caused by the orientation of the propagated wavefront. This antenna provides a solution to the problem and can be used with weather satellites, or any of the polar-orbiting amateur satellites.

Several magazines have published articles on the construction of the quadrifilar helix antenna (QHA) originally developed by Dr Kilgus.[1] A particularly good reference is *Reflections* by Walt Maxwell, W2DU, who had considerable experience evaluating and testing this antenna while employed as an engineer for RCA.[2]

Part of the problem of replicating the antenna lies in its geometry. The QHA is difficult to describe and photograph. Some of the artist's renditions leave more questions than answers, and some connections between elements as shown conflicted with previously published data. However, those who have successfully constructed the antenna say it is *the* single-antenna answer to satellite reception for the low-Earth-orbiting satellites.

DESIGN CONSIDERATIONS

Experts imply that sophisticated equipment is necessary to adjust and test the antenna, but the author found it possible to construct successful QHAs by following a cookbook approach using scaled figures from a proven design. The data used as the design basis for the antenna described here were published in an article describing the design of a pair of circularly polarized S-band communication-satellite antennas for the Air Force and designed to be spacecraft mounted.[3] Using this antenna as a model, the author constructed QHAs for the weather-satellite frequencies and the polar-orbiting 2 meter and 70 cm amateur satellites with excellent results and without the need for adjustments and tuning. By following some prescribed universal calculations, a reproducible and satisfactory antenna can be built using simple tools.

UHF and microwave antennas require a high degree of constructional precision because of the antenna's small size. For instance, the antenna used for the Air Force at 2.2 GHz has a diameter of 0.92 inch and a length of 1.39 inches! On the other hand, a QHA for 137.5 MHz is 22.4 inches long and almost 15 inches in diameter; for 2 meters, the antenna is not much smaller. Antennas of this size are not difficult to duplicate.

ELECTRICAL CHARACTERISTICS

A half-turn ½ λ QHA has a theoretical gain of 5 dBi and a 3-dB beamwidth of about 115°, with a characteristic impedance of 40 Ω. The antenna consists basically of a four-element, half-turn helical antenna, with each pair of elements described as a *bifilar,* both of which are fed in phase quadrature. Several feed methods can be employed, all of which appear complicated except the infinite-balun design, which uses a length of coax as one of the four elements.

To produce the necessary 90° phase difference between the bifilar elements, either of two methods can be used. One is to use the same size bifilars, which essentially consist of two twisted loops with their vertical axes centered and aligned, and the loops rotated so that they're 90° to each other (like an egg-beater), and using a quadrature hybrid feed. Such an antenna requires *two* feed lines, one for each of the filar pairs.

The second and more practical method is the self-phasing system, which uses *different-size loops:* a larger loop designed to resonate *below* the design frequency (providing an inductive reactance component) and a smaller loop to resonate higher than the design frequency (introducing a capacitive-reactance component), causing the current to lead in the smaller loop and lag in the larger loop. The element lengths are 0.560 λ for the larger loop, and 0.508 λ for the smaller loop. According to the range tests performed by Maxwell, to achieve *optimum* circular polarization, the wire used in the construction of the bifilar elements should be 0.0088 λ in diameter.

Maxwell indicates that in the quadrifilar mode, the fields from the individual bifilar helices combine in optimum phase to obtain unidirectional end-fire gain. The currents in the two bifilars must be in quadrature phase. This 90° relationship is obtained by making their respective terminal impedances R +*j*X and R –*j*X where X = R, so that the currents in the respective helices are –45° and +45°. The critical parameter in this relationship is the terminal reactance, X, where the distributed inductance of the helical element is the primary determining factor. This assures the ±45° current relationship necessary to obtain true circular polarization in the combined fields and to obtain maximum forward radiation and minimum back lobe. Failure to achieve the optimum element diameter of 0.0088 λ results in a form of elliptical, rather than true circular polarization, and the performance may be *a few tenths of a decibel* below optimum, according to Maxwell's calculations. Using #10 wire translates roughly to an element diameter of 0.0012 λ at 137.5 MHz — not ideal, but good enough.

