Experimental Investigation of Quadrifilar Helix Antennas for 2400 MHz

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The Quadrifilar Helix Antenna as shown in Figure 1 has already been described in detail and discussed in references [1], [2], [3], [4]. That discussion will not be repeated here. Unfortunately, very little has been written on how to built a Quadrifilar Helix Antenna to radiate with RHCP (Right Hand Circular Polarization) or with LHCP (Left Hand Circular Polarization).

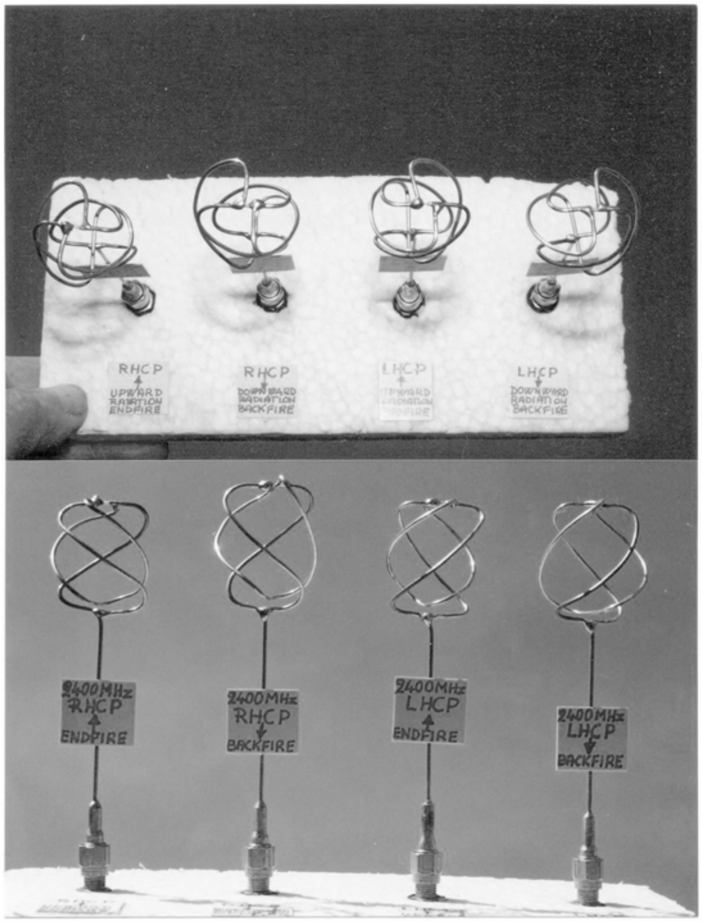


Figure 1
Four sample Quadrifilar Antennas

To test the radiation characteristics of a Quadrifilar Helix antenna, four prototypes were built for 2400 MHz. As can be seen from Figure 1, RHCP or LHCP is achieved if both loops are wound in the reverse direction of the desired field rotation so that LHCP is achieved by winding both loops right hand and RHCP by winding both loops left hand, which is exactly the opposite of a W8JK type helix antenna.

Figure 2 contains the design details. Half of the small bifilar loop was made of semi-rigid coaxial cable, UT-047. Silver plated copper wire with a diameter of 1.2 mm was used for the other half of the small bifilar loop and for the entire larger, second bifilar loop.

In Figure 2 the ends of the loops are connected to a so-called infinite balun having a phase relationship that here reinforces the field in the upward direction to generate endfire radiation. That cancels the field toward the SMA connector and feed point.

In Figure 3 it can be seen how the small and the large bifilar loops of a RHCP Quadrifilar Helix are wound in the left-hand direction and are connected to the infinite balun having a phase relationship that reinforces the field in the downward direction to generate a backfire radiation that reinforces the right-hand circular field toward the feedpoint and creates a null in the upward direction of the picture in Figure 3.

Because the phase relationship in Figures 2 and 3 produces currents that reinforce the field in one direction and a field cancellation in the opposite direction, then both the above RHCP Quadrifilar Helix antennas become a directional antenna, which does not need a reflector.

Figure 4 shows an enlarged view of the infinite balun, which is connected for endfire RHCP, as is shown in Polar Plot 1. In Figure 4 the RHCP radiation pattern points in the direction of the viewer. The interconnection for RHCP backfire radiation is shown in Figure 5 with the pattern shown in Polar Plot 2. In Figure 5 the RHCP radiation takes place in the opposite direction of the viewer and so is toward the feedpoint.

