SPACECRAFT AND GROUND STATION APPLICATIONS OF THE RESONANT QUADRIFILAR HELIX

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Introduction

Since its development in 1968 [1], the resonant quadrifilar helix has found application in a number of spacecraft programs.

Considerable information on the helix is available including integral expressions for the radiation characteristics [2] and information on design techniques [3]. A detailed comparison with other antennas [4] indicates that the helix provides an optimum antenna for narrow bandwidth applications requiring a broad beamwidth, cardioid shaped radiation pattern, circular polarization, and a compact physical configuration.

This report provides new information on techniques for increasing the bandwidth and shaping the beam of the helix; and describes several applications. Further study is described that indicates that the radiation characteristics are insensitive to the presence of metal structure behind the antenna, an important consideration in spacecraft applications.

Performance

The helix consists of four identical resonant elements. Each element is made up of two radials and a helical section (Figure 1). Opposite elements are fed in antiphase to produce two independent bifilar helicies. Each of these bifilar helicies radiates a torroid shaped, circularly polarized radiation pattern with the null perpendicular to the helix axis. Feeding the two bifilar helicies in phase quadrature produces a cardioid shaped radiation pattern with the null along the helical axis (Figure 2).

The helix is described by the parameters:

L_{ele} - length along one element (integer number of half - wavelengths).

N - turns along one element

L_{ax} - axial length between the radials.

Input Impedance and Bandwidth

Resonant input impedances in the range 10 to 20 ohms are realized using element lengths of one-half wavelength. Increasing the element length to one wavelength produces nearly a 50 ohm input impedance at resonance.

Bandwidths of several percent are typical for helicies with thin wire elements one half wavelength long. Attempts to increase the bandwidth in the usual way by using wide strip elements generally resulted in degraded radiation pattern performance. Experimental data is presented indicating that increasing the radial dimension of the elements, i.e., producing a lawnmower-reel shaped helix, allows bandwidths of 10-15 percent.

Radiation Patterns

The radiation pattern characteristics are a complicated function of the helical parameters. Beamwidths from 90° to 240° with good F/B and circular polarization can be realized. The characteristics of the resonant helix with one half wavelength long elements and $\frac{1}{2}$ turn are described as a function of axial length in Figure 3.

Many spacecraft applications require a shaped beam that concentrates energy into a sector. Experimental data is presented on multi-turn resonant helicies that tend to accomplish this e.g., the energy is concentrated into a 110° cone by the 7 turn helix with 5 λ long elements and $L_{ax} = 3\ \lambda$ (Figure 4).

Applications

Several laboratories have applied the resonant helix in a variety of spacecraft programs. Developments at the Applied Physics Laboratory are described in greater detail in the paper.

Navigation Satellites

Navigation satellite systems utilizing simple linear ground antennas generally require excellent circular polarization in the satellite antenna for optimum performance. The resonant helix was originally developed for this application and several have been successfully orbited.

A dual frequency 162/324 MHz helix was developed with element lengths of $\lambda/2$ at 162 MHz and 1 λ at 324 MHz. The antenna was excited with crossed folded baluns adjusted for the median between the frequencies. The beamwidth was optimized at 324 MHz; the link margin allowed the narrower than optimum beamwidth at 162 MHz.

A dual frequency antenna was realized by coaxially mounting a 400 MHz helix inside a 150 MHz helix. The two antennas operate essentially independently, providing a 120° beamwidth at both frequencies. Both antennas were left hand circularly polarized. A 28" long, 6" diameter, rigid version of this antenna was flown. A compressable version has been developed that folds into a cylinder 8" in diameter by 6" high in the launch configuration.