To get a grasp of the QHA's topography,

[1]C. C. Kilgus, "Resonant Quadrafilar Helix;" *IEEE Transactions on Antennas and Propagation*, Vol AP-17, May 1969, pp 349-351.
[2]M.W. Maxwell, W2DU, *Reflections* (Newington: ARRL, 1990). [This book is out of print.]
[3]R. Brickner Jr and H. Rickert, "An S-Band Resonant Quadrifilar Antenna for Satellite Communication," RCA Corp, AstroElectronics Div.

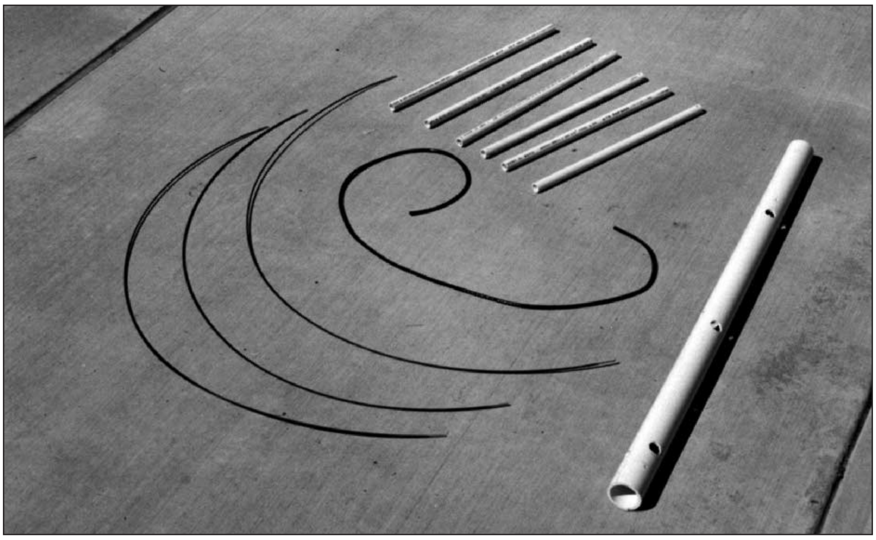

Fig 54 — The quadrifilar helix antenna (QHA) pieces, ready for assembly.

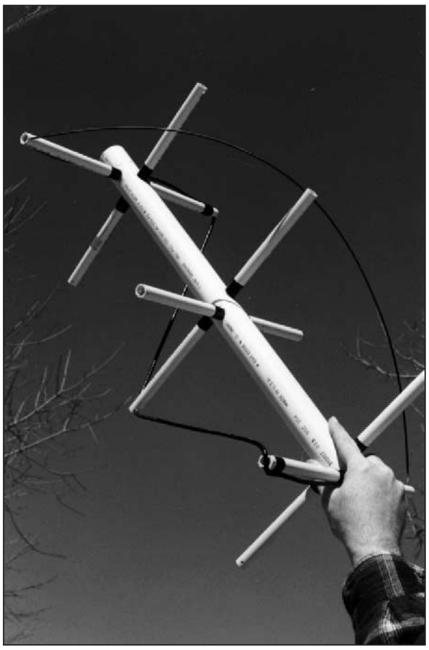

Fig 55 — The antenna with two of the four legs (filars) of one loop attached.

Fig 56 — This view shows the QHA with all four legs in place. The ends of the PVC cross arms that hold the coaxial leg are notched; the wire elements pass through holes drilled in the ends of their supporting cross arms.

visualize the antenna as consisting of two concentric cylinders over which the helices are wound (see **Fig 54** through **Fig 58**). In two-dimensional space, the cylinders can be represented by two nested rectangles depicting the height and width of the cylinders. The width of the larger cylinder (or rectangle) can be represented by 0.173 λ and the width of the smaller cylinder represented by 0.156 λ. The length of the larger cylinder or rectangle can be represented by 0.260 λ, and the length of the smaller rectangle or cylinder can be represented by 0.238 λ. Using these figures, you should be able to scale the QHA to virtually any frequency. **Table 6** shows some representative antenna sizes for various frequencies, along with the universal parameters needed to arrive at these figures.