Figure 6 shows an enlarged view of the infinite balun, which is connected for LHCP endfire radiation, which is shown in Polar Plot 3. In Figure 6 the LHCP radiation pattern points at the viewer. In Figure 7 the interconnection for LHCP backfire radiation is shown in accordance with Polar Plot 4. In Figure 7 the LHCP radiation takes place in the opposite direction of the viewer and so toward the feedpoint.

The radiation pattern in Polar Plot 1 shows the result of these experiments for a RHCP Quadrifilar Helix Antenna with endfire radiation. Polar Plot 2 shows the same for a RHCP Quadrifilar Helix Antenna with backfire radiation.

As a further explanation, endfire radiation by definition takes place opposite to the feed point while backfire radiation points toward the feed point of the antenna. See Polar Plots 1 to 4.

During experimentation with connections of the loops to the infinite balun has been found that a connection producing endfire radiation in a RHCP Quadrifilar generates backfire radiation in a LHCP Quadrifilar as shown comparing Figure 4 to Figure 6. Likewise connections producing endfire radiation in a LHCP Quadrifilar generates backfire radiation in a RHCP Quadrifilar as shown comparing Figure 6 to Figure 5.

Another point, which has not been discussed in great detail in the references, is the feeding and phasing method with help of the infinite balun. This make it possible the self matching of the loop elements to a 50 ohm line as well to feed the loop element in such a way that either circular endfire radiation or circular backfire radiation can be achieved depending on loop connections to the infinite balun as schematically illustrated in each of the radiation patterns.

The gain of a Quadrifilar Helix Antenna amounts to about 5 dBi and radiation patterns from Polar Plots 1-4 show that the major lobe of this type of antenna is very well suited to be used as a feed to illuminate dishes with a f/D ratio of 0.3. Because the illumination angle for feed at the edge of the dish is approximately 159 degrees, the space attenuation is 4.6 dB and the desired taper is 5.4 dB for –10 dB edge illumination.

A further advantage of the Quadrifilar Helix antenna compared to a helix or to a patch used as a feed in a parabolic dish is its small size because the Quadrifilar Helix Antenna is a directional antenna which does not need a reflector, so that the shadow, which a