Satellite Telemetry and Tracking

The resonant helix provides a technique for realizing an omnidirectional S-band telemetry antenna on a complex satellite configuration. A RHC helix and a LHC helix with 180° beamwidth are oriented in opposite directions and mounted on opposite extremes of the satellite body (Figure 5). The individual radiation patterns are preserved by the insensitivity to metal structure behind the helix. The two antennas are connected in parallel; allowing a ground station with polarization diversity to receive an isotropic signal. The cross polarization components of the radiation patterns cause ripples in the ideal pattern; at the present state of development these ripples are 5-7 db deep.

A deployable quadrifilar helix has been developed at the RCA Astro Electronics Division for use as a 130 MHz telemetry antenna [5]. The central balun was eliminated by carrying integral coaxial lines to the feed point utilizing the inside of the antenna elements. The erecting force is provided by the beryllium copper antenna elements with deployment rate and time controlled be a viscous damper. The antenna is 16 inches in diameter by 24 inches long deployed; the compressed length is 2.4 inches.

An S-band SGLS helix developed at RCA is described in a separate paper at this conference.

Interplanetary Spacecraft

A deployable 400 MHz resonant helix has been developed at Philco Ford under JPL direction for use on the Project Viking Mars Orbiter [4]. The antenna design is extraordinary rugged to withstand a severe vibration and thermal environment.

Shipboard Antennas

A series of resonant helicies for bouy and shipboard application have been developed by Chu Associates [6]. The ground plane insensitivity of the helix allows it to be operated close to the surface without the signal drcpouts ordinarily caused by surface motion.

References

[1] Kilgus, C. C., "Multielement Fractional Turn Helicies", IEEE Trans. Antennas and Propogation, Vol. AP-16, July 1968 pp 499-501.

[2] Kilgus, C. C., "Resonant Quadrifilar Helix", IEEE Trans. Antennas and Propogation, Vol. AP-17, May 1969 pp. 349-351.

[3] Kilgus, C. C., "Resonant Quadrifilar Helix Design", Microwave Journal Vol. 13-12 December 1970 pp. 49-54.

[4] Frank, P., "Viking Orbiter Antenna Sub systems, Relay Antenna", Vol. 3, Philco Ford, Palo Alto, California.

[5] Wilkes, R., "Deployable Quadrifilar Antenna", RCA/AED Princeton, New Jersey.

[6] Smith, V., "150 and 400 MHz Improved SATNAV Receiving Antenna", Chu Associates, El Cahon, California.

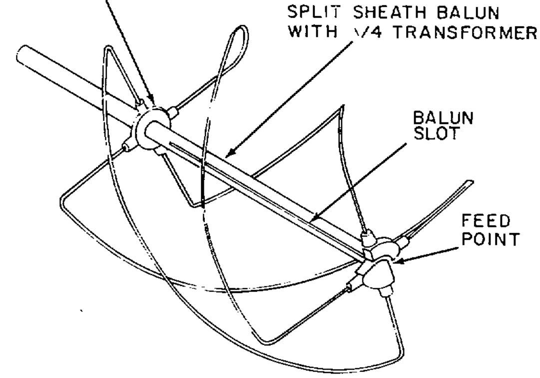
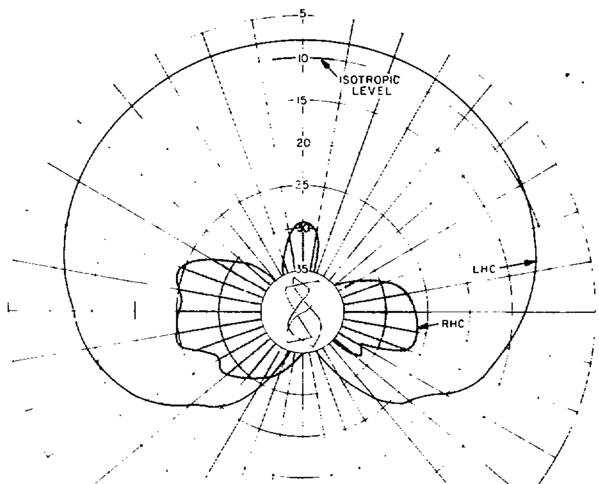