PHYSICAL CONSTRUCTION

Fig 59 shows the construction details. A 25-inch-long piece of schedule 40, 2-inch-diameter PVC pipe is used for the vertical member. The cross arms that support the helices are six pieces of ½-inch-diameter PVC tubing: three the width of the large rectangle or cylinder, and three the width of the smaller cylinder. Two cross arms are needed for the top and bottom of each cylinder. The cross arms are oriented perpendicularly to the vertical member and parallel to each other. A third cross arm is placed midway between the two at a 90° angle. This process is repeated for the smaller cylindrical dimensions using the three smaller cross arms with the top and bottom pieces oriented 90° to the large pieces.

Using ⅝ inch-diameter holes in the 2-inch pipe ensures a reasonably snug fit for the ½-inch-diameter cross pieces. Each cross arm is drilled (or notched) at its ends to accept the lengths of wire and coax used for the elements. Then the cross arms are centered and cemented in place with PVC cement. For the 137 and 146 MHz antennas, use #10 AWG copper clad antenna wire for three of the helices and a length of RG-8 for the balun, which is also the fourth helix. (Do not consider the velocity factor of the coax leg for length calculation.) For the UHF antennas, use #10 AWG soft-drawn copper wire and RG-58 coax. Copper clad wire is difficult to work with, but holds its shape well. Smaller antennas can be built without the cross arms because the wire is

Table 6
Quadrifilar Helix Antenna Dimensions

		Small Loop			Big Loop		
Freq (MHz)	*Wavelength (λ) (inches)*	*Leg Size (0.508 λ)*	*Diameter (0.156 λ)*	*Length (0.238 λ)*	*Leg Size (0.560 λ)*	*Diameter (0.173 λ)*	*Length (0.261 λ)*
137.5	85.9	43.64	13.4	20.44	48.10	14.86	22.33
146	80.9	41.09	12.6	19.25	45.30	14.0	21.03
436	27.09	13.76	4.22	6.44	15.17	4.68	7.04

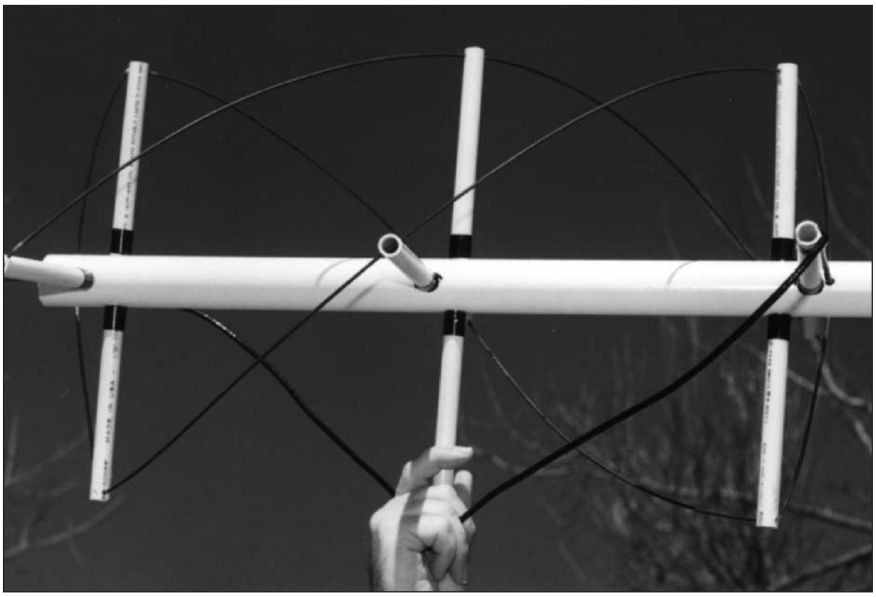

Fig 57 — Another view of the QHA.