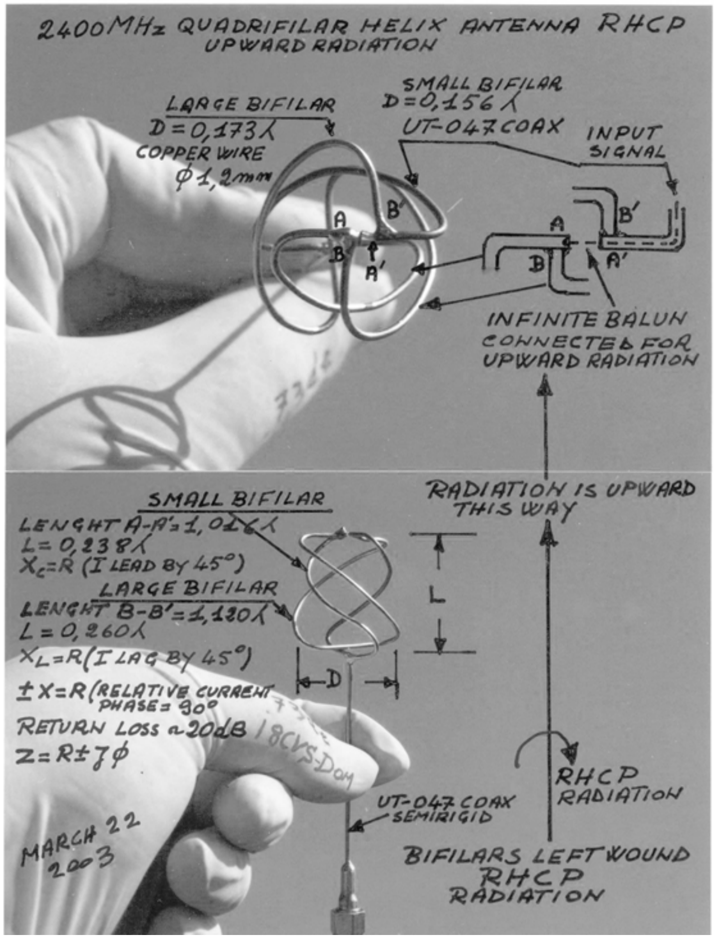


Figure 2 (above)
Construction of the RCHP-Endfire Type

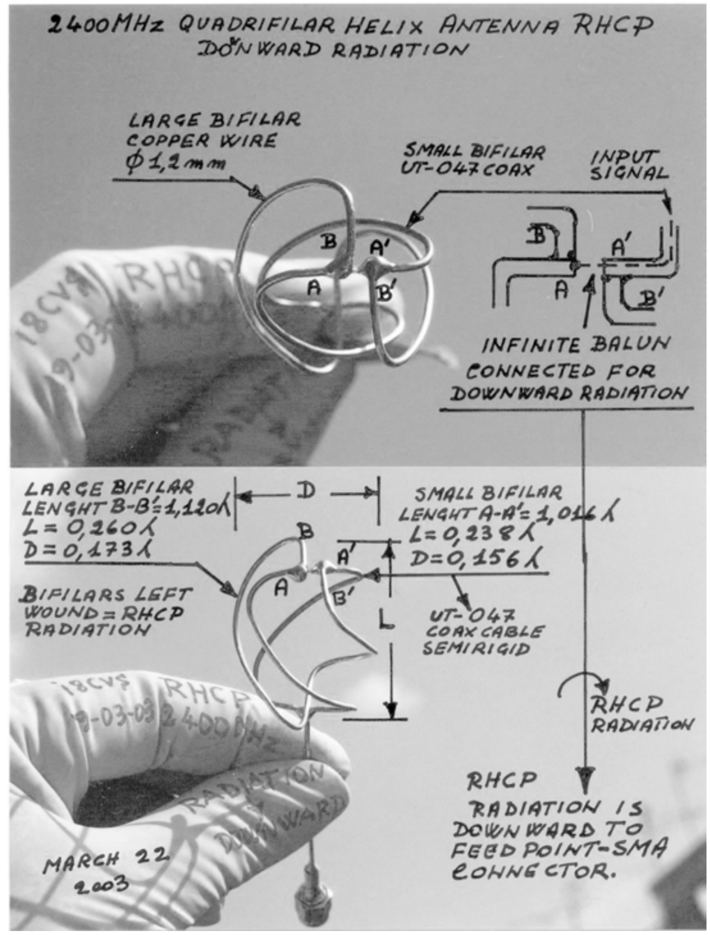


Figure 3 (above)
Construction of the RHCP-Backfire Type

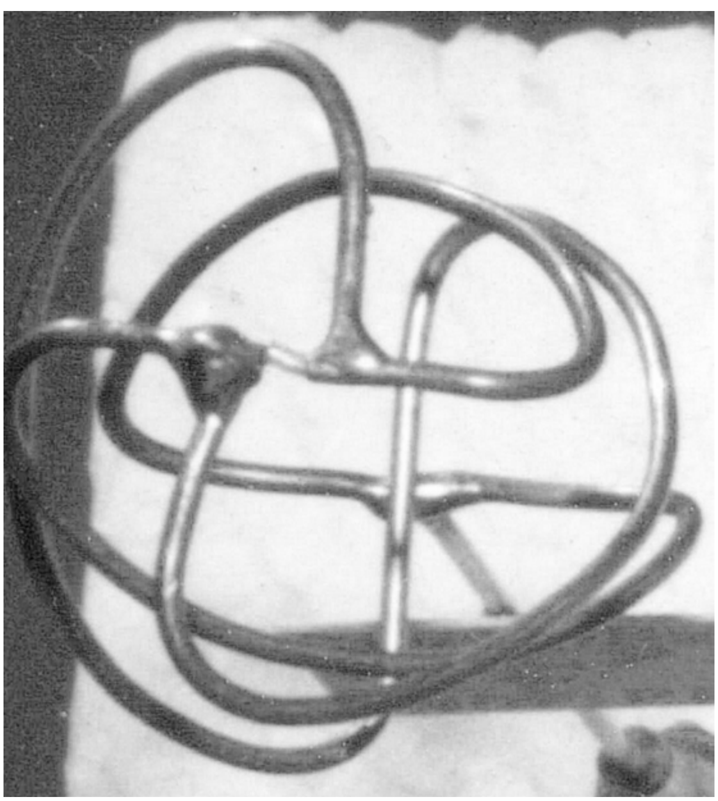


Figure 4 (above)
Detail photograph of the RHCP-Endfire

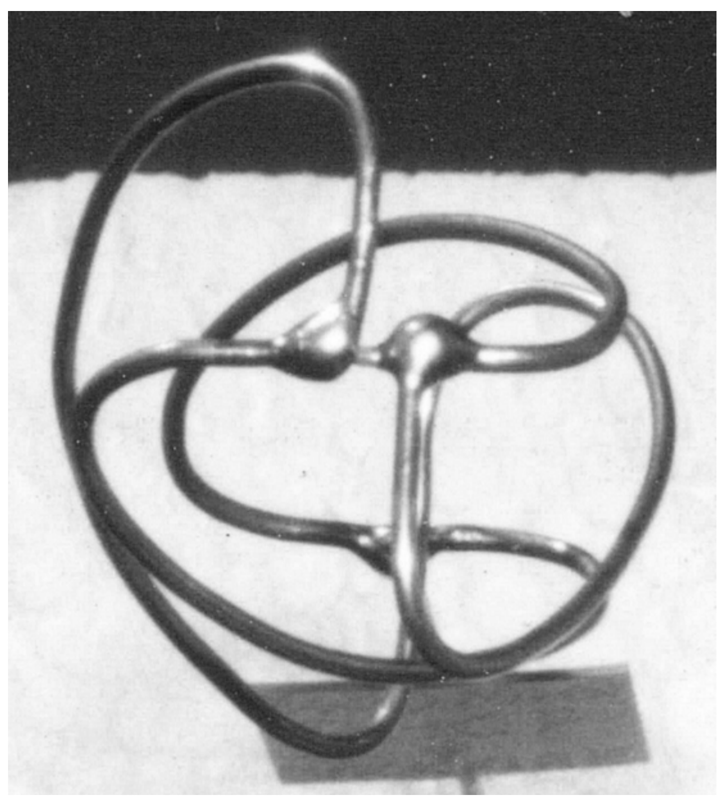
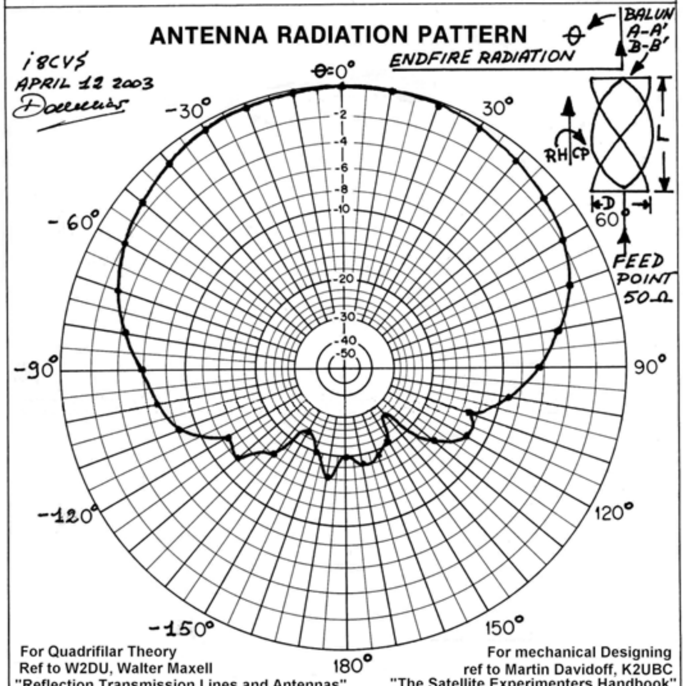