FIGURE I

QUADRIFILAR HELIX ANTENNA



MEASURED PERFORMANCE
$L_{ele} = \lambda/2 \quad N = 1/2$
FIGURE 2

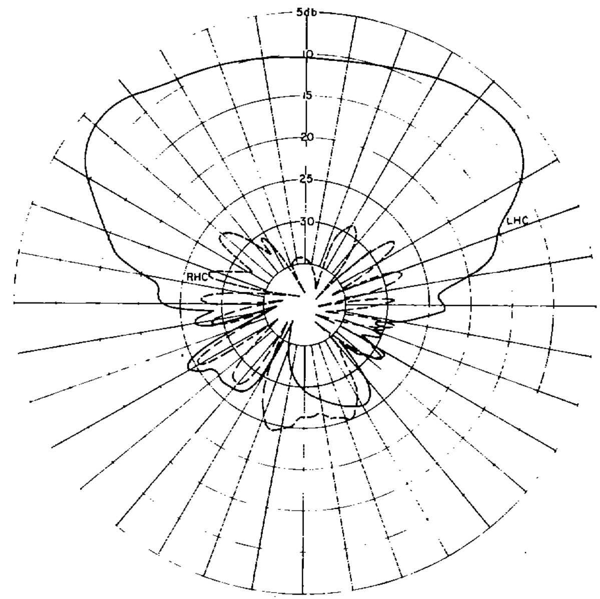
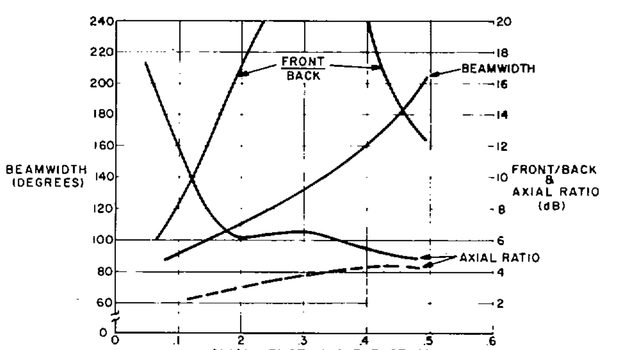


FIGURE 4
SHAPED RESONANT HELIX



NOTES ——— PEAK AXIAL RATIO OVER THE HEMISPHERE IN FRONT OF THE HELIX.
– – – PEAK AXIAL RATIO OVER THE 3db BEAMWIDTH OF THE HELIX.

RESONANT HELIX PERFORMANCE
$L_{ele} = \lambda/2 \quad N = 1/2$
FIGURE 3

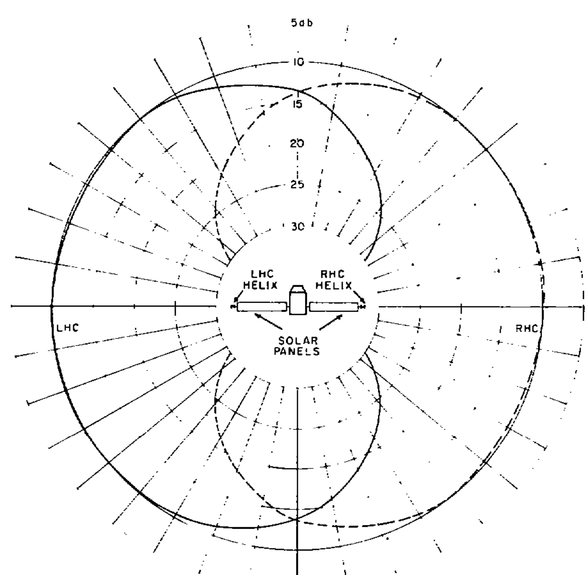


FIGURE 5
OMNIDIRECTIONAL S-BAND ANTENNA