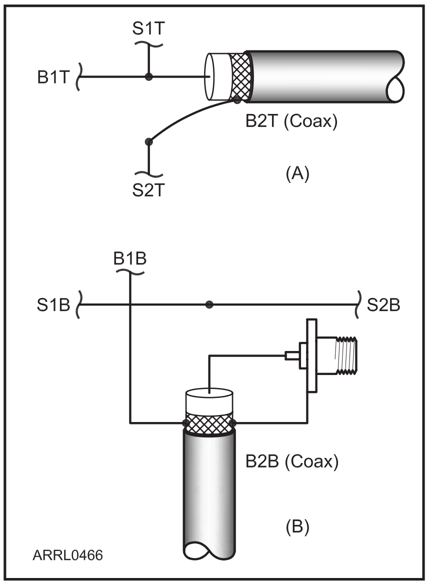

Fig 60 — At A, element connections at the top of the antenna. B shows the connections at the bottom of the antenna. The identifiers are those shown in Fig 59 and explained in the text.

Fig 58 — An end-on view of the top of the QHA prior to soldering the loops and installing the PVC cap.

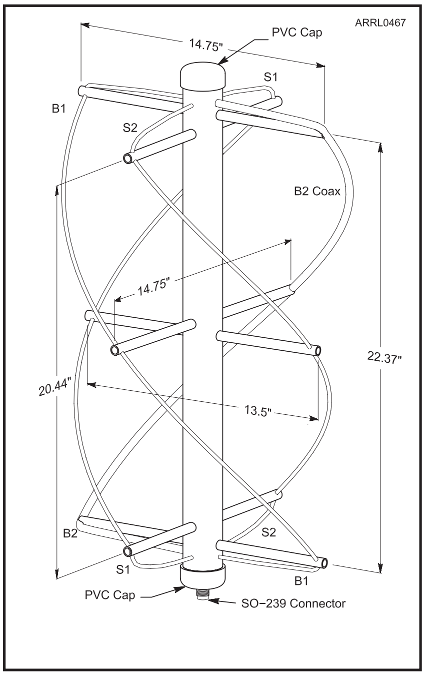

Fig 59 — Drawing of the QHA identifying the individual legs; see text for an explanation.

sufficiently self-supporting.

To minimize confusion regarding the connections and to indicate the individual legs of the helices, label each loop or cylinder as B (for big) and S (for small); T and B indicate top and bottom. Each loop can be further split using leg designators as B1T and B1B, B2T and B2B, S1T and S1B and S2T and S2B, with B2 being the length of coax and the other three legs as wires. For righthand circular polarization (RHCP) wind the helices *counterclockwise* as viewed from the top. This is contrary to conventional axial mode helix construction. (For LHCP, the turns rotate *clockwise* as viewed from the top.) See **Fig 60** for the proper connections for the top view. When the antenna is completed, the view shows that there are two connections made to the center conductor of the coax (B2) top. These are B1T and S1T, for a total of three wires on one connection. S2T connects to B2T braid. The bottom of the antenna has S1B and S2B soldered together to complete the smaller loop. B1B and the braid of B2B are soldered together. Attach an SO-239 connector to the bottom by soldering the center conductor of B2B to the center of the connector and the braid of B2B to the connector's shell. The bottom now has two connections to the braid: one to leg B1B, the other to the shell of the connector. There's only one connection to the center conductor of B2B that goes to the SO-239 center pin.

Total price for all new materials-including the price of a suitable connector-should be in the neighborhood of $10 or less.

RESULTS

With a 70-foot section of RG-9 between the receiver and antenna, which is mounted about 12 feet above ground, and a preamp in the shack the author receives fade-free passes from the weather satellites. Although the design indicates a 3-dB beamwidth of 140°, an overhead pass provides useful data down to 10° above the horizon. The 70 cm antenna works fine for PACSATs, although Doppler effect makes manual tracking difficult. The weather-satellite antenna prototype worked better than expected and a number of copies built by others required no significant changes.

Thanks to Chris Van Lint, and Tom Loebl, WA1VTA, for supplying technical data to complete this project, and to Walt Maxwell, W2DU, for his review and technical evaluation and for sharing his technical expertise with the amateur satellite community.