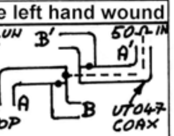
Figure 5 (above)
Detail photograph of the RHCP-Backfire

Radiation Pattern of a 2400 MHz RHCP Quadrifilar Helix Antenna when illuminated by a RHCP Source (RHCP Patch) and infinite Balun connected for a 90° self-phasing and Endfire Radiation



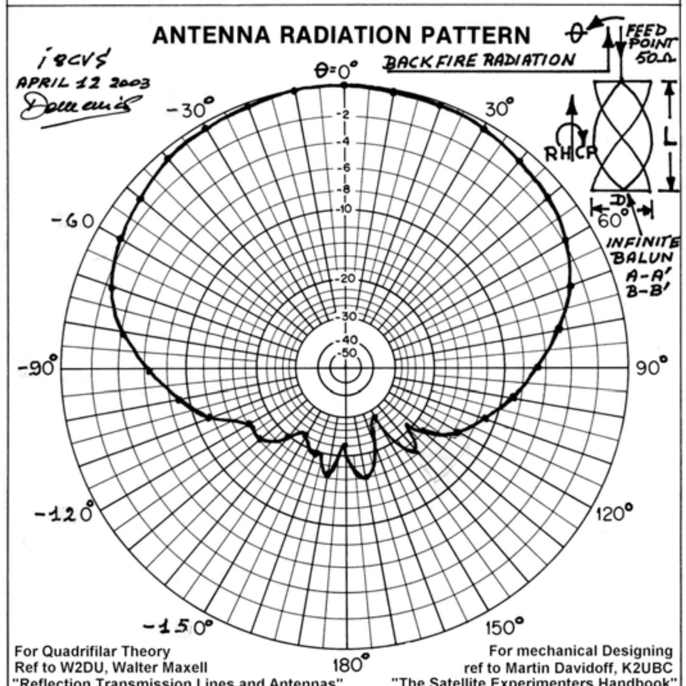
OTHER DATA: For RHCP Radiation, Bifilar Loops must be left hand wound

BIFILARS DATA 2400 MHz	SMALL LOOP	LARGE LOOP	INFINITE BALUN CONNECTION FOR RHCP ENDFIRE RADIATION AS SEEN FROM THE TOP
DIAMETER D	19,50	21,62	
AXIAL LENGHT L	29,75	32,50	
LOOP LENGHT A-A'	127,0	——	
LOOP LENGHT B-B'	——	140,0	
WIRE DIAMETER (mm)	1,2 (UT047)	1,2 COPPER	



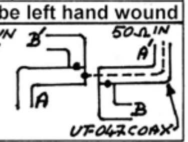
Polar Plot 1 (above)
Radiation characteristics of the Endfire-RHCP with several dimensions and construction hints.

Radiation Pattern of a 2400 MHz RHCP Quadrifilar Helix Antenna when illuminated by a RHCP Source (RHCP Patch) and infinite Balun connected for a 90° self-phasing and Backfire Radiation



OTHER DATA: For RHCP Radiation, Bifilar Loops must be left hand wound

BIFILARS DATA	SMALL LOOP	LARGE LOOP	INFINITE BALUN CONNECTION FOR RHCP BACKFIRE RADIATION AS SEEN FROM THE TOP
DIAMETER D	0,156λ	0,173λ	
AXIAL LENGHT L	0,238λ	0,260λ	
LOOP LENGHT A-A'	1,016λ	——	
LOOP LENGHT B-B'	——	1,120λ	
WIRE DIAMETER	0,0088λ	0,0088λ	



Polar Plot 2 (above)
Radiation characteristics and hints for the Backfire-RHCP.

reflector can produce with a small diameter dish, can be neglected and thus increase the overall efficiency of the dish.

In addition to the above advantage, a dish with f/D=0.3 or less has only a small spillover since its focal length is short and the feed is close to the bottom of the dish. These conditions improve the G/T ratio of the system in comparison to other receiving systems, which use the same receiver to a dish with the same diameter but larger f/D ratios.

Since a parabolic dish reverses by reflection the direction of polarization of a circularly polarized wave, then a LHCP Quadrifilar Helix Antenna is needed as a parabolic feed to receive a RHCP signal transmitted by AO40. For this reason two LHCP prototypes for 2400 MHz where built .The first one was connected for LHCP endfire radiation as shown in Figure 6 and Polar Plot 3 and the second one was connected for LHCP backfire radiation as shown in Figure 7 and Polar Plot 4.

In the case of a feed with a LHCP endfire radiation pattern as in Polar Plot 3 mounted in a dish, the Quadrifilar Helix must point toward the dish and the SMA connector for the downconverter must point outward to the outer space. This is the best method for mounting the feed. On the other hand, in the case of a feed with a LHCP backfire radiation pattern as in Polar Plot 4 the helix must point to the outer space and the SMA connector for the downconverter must point toward the dish.

During the above experimental investigation it was found that another desirable characteristic of a Quadrifilar Helix Antenna used as a feed in a parabolic dish is its circularity, as shown in Polar Plot 5.

To measure the circularity a RHCP endfire Quadrifilar Helix Antenna was installed in front of a half wave slowly spinning dipole, which was fed by a signal generator through a rotating coaxial joint. As shown in Polar Plot 5, the Quadrifilar Helix was directed first toward the spinning dipole, which was at an angle of 0 degrees. The signal received from a spectrum analyzer was measured and resulted in the curve marked "circularity at 0", which had a maximum axial ratio of only 1 dB between the 0-degree and 180-degree points of the polar plots.

Then the axis of radiation of the Quadrifilar Helix was changed by 30 degrees in relation to the slowly spinning dipole and the circularity Polar Plot was again measured. This resulted in the curve marked "circularity at 30°" which showed a maximum axial ratio of only 1 dB in the case of the 90-degree and 270-degree-points on the polar plots. Similarly the Quadrifilar Helix antenna was turned by 60 degrees relative to the spinning dipole, and the curve resulted in an axial ratio of 3 dB maximum between the 90 and 270-degree points of the polar plots.

And finally the Quadrifilar Helix antenna was turned by 90 degrees relative to the spinning dipole and the maximum axial ratio was measured at 16 dB at the 90 and 270-degree points. However, it decreased by less than 1 dB at the 0 and 180-degree points, as can be seen in the curve marked "circularity at 90°". The Polar Plot circularity indicates that a Quadrifilar Helix antenna is ideal for illuminating the entire surface of a dish with very good circular polarization and has a very small axial ratio from the center of the dish to about its edge.

During the above experimental investigation the unknown circularity direction of a Quadrifilar Helix antenna was determined

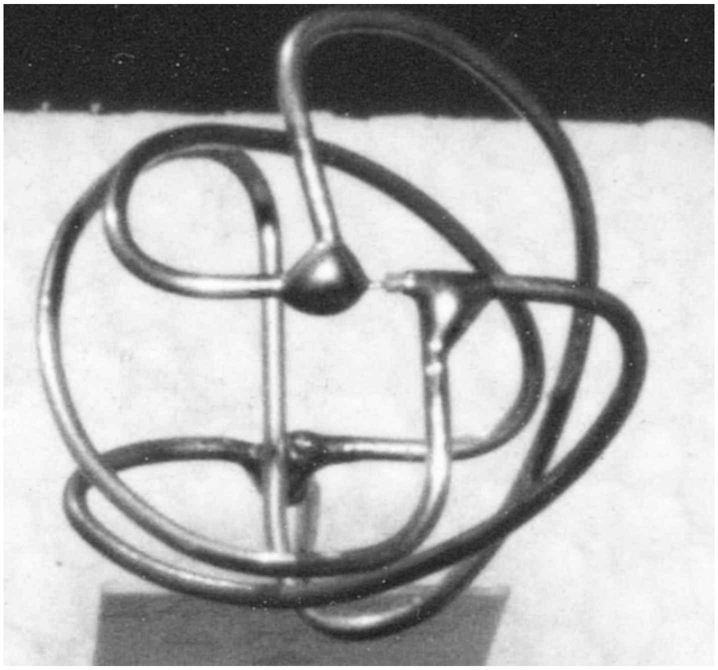


Figure 6 (above)
Detail photograph of the LHCP-Endfire.

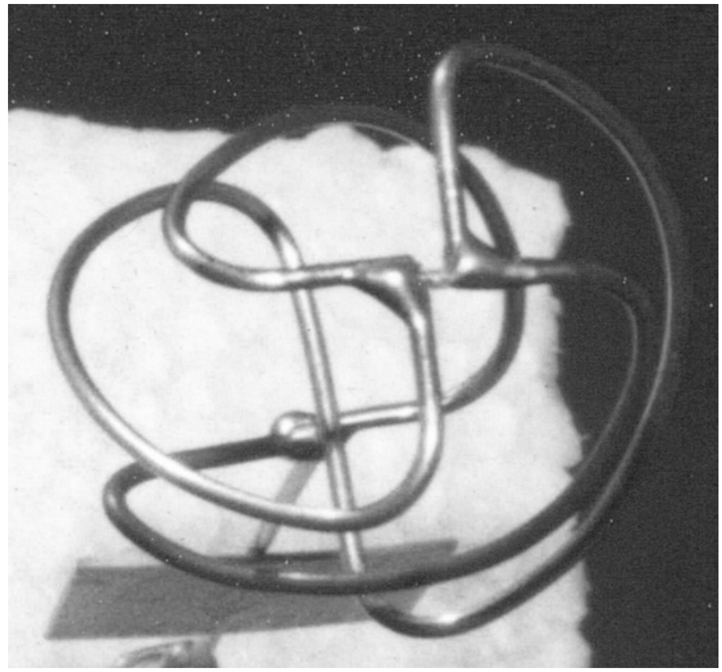


Figure 7 (above)
Detail photograph of the LHCP-Backfire.

against a reference patch antenna connected for LHCP. A 2400 MHz signal generator as a transmitter drove the patch antenna while the Quadrifilar Helix antenna was connected to a spectrum analyzer as a receiver as seen in Figure 8. If the output from the Quadrifilar Helix antenna remains constant or varies very little, by less than 1 dB, as the patch is rotated manually through 360°, then the Quadrifilar Helix antenna under test is also LHCP. If, however, there are two deep nulls and two peaks observed when rotating the source patch antenna through 360°, then the Quadrifilar Helix antenna under test has opposite polarization or RHCP in this example.

For those who would like to build and duplicate the Quadrifilar Helix antenna for RHCP or LHCP all of the electrical dimensions and materials to be used as well as winding directions for the smaller and larger loops are given in their respective illustrations, Figures 2 to 5. For still more detailed construction designs consult the references (3) and (4). For those who would like to know more about the theory and how Quadrifilar Helix Antennas function in general and who want to learn more details of the workings of infinite baluns, including how the 90-degrees phase shift for circular polarization as well as the self-matching to a 50-Ohm-feedline takes place, should definitely study the references (1) and (2).

An additional article being planned will deal with the results obtained with a Quadrifilar Helix Antenna for 2400 MHz used as a feed on dishes with f/D ratio ranging from 0.3 to 0.35 hopefully using the RHCP medium beacon of AO40 otherwise using the 2401.500 MHz LHCP beacon of UO-11.

References:

[1] "Reflection Transmission Lines and Antennas" by M. Walter Maxwell, W2DU, ARRL, order no. 2995, ISBN 0-87259-299-5.

[2] "The ARRL Antenna Book" published by The American Radio Relay League (ARRL).

[3] "The Satellite Experimenters Handbook" by Martin Davidoff, K2UBC, second edition, ARRL order No. 3185.

[4] "The AMSAT Journal", March/April 1994, "Quadrifilar Antennas for Amateur and 137 MHz Satellites", by Dave Guimont, WB6LLO.

Figures continue on the next page.

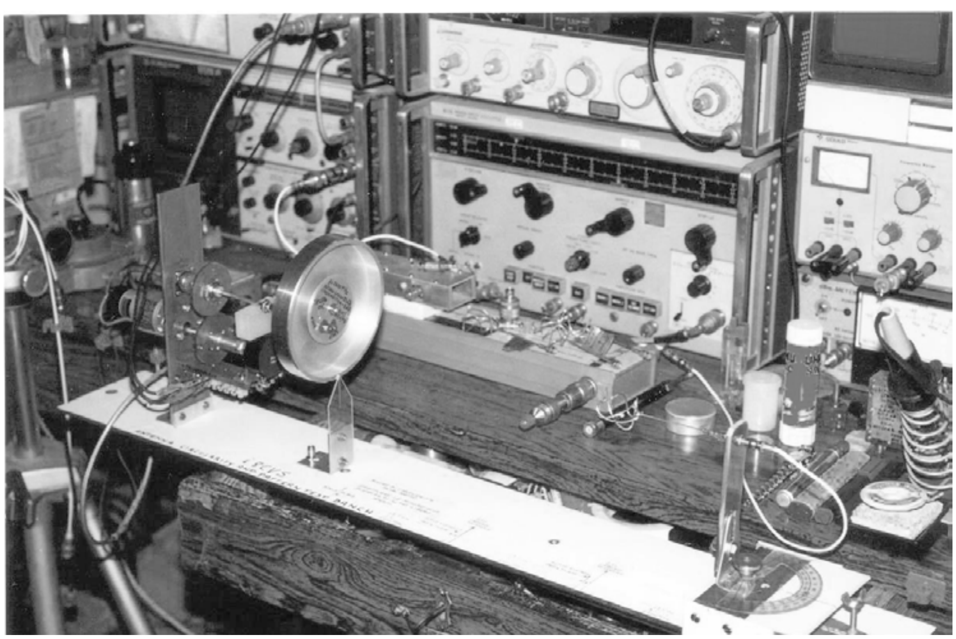
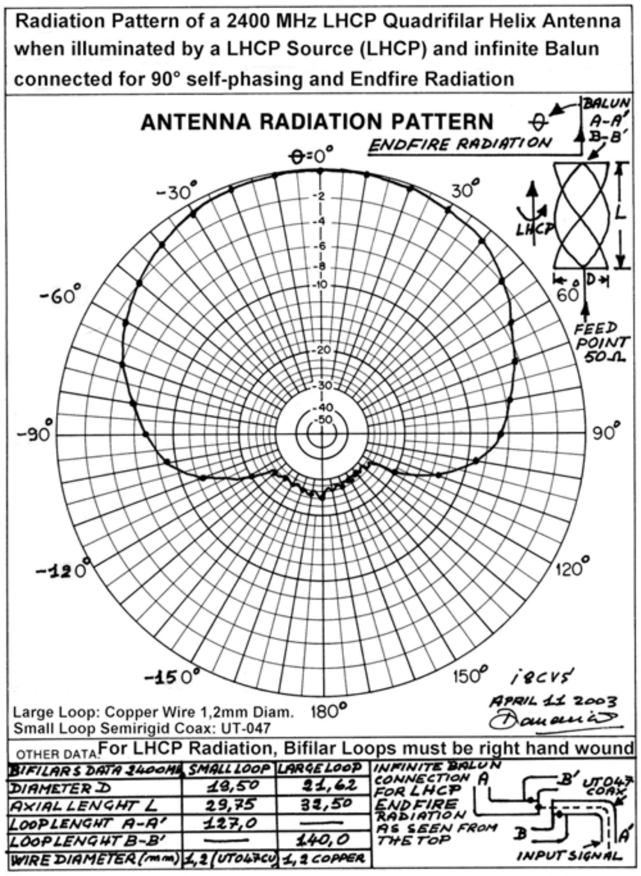
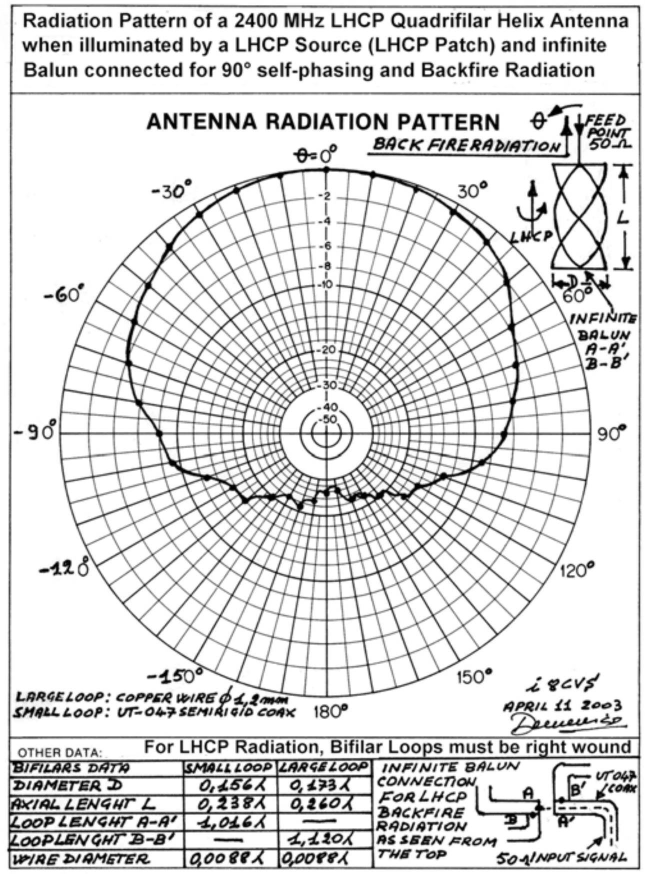


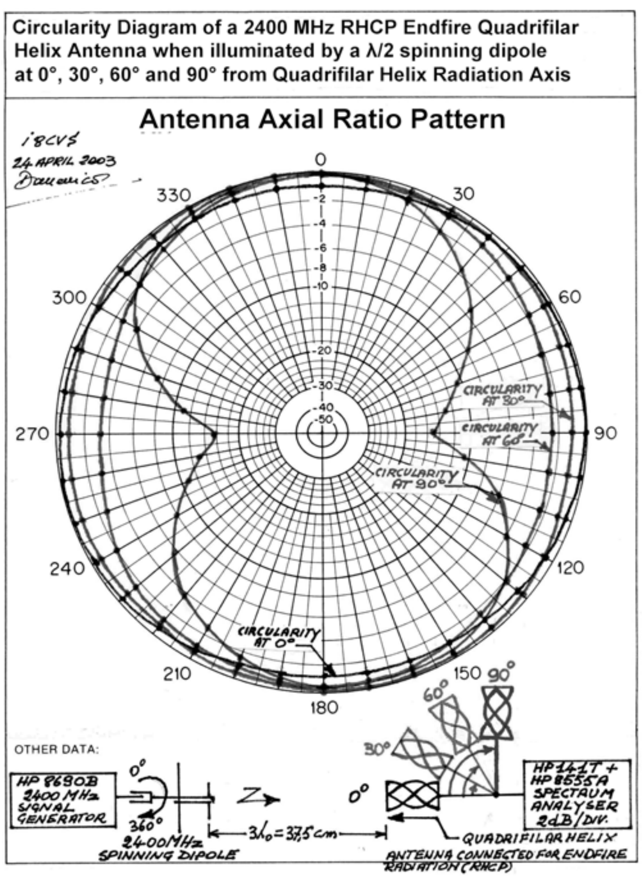
Figure 8 (left)
Measurement bench to determine the unknown circularity direction of a Quadrifilar-Helix antenna against a reference patch antenna connected for LHCP (see text).



Polar Plot 3 (above)
Radiation characteristics and hints for the Endfire-LHCP.



Polar Plot 4 (above)
Radiation characteristics and hints for the Backfire-LHCP.



Polar Plot 5 (left)
Antenna axial ratio pattern and measurement bench to determine the circularity of the Quadrifilar-Helix at different squint angles against a spinning half wave dipole.